Memorandum

To: MIDS Work Group
From: Barr Engineering Company
Subject: Preliminary Performance Goal Alternatives Evaluation (Item 2, Work Order 1)
Date: December 6, 2010
Project: 23/62 1050 MIDS

Design approaches developed to control the volume of stormwater runoff vary widely throughout the state and nation. This memorandum serves to describe three common approaches to stormwater runoff volume control design standards and discuss advantages and disadvantages of each approach with regard to effectiveness in achieving the goals of the MIDS legislation. Variables to consider for different ecoregions of Minnesota and for existing urban development areas are also discussed.

Common Stormwater Volume Control Approaches

Three common stormwater volume control performance goal approaches will be evaluated in this memorandum:

Approach 1: Retain a runoff volume on-site equal to one inch of runoff from proposed impervious surfaces.

Approach 2: Retain the post-construction runoff volume on site for the 95th percentile storm (1.4 inches in Minneapolis).

Approach 3: Limit post-construction runoff from a 1-, 2-, and 5-year 24-hour design storm to a volume equal to or less than native soil and vegetation conditions.

The three common performance goal approaches evaluated are event-based (i.e., the design calculations are completed to show that the BMP is sized to retain a volume of stormwater from a specific precipitation event). Although not as widely used, another potential volume control performance goal approach is based on annual precipitation and limits the annual post-construction stormwater runoff volume to less than or equal to a native soil and vegetation condition (or some other condition, such as the year an Outstanding Resource Value Water was designated). Designing individual developments and proving conformance to an annual-based standard can be difficult for designers and regulators. The volume of stormwater runoff captured and retained by a BMP during any given year is dependent on numerous factors, including the amount of annual precipitation, precipitation patterns (e.g., the amount of rainfall that falls in small events versus large, intense events, occurrence of back-to-back storm events, etc), and winter conditions that affect the soil freeze/thaw timeline and snowmelt runoff. Documentation of compliance with an annual standard would likely require a long-term continuous modeling analysis or a comprehensive assessment of performance based on modeling or monitoring data to help translate BMP design to annual performance (similar to the assessment conducted by the Nationwide Urban Runoff Program to facilitate prediction of the annual pollutant removal efficiency of stormwater detention ponds). Due to the familiarity of event-based design for designers and regulators, and the added complexities of documenting conformance with annual-based performance standards, regulators have typically adopted event-based performance standards similar to one of three identified common approaches.

Descriptions of Common Approaches

Approach 1

Retaining a runoff volume on-site equal to one inch of runoff from the proposed impervious surfaces is a very simple approach for designers and for reviewers to verify conformance to the standard. A stormwater model is not needed for calculations. Through this approach, the impervious surface areas are totaled and multiplied by one inch to determine a required runoff control volume. Infiltration during the storm event is not considered so stormwater management facilities are designed to hold and infiltrate the runoff control volume.

This approach does not account for the site's existing soil conditions in determining the runoff control volume. However, the soil conditions would need to be known and accounted for in designing the stormwater management facility.

Rather than using a runoff volume equal to one inch of runoff from the proposed impervious surface, a runoff volume equal to a one inch precipitation event is sometimes used. Here the runoff control volume is adjusted to account for abstractions (losses in runoff due to shallow depressions, interception from vegetation, etc.). Capital Region Watershed District and Ramsey-Washington Metro Watershed District have adopted this type of stormwater volume control rule and allow for a 0.1-inch abstraction. Therefore, under their rules, the calculation of the runoff control volume is 0.9 inches times the total impervious surface area. In regions of Minnesota that have higher or lower precipitation, this approach could be modified to use a different runoff value.

Approach 2

Retaining the post-construction runoff volume on site for the 95th percentile storm (or some other percentile storm, such as the 90th percentile storm) is slightly different than Approach 1. Approach 2 includes the runoff from impervious and pervious surfaces as opposed to only impervious surfaces in

Approach 1. The required runoff control volume in Approach 2 is typically calculated for the pervious and impervious areas using the SCS (Soil Conservation Service) runoff curve number method, which can be done by hand computations or using a simple computer model, such as HydroCAD. The inputs are watershed area, soil and land cover data (curve numbers to reflect pervious and impervious areas) and rainfall depth. The rainfall depth used for the analysis corresponds to the 95th percentile storm for a given region (1.4 inches in Minneapolis). The stormwater management facility is sized for the total runoff control volume from both the impervious and pervious surfaces.

Because Approach 2 is based on the 95th percentile storm, the runoff treatment amount can vary throughout Minnesota so that drier areas would be required to retain less runoff than wetter areas. Similar to Approach 1, abstractions could be included in the calculation.

Approach 3

Limiting post-construction runoff from a 1-, 2-, and/or 5-year 24-hour design storm to a volume equal to or less than native soil and vegetation conditions requires a designer to calculate the runoff from native conditions and then calculate the runoff from proposed development and design the stormwater management facility such that there would be no increase in stormwater runoff volumes. Runoff volume is calculated from the entire site – impervious surfaces and pervious surfaces. The runoff volumes for both conditions are typically calculated using the SCS runoff curve number method, which can be done by hand computations or using a simple computer model, such as HydroCAD. The inputs are watershed areas, soil and land cover data (curve numbers to reflect pervious and impervious surfaces), and rainfall depth. The rainfall depths used for this analysis correspond to the selected design storm (2.3 inches for a 1-year, 24-hour event in Minneapolis).

Because Approach 3 uses design storms, the precipitation used in the calculation will vary throughout Minnesota. Abstractions could be included in the calculation as with other approaches. This approach can allow the designer to include infiltration in the stormwater management facility during the storm event.

Achievement of MIDS Legislation

The MIDS legislation is as follows:

> *The agency shall develop performance standards, design standards, or other tools to enable and promote the implementation of low-impact development and other stormwater management techniques. For the purposes of this section, "low-impact development" means an approach to storm water management that mimic's a site's natural hydrology as the landscape is developed. Using low-impact development approach, storm water is managed on-site and the rate and volume of*

predevelopment stormwater reaching receiving waters is unchanged. The calculation of predevelopment hydrology is based on native soil and vegetation.

The MIDS legislation is to "mimic a site's natural hydrology" using "native soil and vegetation." Detailed calculations, which will be done in a future MIDS work task, are needed to determine how well any proposed performance standard mimic's natural hydrology. Table 1 includes general statements in regards to mimicking natural hydrology for each of the identified common approaches as well as other items to consider before implementing any approach.

Table 1. Review of Common Volume Control Approaches

	Volume Control Approach		
Issue	**Approach 1:** **Retain a runoff volume on-site equal to one inch of runoff from proposed impervious surfaces.**	**Approach 2:** **Retain the post-construction runoff volume on site for the 95th percentile storm.**	**Approach 3:** **Limit post-construction runoff from a 1-, 2-, and 5-year 24-hour design storm to a volume equal to or less than native soil and vegetation conditions.**
Mimics native soil and vegetation hydrology?	*Possibly for some soil and vegetation areas, but not for all. Might require more retention than needed on some sites and not enough on others. See following Volume Retention Analysis discussion.*	*Possibly for some soil and vegetation areas, but not for all. Might require more retention than needed on some sites and not enough on others. See following Volume Retention Analysis discussion.*	*Of three approaches, this approach is expected to most closely mimic natural hydrology for all soil and vegetation types. See following Volume Retention Analysis discussion.*
Promotes low impact development?	*Yes, indirectly.*	*Yes, indirectly.*	*Yes, indirectly.*

	Volume Control Approach		
Issue	**Approach 1:** **Retain a runoff volume on-site equal to one inch of runoff from proposed impervious surfaces.**	**Approach 2:** **Retain the post-construction runoff volume on site for the 95th percentile storm.**	**Approach 3:** **Limit post-construction runoff from a 1-, 2-, and 5-year 24-hour design storm to a volume equal to or less than native soil and vegetation conditions.**
Provides incentive to reduce impervious surface?	*Yes. Of the three approaches, it provides the most incentive because the stormwater management facility is sized only based on the proposed amount of impervious (there is a direct relationship between impervious surface reduction and required volume retention). See following Volume Retention Analysis discussion.*	*Yes, but because calculation takes into account runoff from both pervious and impervious surfaces, there is not a direct relationship between impervious surface reduction and required volume retention. Therefore, for some sites, there is less incentive to reduce impervious surfaces. For example, sites with higher runoff potential from pervious surfaces (for example, C and D soils), incentive for reducing impervious surface lessens with lower site imperviousness (for example, residential sites). See following Volume Retention Analysis discussion.*	*Yes, but because calculation takes into account runoff from both pervious and impervious surfaces, there is not a direct relationship between impervious surface reduction and required volume retention. Therefore, for some sites, there is less incentive to reduce impervious surfaces. For example, sites with higher runoff potential from pervious surfaces (for example, C and D soils), incentive for reducing impervious surface lessens with lower site imperviousness (for example, residential sites). See following Volume Retention Analysis discussion.*
Addresses Total Maximum Daily Load (TMDL) requirements?	*Not necessarily. Dependent on individual TMDL.*	*Not necessarily. Dependent on individual TMDL.*	*Not necessarily. Dependent on individual TMDL.*
Takes into account different ecoregions?	*No, but it could by adjusting the one-inch standard up or down.*	*Yes.*	*Yes.*
Takes into account difficulties of developing on ultra urban sites?	*No.*	*No.*	*No.*
Simple to calculate?	*Yes - very simple.*	*Yes - simple.*	*Yes – moderately simple.*

	Volume Control Approach		
Issue	**Approach 1:** **Retain a runoff volume on-site equal to one inch of runoff from proposed impervious surfaces.**	**Approach 2:** **Retain the post-construction runoff volume on site for the 95th percentile storm.**	**Approach 3:** **Limit post-construction runoff from a 1-, 2-, and 5-year 24-hour design storm to a volume equal to or less than native soil and vegetation conditions.**
Open to subjectivity?	*No.*	*Somewhat, but hydrologic parameters can be defined by regulator to reduce.*	*More so than others, but hydrologic parameters can be defined by regulator to reduce.*
Feasible to construct above-ground infiltration system to manage required volume?	*Not for all soil types. See following discussion.*	*Not for all soil types. See following discussion.*	*Not for all soil types. See following discussion.*

Volume Retention Analysis

Required Retention Volumes of Approaches

A simple volume retention analysis was completed to quantify the required amount of runoff volume to be retained under each design standard approach. The required volume retention was calculated for two hypothetical development sites, with the soil conditions varying from A to D soils. The first hypothetical development site is a 40-acre residential development with 30% imperviousness. The second hypothetical development site is a 10-acre commercial site with 80% imperviousness. For Approach 2, the required volume retention was calculated using the SCS Curve Number method, with a curve number of 98 being assigned to the impervious areas and a curve number representing open space in good condition for each soil type being assigned to the pervious areas. For Approach 3, the native soil and vegetation runoff was calculated using the SCS Curve Number method, with a curve number representing meadow being used for each soil type to mimic native vegetative conditions. The proposed-condition runoff was calculated using the SCS Curve Number method, with a curve number of 98 being assigned to the impervious areas and a curve number representing open space in good condition for each soil type being assigned to the pervious areas. Note that for the purposes of this analysis, calculation of required volume retention did not account for any infiltration from the basin during the design event.

A comparison of the required volume retention for the hypothetical residential and commercial development sites under A, B, C, and D soils is presented in Figures 1 and 2, respectively. Based on the volume retention analysis, volume control Approach 3 (post-development runoff equal to or less than native soil and vegetation runoff for 1-, 2-, and 5-year, 24-hour event) generally results in volume retentions greater than those of Approach 1 or Approach 2, with the exception of the residential development with D soils. Approach 3 results in volume retention that varies by soil type, with the differentiation between soil types getting larger with the larger storm event (1-year versus 5-year). Volume control Approaches 1 and 2 result in similar volume reductions, although Approach 1 has a slightly lower volume requirement and has no differentiation by soil type. The required volume retentions (acre-feet / development acre) for the commercial site are two to three times higher than those of the residential site

Land Footprint Requirements

One method of evaluating the feasibility of the three identified design approaches is to assess the amount of land required to implement stormwater volume control Best Management Practices (BMPs), or the BMP "footprint". The BMP footprint is dependent on numerous variables, most notably the required volume of runoff to be retained, the type of volume control BMP, and the infiltration characteristics of the soil. The BMP footprints were estimated for each of the development scenarios by sizing hypothetical above-ground bioretention systems (without underlying draintile) based on soil type (A, B, C, and D). The allowable depths of the bioretention basins were calculated for each development scenario and soil type by using the infiltration rates shown in Table 2 and a maximum drawdown time of 48 hours. These infiltration rates are conservative for each soil group, resulting in the worst case scenario with respect to BMP footprint. The maximum basin depth for A soils based on the infiltration rate in Table 2 and a 48-hour drawdown time is 3.2 feet; however, a depth of 1.5 feet was used for this bioretention BMP footprint analysis, in accordance with the bioretention system design guidance in the MPCA Minnesota Stormwater Manual. If other infiltration BMPs that do not include plants (such as infiltration basins and infiltration trenches), are utilized, greater basin depths are allowed, and therefore, the BMP footprint for A soils can be reduced.

Table 2. Soil Infiltration Rates and Infiltration Basin Depths

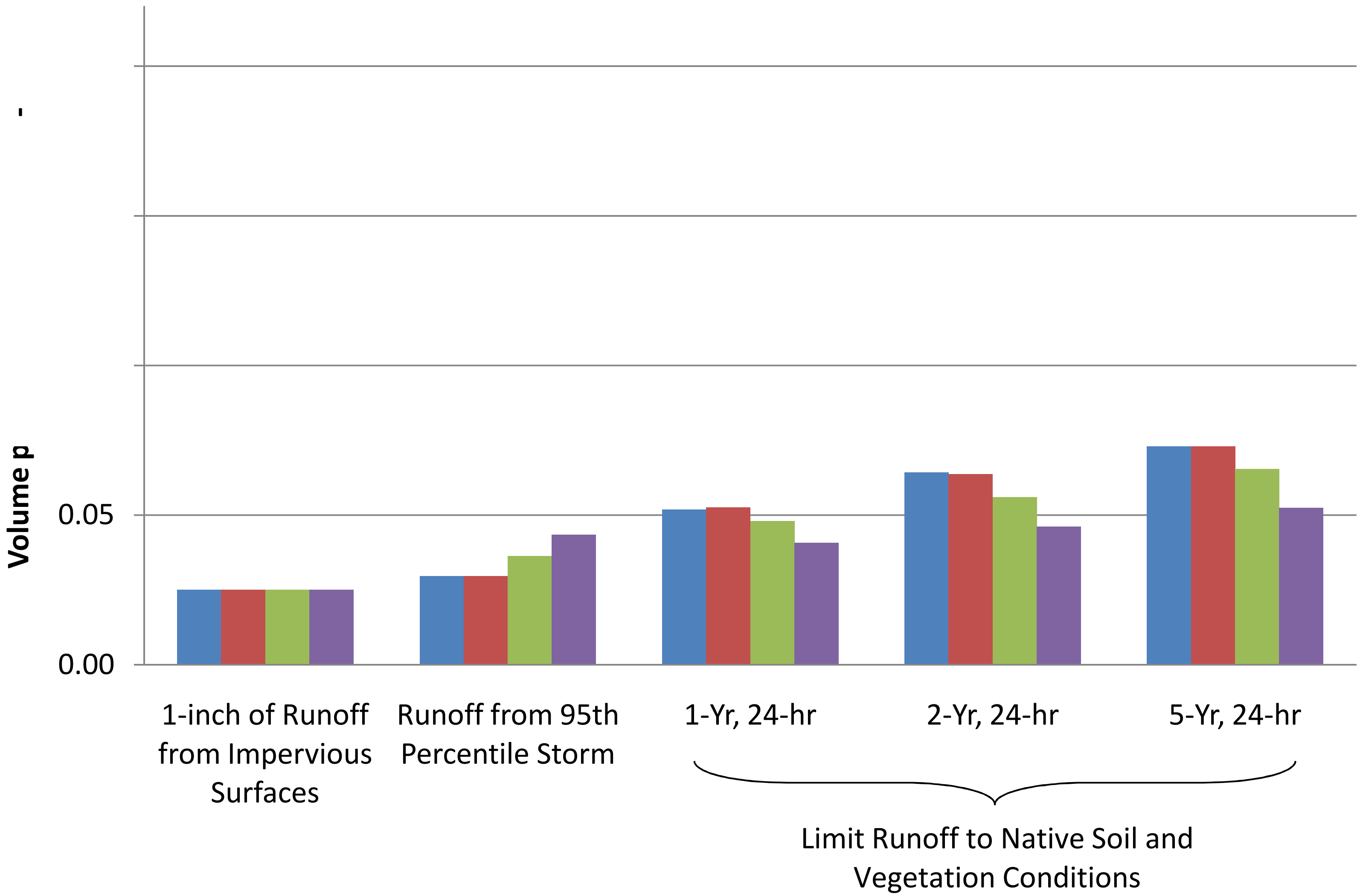
Hydrologic Soil Group	Infiltration Rate (inch/hour)	Maximum Depth of Basin (feet)	Reference
A	0.8	1.5	1, 2
B	0.3	1.2	1
C	0.2	0.8	1
D	0.03	0.1	3
[1] Infiltration rate from MPCA Minnesota Stormwater Manual, Version 2 (2008)			
[2] Note that for A soils, the depth based on the infiltration rate of 0.8 inch/hour and 48-hour drawdown time is 3.2 feet. However, the depth of infiltration basin was assumed to be 1.5 feet, which is the maximum depth allowed per the MPCA Minnesota Stormwater Manual, Version 2.			
[3] Infiltration rate from Metropolitan Council Urban Small Sites Best Management Practice Manual (2001)			

Comparison of the BMP footprints for the residential and commercial development scenarios under A, B, C, and D soils are presented in Figure 3 and Figure 4, respectively. The most notable conclusion from Figures 3 and 4 is that the BMP footprint for D soils is significantly large under all three volume control approaches, varying from 25% to 120% of the land area of the two hypothetical development sites. This implies that the feasibility of implementing any of the four approaches on D soils is limited.

Application of Evaluation to MIDS

There are simple, common stormwater volume control approaches. Some approaches might work better on developed sites with a lower amount of impervious surfaces and other approaches might work better on developed sites with a higher amount of impervious surfaces. Problems exist with implementing volume control approaches on sites with D soils. Each approach might mimic a site's natural hydrology using native soil and vegetation, but further analysis is needed to determine how closely and under what situations some match closer than others. After a robust analysis is completed, the results can be compared and contrasted. The MIDS Work Group can review the findings and take into account other factors (such as ease of implementation, promotion of Low Impact Development techniques, and costs) to determine the preferred stormwater volume control approach.

Figure 1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1-inch of Runoff from Impervious Surfaces
Runoff from 95th Percentile Storm
1-Yr, 24-hr
2-Yr, 24-hr
5-Yr, 24-hr
Limit Runoff to Native Soil and Vegetation Conditions

Figure 2

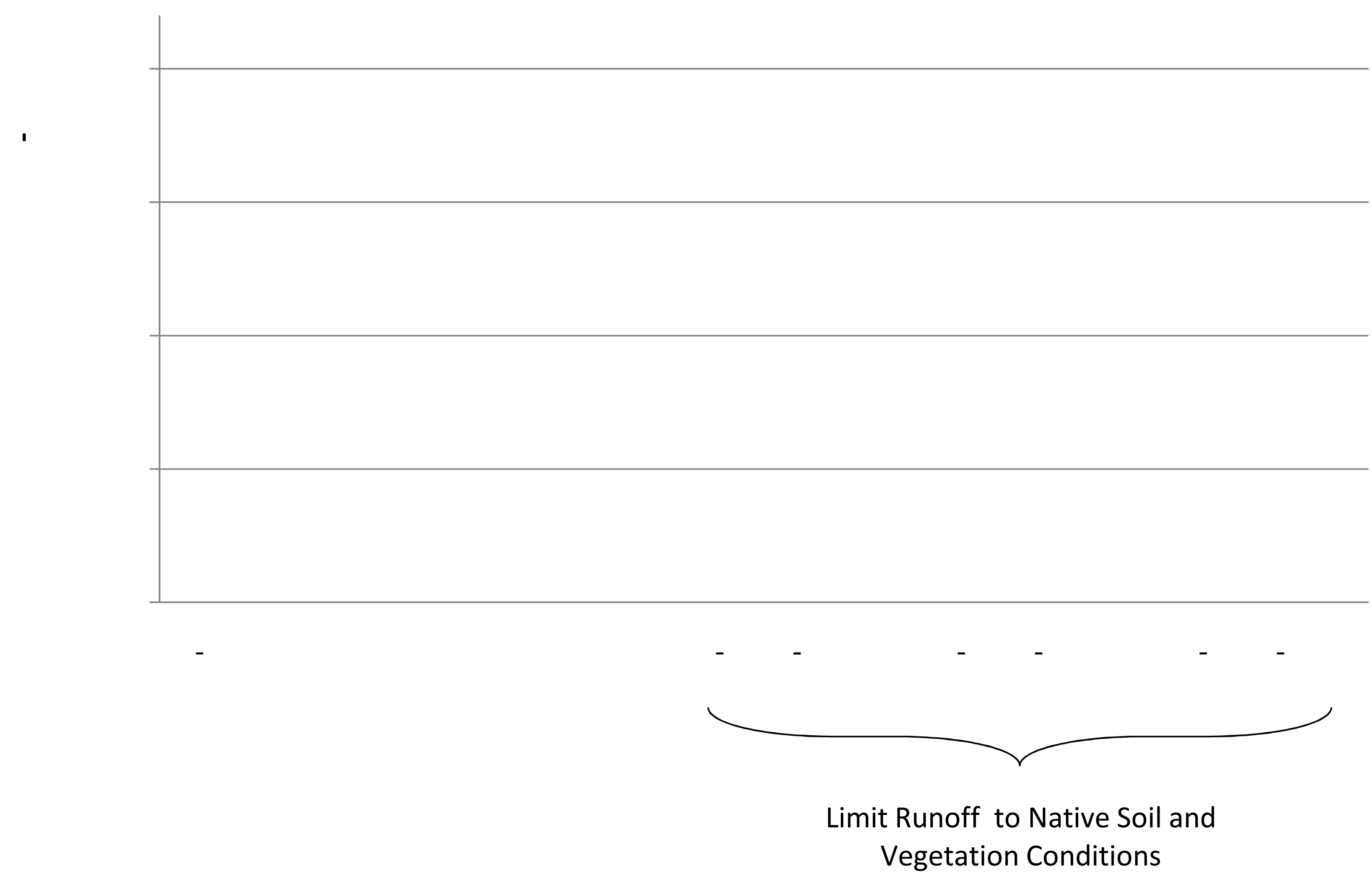
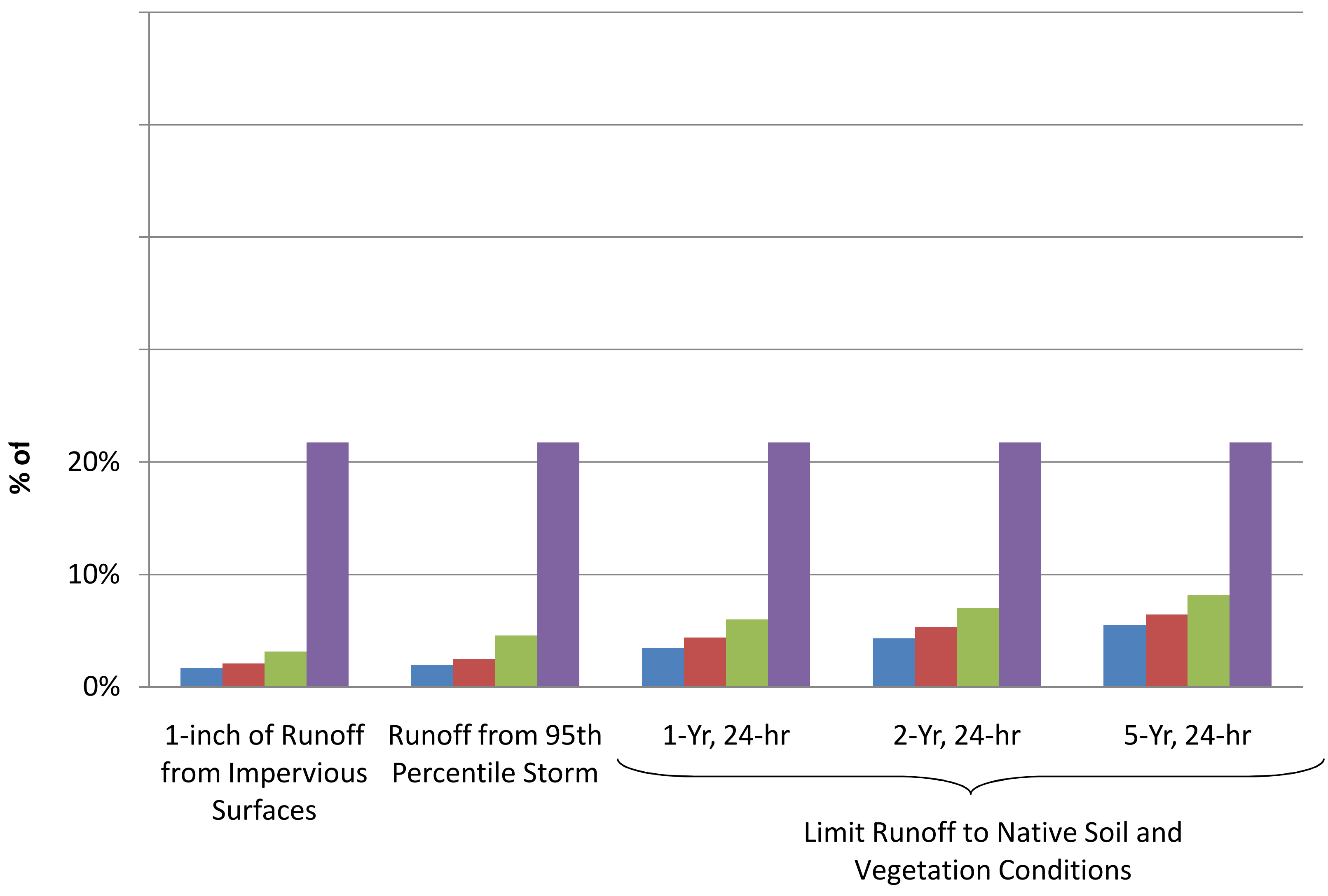


Figure 3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1-inch of Runoff from Impervious Surfaces
Runoff from 95th Percentile Storm
1-Yr, 24-hr
2-Yr, 24-hr
5-Yr, 24-hr
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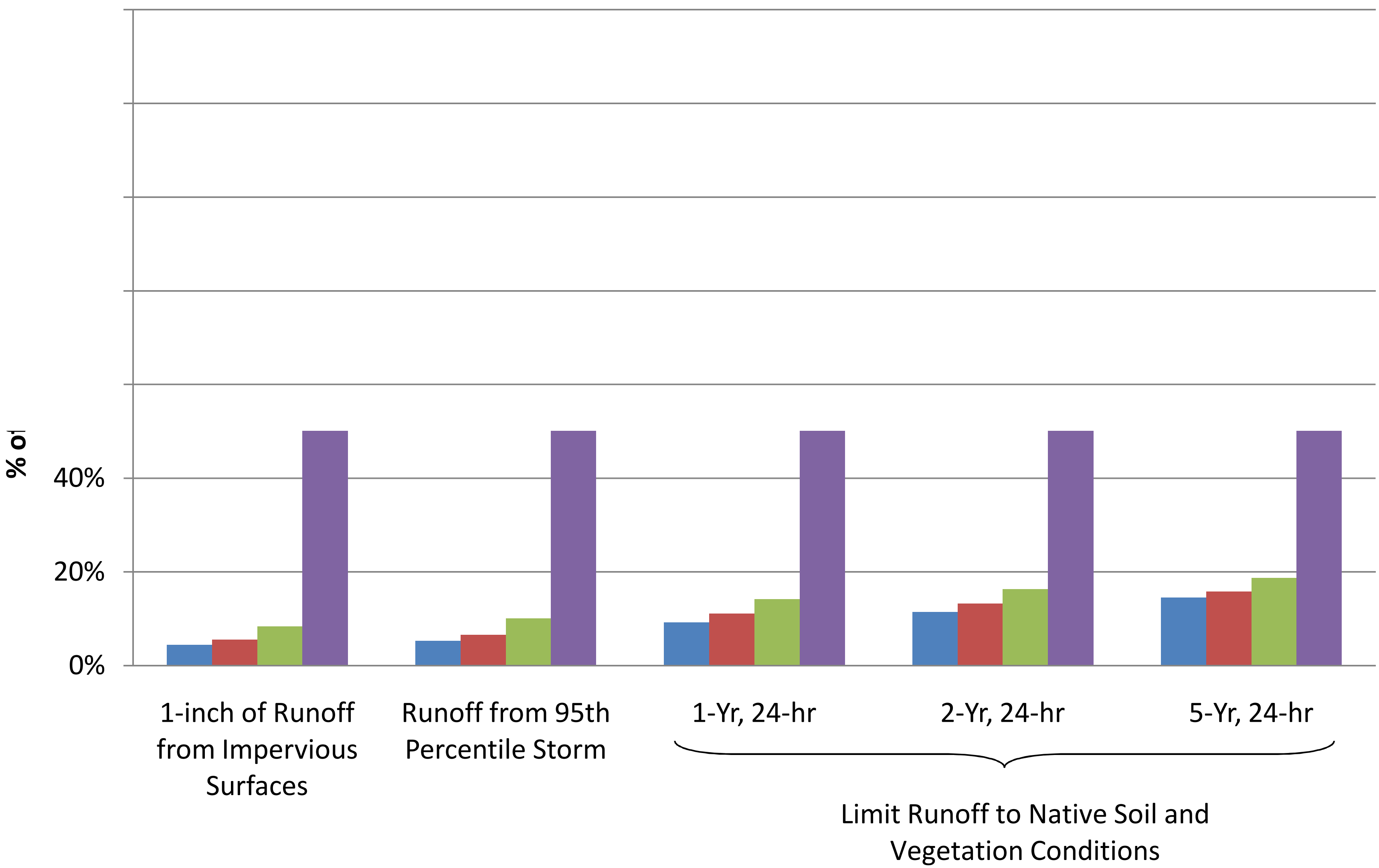
Figure 4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