University of Central Florida

Stormwater Management Academy
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Technical Memorandum: Retention for Pollution Control and Estimated Runoff for Flood Control as a Function of the Maximum Water Storage Capacity of Pervious Pavement Systems

The objectives of this report are to demonstrate and present data in support of calculations for pervious pavement systems that are used to satisfy the mass removal pollution objectives of the Statewide Stormwater Rule and to further expand pervious pavement design for flood control. The design procedure must start with a known retention volume needed for annual percent removal effectiveness and it is understood that it can be obtained for any area in the State. Then it is postulated that the design of the pervious pavement section can be specified to achieve the annual pollution effectiveness as well as the reduction in runoff volume.

Pollution Control Effectiveness

It is important to emphasize or repeat important facts related to the definition of pervious pavement systems. First, a pervious pavement system is defined as the pervious pavement and the reservoir, if one exists. Next the data and results reported in this memorandum are good for pervious pavement section installation completed by certified contractors. Next, the permeability of parent soils and reservoir materials meet a required storage recovery time.

All materials and depth of each used within the reservoir and the pervious pavement must be specified to estimate the storage within the system. The depth to the seasonal high water table must also be specified. Typically when the pervious pavement system storage exceeds 1.15 inches and the rate of infiltration through the section is greater than 1.5 inches per hour, the system will function on a yearly basis to remove 80% or better of the rainfall for the average year. This is shown in Figure 1 for various maximum storage capacities. The assumptions on parent and aquifer conductivity were limiting ones encountered in sampling existing systems (Wanielista and Chopra, Hydraulic Performance of Pervious Concrete, BD521-02, FDOT, 2007).

In Figure 1 provided are additional estimates of average annual rainfall removal as a function of infiltration rates. As an example, if the limiting rate is 3 inches per hour and the storage is about 1.7 inches, the average annual removal is 95%. The limiting infiltration rate must be determined using an Embedded Ring Infiltrometer Kit (ERIK). Testing of pervious pavement sections to date has shown that the rates of infiltration do commonly exceed 3 inches/hour.

The annual mass percent reduction shown in Figure 1 as a function of system (surface measured infiltration rate) did not significantly change with increased storage above 2.2 inches. Thus additional storage above 2.2 inches does not affect the annual mass reduction at any of the limiting infiltration rates shown in Figure 1. However, additional storage does affect the volume of storage within the pervious pavement system and thus the amount and rate of runoff from the pervious pavement section.

There are many combinations of pervious pavement and reservoir materials and depth that can achieve many storage values above a minimum storage of 0.80 inches used in Figure 1. As one example, pervious pavement at a depth of 6 inches with no storage reservoir typically holds 0.90 inches. Other designs specify reservoir depth or increased pavement thickness to support high traffic loads and thus storage has been estimated at up to 6 inches. The use of Figure 1 is considered valid for all practical pavement and reservoir depths. The additional storage affects the runoff volume and thus there is a trade-off between the storage within the pervious pavement system and the storage of water off-site of the pervious pavement that is used for flood control.

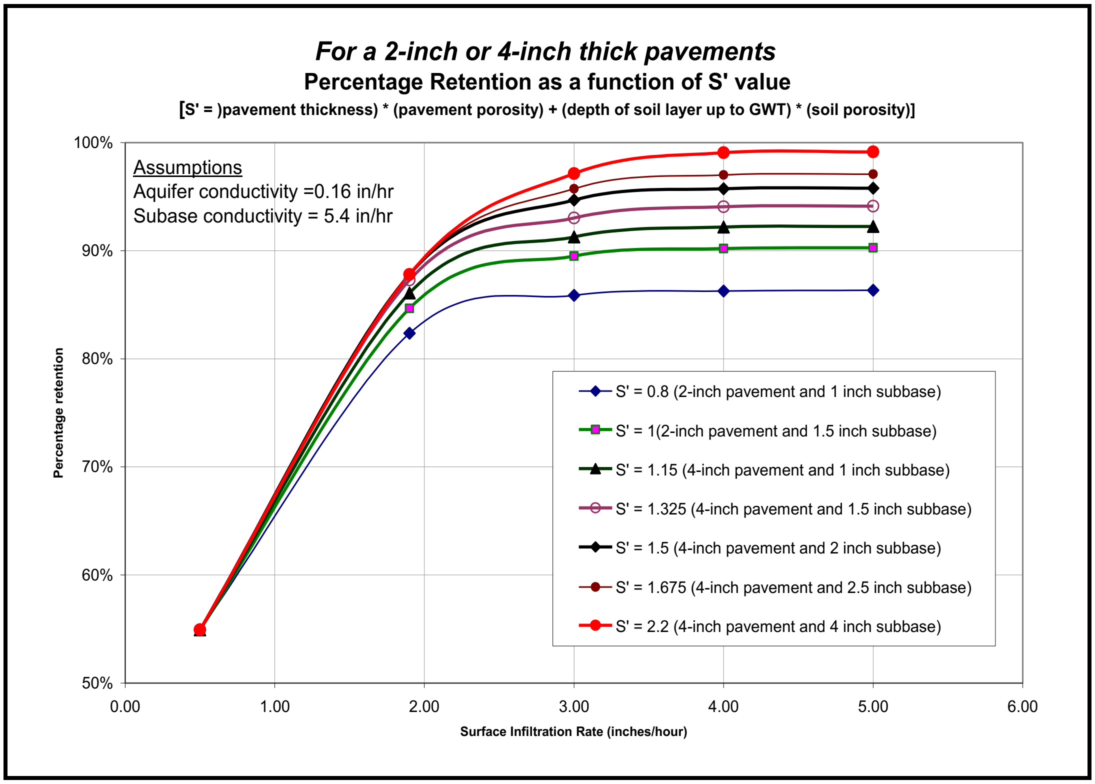

Figure 1. Average Annual Removal Mass as a Function of Surface Infiltration

The Value of Pervious Pavements for Flood Control Using a Design Storm

As noted, a pervious pavement section can be used to reduce flood control storage volume needed off-site of the pervious pavement, thus the importance of calculating runoff volume from pervious pavements resulting from a design storm. In addition, that runoff volume can be determined from the rainfall excess formulas of the curve number method and the ratio of rainfall excess to rainfall volume. The runoff coefficient is defined as the ratio of rainfall excess to precipitation. The governing equations are:

Rainfall Excess (in)	R=[P-0.2S']^2/[P+0.8S']	
Maximum Storage (in)	S' = [1000/CN]-10	and CN=1000/(S'+10)
Runoff Coefficient	C=R/P	

Figure 2 illustrates the best mathematical fit relationship between the runoff coefficient and the maximum storage of water in a pervious pavement system given a rainfall design volume. Thus for various sections of pervious pavement systems which includes the pavement and the reservoir storage, the runoff coefficient can be determined for a design storm volume. Similar curves can be developed for other design rainfall depths.

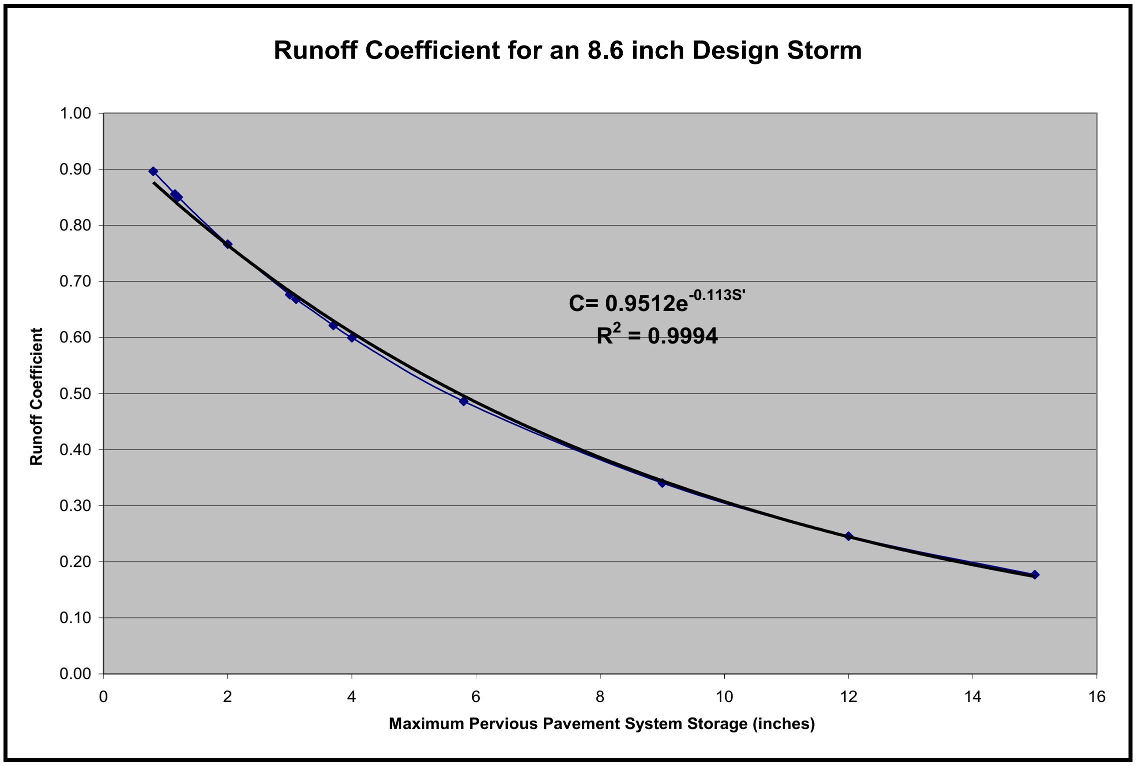

Figure 2. Runoff Coefficient Curve for Pervious Pavements as a Function of Storage and for an 8.6 inch Design Storm Event.

Example Problem

To illustrate the use of Figures 1 and 2, consider an area in the State of Florida where retention of 2.5 inches is needed for a specified mass loading reduction. For this example, a design section is specified that is a 6 inch deep pervious pavement with water holding capacity of 0.15 inch per inch depth, and a reservoir that is 8 inches deep with a water holding capacity of 0.2 inch per inch depth. The seasonal high water table is 24 inches below the reservoir. The reservoir can recover within the stated time period. The water holding capacity of the section is 2.5 inches (0.9 + 1.6). This storage capacity with parent and aquifer conductivities is sufficient to capture at least 80% of the annual rainfall and the pollution mass at a minimum 1.5 inches per hour infiltration rate, and over 95% at a limiting infiltration rate of 3.0 inches per hour (see Figure 1).

The runoff coefficient for an 8.6 inch storm event and 2.5 inches of storage (Figure 2) is estimated at over 0.70 and calculated using the formula as 0.72. Thus 72% of 8.6 inches is runoff or 6.19 inches. Most pervious pavement sections are designed for greater storage because of greater depth of the reservoir, or thicker pervious pavements, thus less rainfall excess results for a design storm. For this example pavement section, if there were an additional 12 inches of reservoir storage at 0.20 inch of storage per inch depth (20 inch deep reservoir), the resulting storage would be 4.9 inches. Thus the runoff coefficient would be reduced to 0.55 and runoff volume to 4.73 inches.

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Other Considerations

Runoff volumes can be calculated using the Curve Number Method. The curve number is calculated directly from the maximum storage using CN=1000/(S'+10). For a maximum storage of 2.5 and 4.9 inches as in the example problem, the Curve Numbers are 80 and 67 respectively.

The runoff volume calculation requires an assumption of initial abstraction. The initial abstraction used is typically set at 20% of the total storage, and 20% was assumed in the development of Figure 2. As additional experimental data are obtained, the typical value may be verified or a new initial abstraction may be recommended.

Frequent infiltration tests using the ERIK are being conducted at the UCF Stormwater Management Academy laboratory to further document the hydrologic operations of five different pervious pavements systems. These tests include the loading of the pervious pavement sections with sand, limestone, and debris. The infiltration rates are measured with the ERIK device before and after loading. When completed, results of these tests will be published as another technical memorandum.

The amount of water stored in the pervious pavement system is estimated from the storage voids within the pervious pavement sections. After the pervious system is loaded with sand, limestone, and debris, the sustainable water storage capacities will be determined for each material based on the extreme soil and debris loadings at the laboratory. When completed, results of these tests will also be published as another technical memorandum.

Marty Wanielista: July 26, 2008