Technical Note for Conducting Pavement Surface Infiltration Rate, Pollutant Load and Runoff Volume Reduction Modeling in Accordance with WDNR Conservation Practice Standard 1008, Permeable Pavement

I. INTRODUCTION

This technical note describes the input parameters for continuous simulation modeling that must be used when determining surface infiltration rate, pollutant load reductions and runoff volume reductions associated with permeable pavement systems. Specific modeling input parameters addressed in the technical note include rainfall data, initial surface infiltration rate, surface clogging capacity, surface cleaning efficiency, surface cleaning frequency, aggregate storage reservoir properties, underdrain discharge properties and soil subgrade infiltration rate.

PAVEMENT SURFACE INFILTRATION RATE REDUCTION

Calculating the decrease in pavement surface infiltration rate over time is important to evaluate the significance of run-on and permeable pavement surface cleaning and estimate when permeable pavement surface restoration or replacement will need to occur. In addition to permeable pavement surface area and run-on source area characteristics, model input parameters used to estimate when the pavement surface infiltration rate will drop below 10 inches per hour (in/hr) include rainfall data, initial surface infiltration rate, surface clogging capacity, surface cleaning efficiency and surface cleaning frequency.

Modeling results are estimates used for design and maintenance planning purposes. Ultimately, permeable pavement surfaces are considered failed and in need of restoration or replacement when the in service surface infiltration rate is less than 10 in/hr regardless of modeling results.

POLLUTANT LOAD & RUNOFF VOLUME REDUCTION

Pollutant load and runoff volume reductions associated with permeable pavement systems are typically quantified for regulatory purposes, including compliance with the ch. NR 151, Wis. Adm. Code, performance standards for new development, re-development and developed urban areas. In addition to the parameters used to evaluate pavement surface infiltration rate, model input parameters for pollutant load and runoff volume reduction calculations include aggregate storage reservoir properties, underdrain discharge properties and soil subgrade infiltration rate.

II. MODEL INPUT PARAMATER

RAINFALL DATA

Continuous simulation modeling typically uses actual rainfall data to evaluate performance of storm water control practices over time. For permeable pavement surface modeling, rainfall data must be selected that accurately represents the geographic area where the pavement will be installed and the anticipate life of the pavement. The Department will identify specific rainfall data files that should be used for different regions for a series of anticipated pavement life (e.g., 10 years, 20 years and 30 years). The rainfall data files for each region are included in WinSLAMM version 10.1 and will be posted on the DNR Storm Water Program website (http://dnr.wi.gov/topic/stormwater) or USGS Wisconsin Water Science Center website (http://wi.water.usgs.gov/slamm).

INITIAL SURFACE INFILTRATION RATE

The initial pavement surface infiltration rate of 100 in/hr was selected based on literature review and discussions with industry experts. It is understood that most permeable pavement surfaces will exceed the 100 in/hr value at the time of installation. However, 100 in/hr was selected as the initial surface infiltration rate for modeling purposes to represent the minimum expected operating range or worst case scenario.

SURFACE CLOGGING CAPACITY

Surface clogging capacity is used in the model to calculate the reduction in pavement surface infiltration rate that occurs as the result of each rain event. It approximates the amount of total suspended solids (TSS) needed to fill the void spaces in the surface of the pavement. As the surface clogging capacity is increased, the number events required to fill the void spaces also increases. Increasing the surface clogging capacity also has the effect of increasing the time it takes for the surface infiltration rate to reach the lower limit of 10 in/hr.

An important factor that guided the selection of a default surface clogging capacity value is the observed clogging times for permeable pavements. Although observed clogging times do vary between sites, some data in the literature indicates the pavement infiltration rates can decline to 10 inches/hour in 8 to 10 years.

A range of surface clogging capacity values were used in a continuous simulation model (WinSLAMM) to determine which value would reduce the infiltration rate to 10 inches/hour in about 10 years using a run on ratio of 3:1. A parking lot with no surface cleaning was used as the source area in the model runs. Based on the model results, a surface clogging capacity of 0.06 pounds per square foot came closest to the 10 year goal and was selected as the default surface clogging capacity.

In WinSLAMM version 10.1, the default surface clogging capacity will be automatically used by the model when the user is determining the decline in infiltration rates over time. Assuming no permeable pavement surface cleaning, a surface infiltration rate of 10 in/hr will be reached in less than 10 years for run-on ratios greater than 3:1 and the pavement will have added life for run-on ratios less than 3:1.

SURFACE INFILTRATION RATE RESTORATION

The permeable pavement surface infiltration rate will decrease over time due to the accumulation of material at or near the pavement surface. The pavement surface infiltration rate can be restored by surface cleaning. However, surface cleaning can only restore a portion of the infiltration rate reduction that occurs between cleaning events. To be conservative, the permeable pavement technical standard assumes that only 50% of the infiltration rate reduction that occurs between cleaning events can be restored. When this value is used in a continuous simulation model, a slower rate of surface infiltration rate decline will occur in comparison to no surface cleaning. For the purpose of modeling, it is assumed that only surface cleaning is conducted rather than full surface restoration or replacement.

Example

Question: If the model indicates that the surface infiltration rate prior to the first surface cleaning is 92 in/hr., what is the surface infiltration rate immediately after the first surface cleaning?

Answer: The surface infiltration rate reduction that occurred from the start of the model run to the first surface cleaning is 8 in/hr. (100 in/hr. – 92 in/hr.). Surface cleaning restores 50% of the surface infiltration rate reduction or 4 in/hr. (50% of 8 in/hr.). Thus, the surface infiltration rate after the first cleaning would be 96 in/hr. (92 in/hr. + 4 in/hr.).

SURFACE CLEANING FREQUENCY

Per the permeable pavement technical standard, a minimum surface cleaning frequency of twice per year is required and should be used in the model. However, higher surface cleaning frequencies can be considered and evaluated.

AGGREGATE STORAGE RESERVIOR PROPERTIES

Properties of the aggregate storage reservoir that must be considered in the model include the depth or thickness of the aggregate, surface area of the reservoir and porosity of the stone. These parameters are used to establish the available storage volume or volume of the voids.

UNDERDRAIN DISCHARGE PROPERTIES

If an underdrain is proposed, the diameter and invert of the pipe must be considered in the model. The number of pipes must also be considered if multiple pipes with separate outfalls will be used. The total suspended solids (TSS) and total phosphorus (TP) removal efficiencies identified in the technical standard (see Table 2 – Permeable Pavement Underdrain Discharge Credit) can be applied to the runoff volume and associated pollutant load that discharges from the underdrain.

SOIL SUBGRADE INFILTRATION RATE

For systems that will infiltrate to the soil subgrade, an infiltration rate appropriate for the site-specific conditions must be used in the model. The soil subgrade infiltration rate should be applied across the bottom of the aggregate storage reservoir, otherwise known as the effective infiltration area. A pollutant and runoff volume reduction efficiency of 100% can be applied to the volume of runoff that infiltrates into the soil subgrade.

III. MODELING PROCEDURE

Continuous simulation models must be able to develop runoff hydrographs and pollutant loads for proposed source areas, accept and evaluate the required model input parameters and generate output documenting compliance with the 10 in/hr minimum surface infiltration rate criteria and the site-specific pollutant load and runoff volume reduction requirements. WinSLAMM v 10.1 is a continuous simulation model that is capable of conducting these calculations. A summary of the modeling procedure using WinSLAMM v 10.1 is as follows.

1. After opening the model, select the appropriate land use and join the land use to the outfall icon on the screen.

2. Select the appropriate run-on source areas and enter the areas.

3. Enter the appropriate rain file based on the region and anticipated pavement life. The 20-year file will be appropriate for most sites.

4. Check to make sure you are using the correct Wisconsin default parameter files.

5. Find the source area control practice - "first control practice" - in the source area grid and select permeable pavement. In WinSLAMM v 10.1, permeable pavement is known as "porous pavement".

6. Enter the area of the permeable pavement.

7. Enter the permeable pavement geometry and properties. Some of these, such as the “Aggregate Base Reservoir Thickness”, are presented on Figure 1 of Permeable Pavement Technical Standard 1008.

8. Enter the Outlet and Discharge Options. Check the standard for appropriate drain tile diameters and seepage rates in the native soil.

9. Enter “55” as the “Underdrain Discharge Percent TSS Reduction”.

10. Enter the Surface Pavement Layer Infiltration Rate Data.

11. Enter the Restorative Cleaning Frequency. A semi-annual cleaning frequency is specified in the technical standard.

12. Exit the Porous Pavement form.

13. In the “Program Options” tab, select the “Detailed File Output Options” tab.

14. Select “Surface Seepage Rate”, and then select “Save INI File”. This will generate a detailed output file in the project directory that your model files are saved. This file will indicate when the permeable pavement surface reaches an infiltration rate of 10 in/hr.

15. Save the files and run the model.

16. Review the detailed output file to determine the time at which the permeable pavement surface infiltration rate reaches 10 in/hr (end of the anticipated pavement life).

17. Review the output summary to determine the pollutant load and runoff volume reductions.

18. Annualize pollutant load and runoff volume reductions for regulatory purposes.

IV. EXAMPLE OF USING MODEL

PERMEABLE PAVEMENT DEVICE FORM

The following is an example of using WinSLAMM to determine pollutant load and runoff reduction for permeable pavement. Version 10.1.1 of the model was used. All the steps outlined above in Section III were used in entering the required information into the model. For the purpose of the example, the geometry and properties of the pavement are based on the dimensions found in Figure 1 for Permeable Interlocking

Pavers. The land use selected is a commercial site with 3 acres of impervious parking lot draining to 1acre of permeable pavement or a run-on ratio of 3:1. A twenty year rainfall file was used that can be found listed in the model files or on the USGS web site.

Figure 1 below is the form used by the model for a permeable pavement device. All the properties and outlet options are based on recommendations in the standard. Values for the outlet invert elevation, number of drain tiles, and subgrade infiltration were selected to represent a typical installation. It is important to not change the values in the “Surface Pavement Layer Infiltration Rate Data” table. The model was run with no cleaning and cleaning semi-annually.

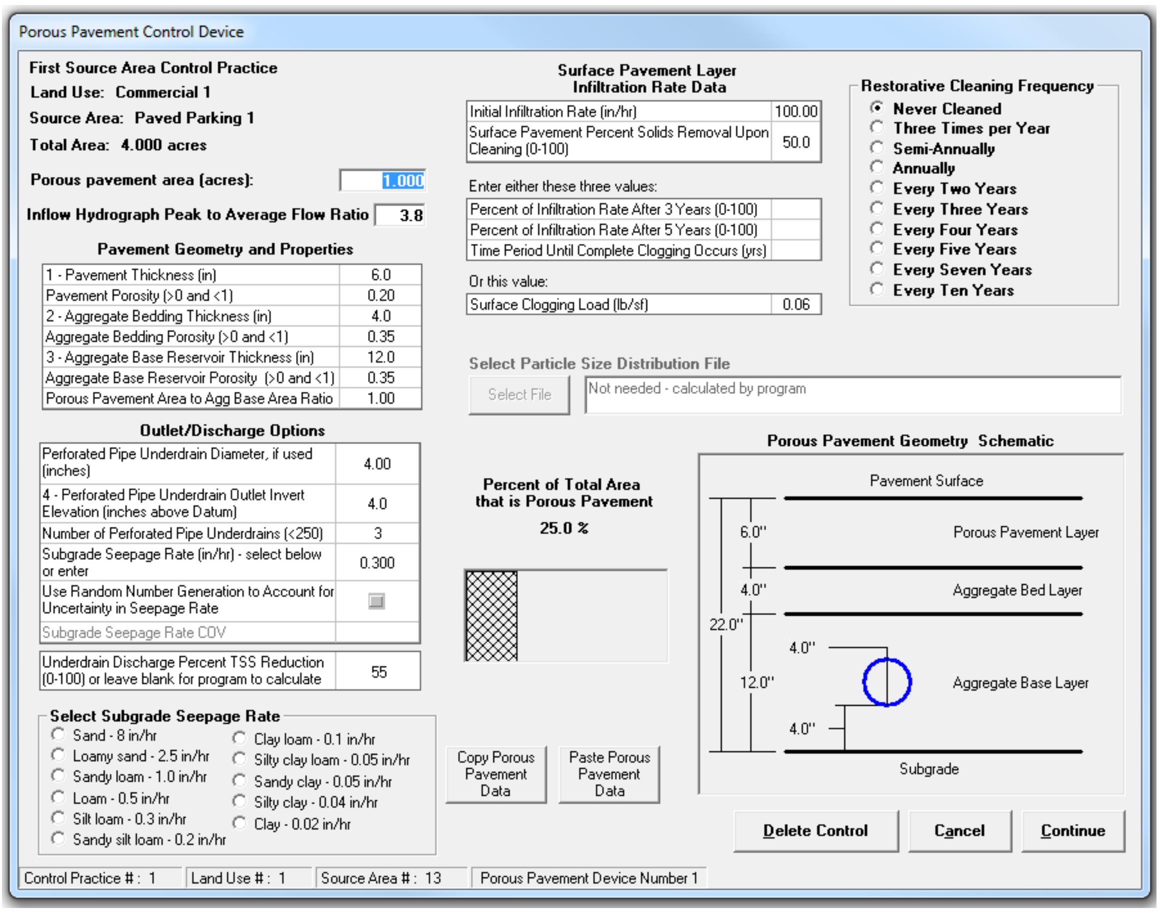

Figure1. Inputs for permeable pavement control device

OUTFAL OUTPUT SUMMARY FORM

Running the model with the data in Figure 1 should produce the results in Figures 2 and 3. The percent TSS reduction with no cleaning is about 55% and about 87% with semi-annual cleaning. Since the TSS reductions are mostly related to a reduction in discharge volume, the percent volume reductions in the Form 2 and 3 are similar to the percent TSS reductions. The semi-annual cleaning had the effect of greatly increasing the TSS reduction. The detailed output provides more information on how the cleaning extends the life of the permeable pavement with the result of increasing the volume reduction.

For regulatory purposes the percent volume and TSS reductions must be annualized. Annualized numbers for the volume and TSS load with controls is provided on the summary form. The annualized percent volume and TSS reductions are the same as the percent reductions that are already presented in the output summary. It is not necessary to re-calculate the percent reductions, because the answers would be the same after dividing by 20.

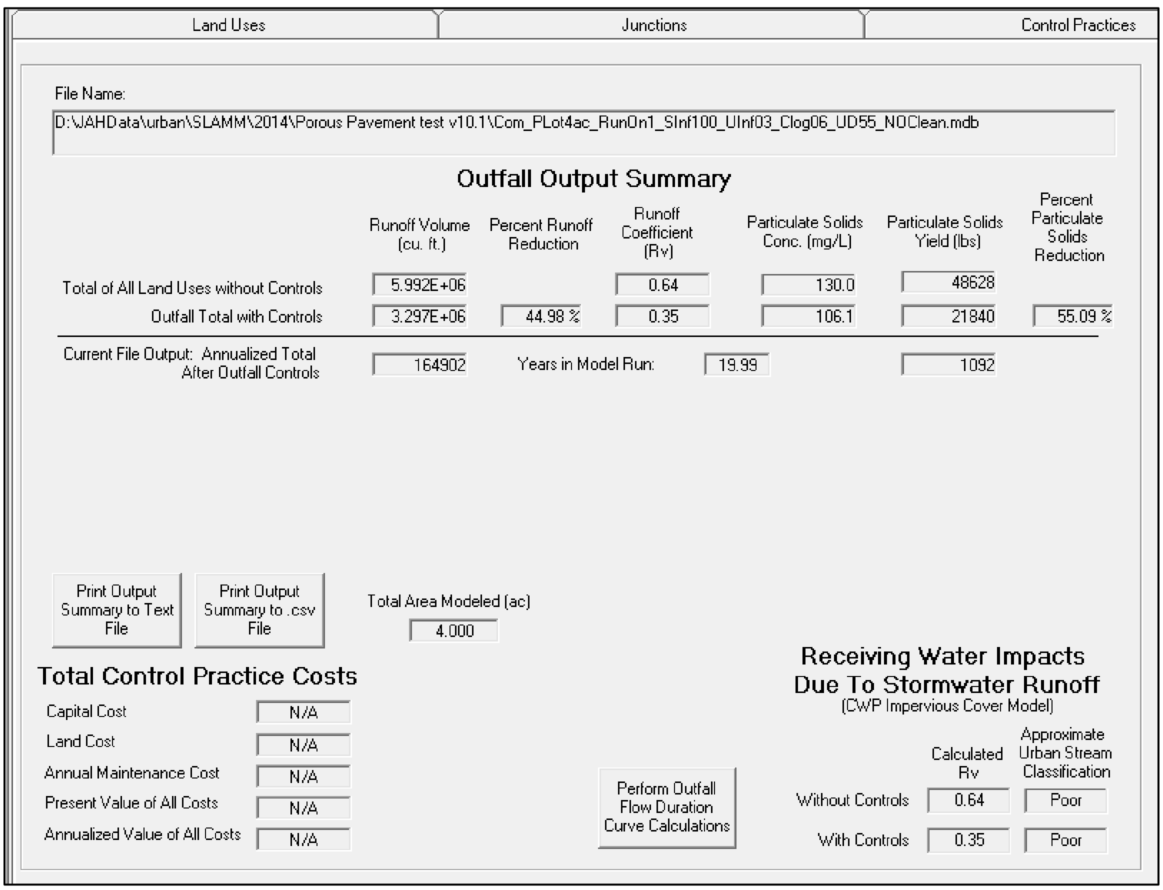

Figure2. Outfall Output Summary for Permeable Pavement with No Cleaning

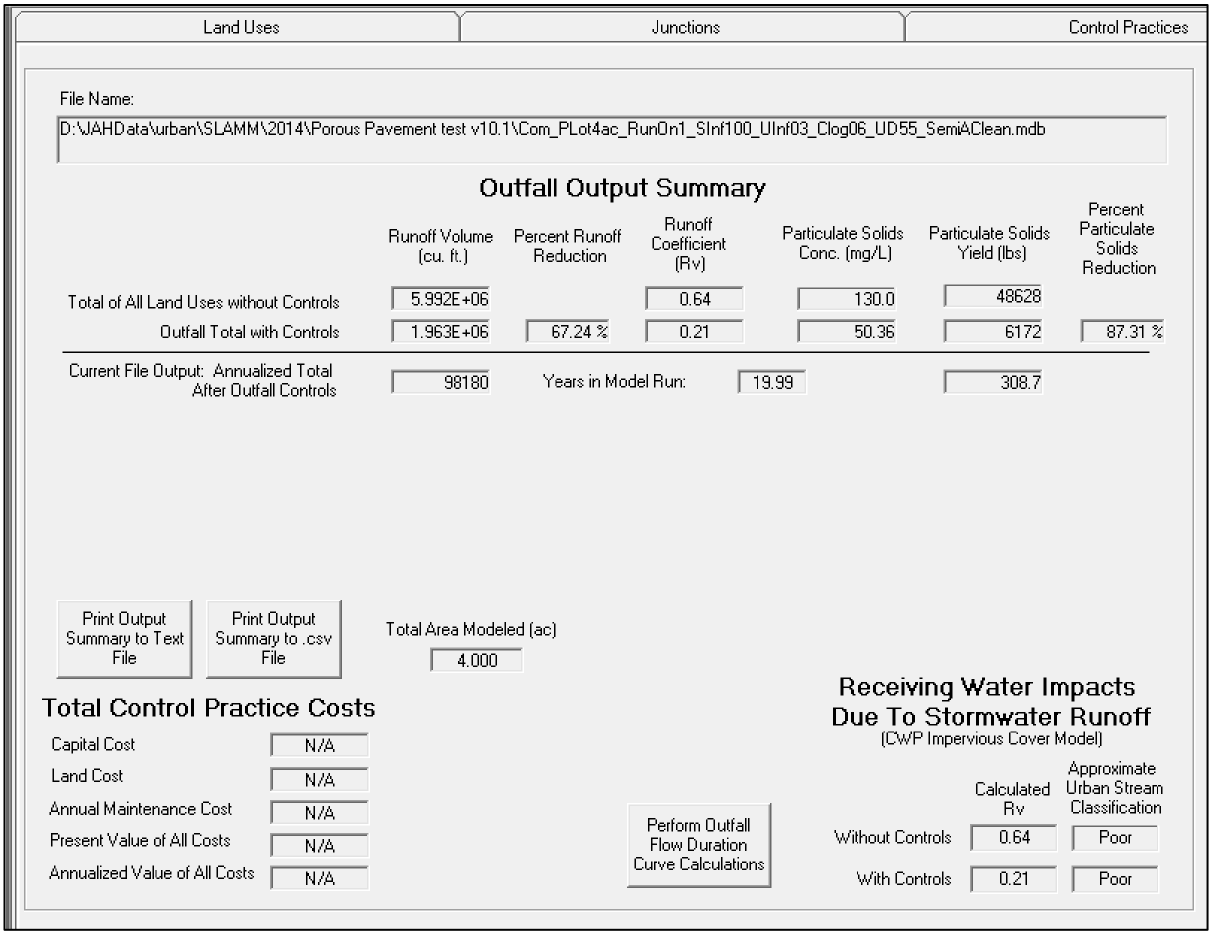

Figure3. Outfall Output Summary for Permeable Pavement with Semi-annual cleaning.

<u>DETAILED OUTPUT</u>

One of the most useful applications of the detailed output is to determine when the permeable pavement infiltration rate has reached the minimum allowed value of 10 inches/hour. The infiltration rates for the permeable pavement with time are listed under the column labeled “Pavement Seepage Rate”. To more clearly track the decline in the infiltration rate as the pavement clogs, the “Pavement Seepage Rate” values should be plotted versus time (Figure 4). For this example the pavement would reach 10 inches/hour in 11.6 years with no cleaning and the cleaning would extend the time before 10 inches/hour is reached to more than 20 years (Figure 4). Since the example does not include the 3 winter months, the number of months on the time axis must have 3 months added for each year.

In the example the semi-annual cleaning helps the pavement meet regulatory requirements for almost the predicted life of a permeable pavement. Lowering the run-on ratio would also increase the time before the clogging would reduce the infiltration rate to 10 inches/hour.

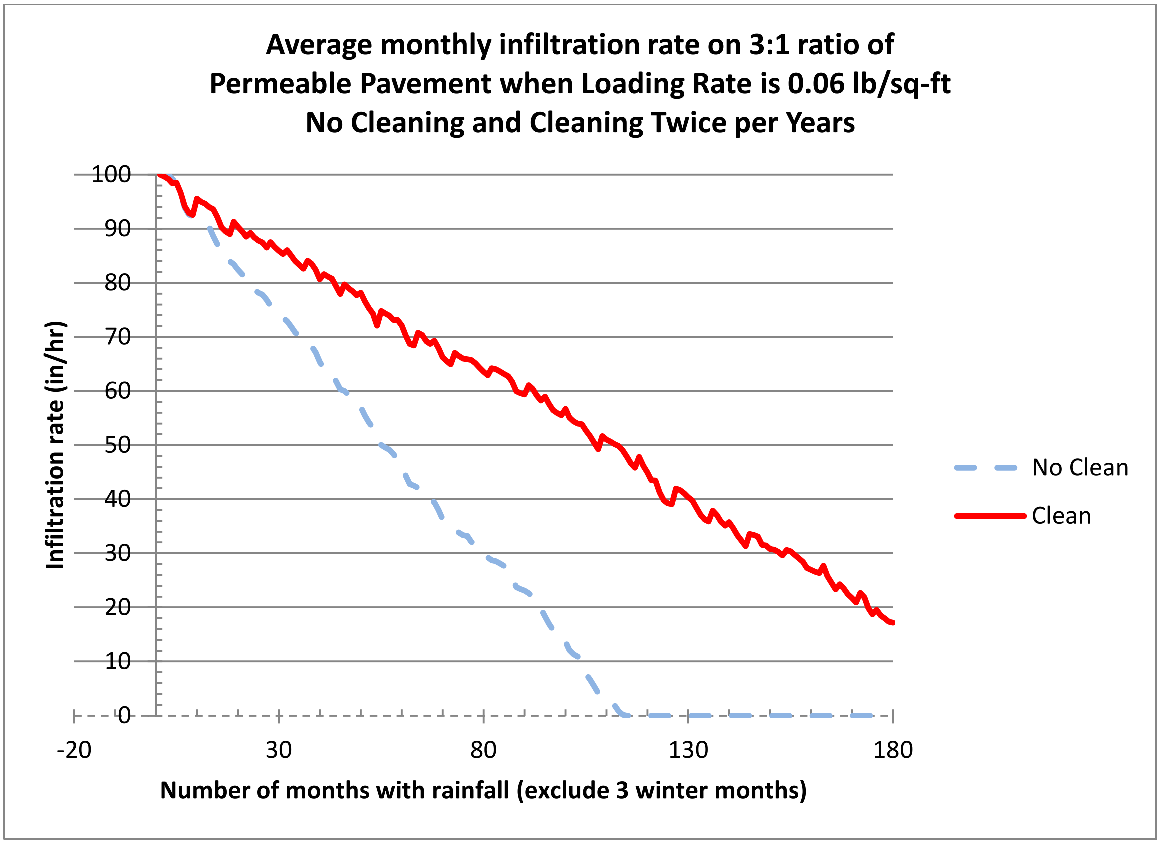

Figure4. The change in permeable pavement infiltration rates with time.

V. REFERENCES

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