APPENDIX II
INFILTRATION MODELING

INFILTRATION PRACTICE DESIGN

Infiltration practices must be designed to meet the average annual infiltration goals included in the Dane County Erosion Control and Stormwater Management Ordinance. Infiltration practice design takes into account the physical characteristics of the site such as: water table, soil types, limiting layers, and tributary land use. In addition, infiltration practices may serve a dual purpose by mitigating thermal impacts. Bioretention basins are often designed to achieve the county requirement for oil and grease treatment and sediment removal.

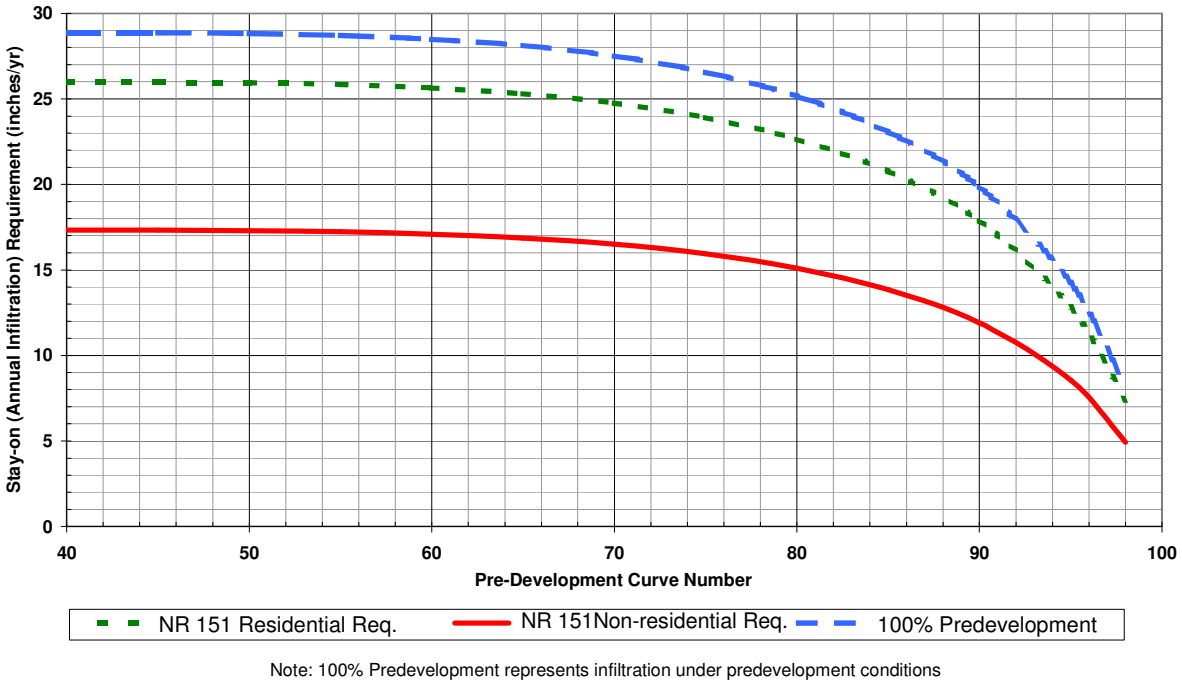
REGULATORY APPROACH TO INFILTRATION

The Dane County infiltration standard is modeled after the Wisconsin Department of Natural Resources (WI DNR) standard. The standard is based upon requiring a percentage of precipitation infiltrated in the predevelopment condition (also known as predevelopment infiltration) to be infiltrated in the post development condition. For residential developments, 90% of the predevelopment infiltration must be infiltrated. For nonresidential sites, 60% of the predevelopment infiltration must be infiltrated. The county utilizes the same "stay-on" approach the WI DNR uses for modeling. Stay-on is defined as all precipitation that does not runoff. Therefore, stay-on includes evaporation, plant transpiration, and recharge. While commonly referred to as an infiltration standard, it is technically a stay-on standard.

The county's regulatory approach differs from the WI DNR approach in two main ways. First, no event-based goals for infiltration are included in the county's standard. Dane County's standard is based solely on an average annual goal and requires the use of continuous flow modeling. Second, there are no limits or "caps" placed on the amount of site area that must be dedicated to infiltration practices to meet the County's standard. If more than 1% of a residential development or 2% of a non-residential development must be dedicated to meet the stay-on goal, the Dane County standard allows designers to alternatively achieve a target average annual recharge goal of 7.6 inches. The target stay-on and target recharge goals are discussed in the following sections.

TARGET STAY-ON REQUIREMENT

Before an infiltration practice can be designed and sized the target stay-on requirement must be determined. The target stay-on is dependent upon the predevelopment curve number (CN). Target stay-on for residential and non-residential developments, for a range of predevelopment CNs, can be determined using figure 1.



Note: 100% Predevelopment represents infiltration under predevelopment conditions

Figure 1 Target Stay-on Requirement as published in the WI DNR Technical Note for Sizing Infiltration Basins and Bioretention Devices.

The target stay-on requirement is given in depth (inches per year), but it may be advantageous to convert this depth to a volume (cubic feet per year). A conversion equation is given in Figure 2.

$$T_v = \left(\frac{T_d}{12}\right)(A_s)$$

T_v = Target Stay-on Volume (ft^3)
T_d = Target Stay-on Depth (in)
A_s = Area of Site (ft^2)

Figure 2 Target Stay-on conversion from depth to volume

TARGET RECHARGE REQUIREMENT

If more that 1% of a residential development or 2% of a non-residential development must be dedicated to meet the stay-on requirement, the designer may instead chose to design infiltration practices to meet Dane County's recharge goal. The target recharge requirement for Dane county is 7.6 inches per year. At the time of publication, the only accepted model for determining the amount of recharge achieved by an infiltration practice is RECARGA. When designing practices to meet the recharge goal, at least 1% of a residential development or 2% of a non-residential development must be dedicated to infiltration practices.

Calculating Recharge

There is no limit or "cap" on the amount of site area that must be dedicated to infiltration practices to meet the County's standard. If more that 1% of a residential development or 2% of a non-residential development must be dedicated to meet the stay-on goal, designers may alternatively design practices to achieve a target average annual recharge goal of 7.6 inches. The recharge calculation is based upon the RECARGA model output, 'Recharge'. An example recharge calculation is provided in Figure 3.

$$R_{Post} = R_F + R_T$$

Where:

R_{Post} = Post development recharge depth

R_F = Calculated facility recharge depth (from RECARGA)

R_T = Calculated tributary recharge depth (from equation)

$$R_T = P \bullet R_{Dane}$$

Where:

P_p = Percent Pervious (decimal format)

R_{Dane} = 7.6 in/yr (Design Recharge Rate for Dane County)

Note: Equations are valid when the entire site drains to the infiltration facility. The facility recharge would need to be prorated if a portion of the site does not drain to the infiltration facility (see Example 2).

Figure 3 Calculation of recharge for post-development condition

Example 1: One-acre residential development

The development consists of several single-family residences. The post development condition will is 60% impervious, 40% impervious. The entire site drains to a bioretention device. RECARGA gives a recharge depth of 5.0 inches.

Then:

R_F = 5.0 in

P_p = 0.40

and,

R_{Post} = 5.0 in + (0.40 x 7.6 in) = 8.0 in

Example 2: Five-acre commercial development

The development consists of several storage units. The post development condition is 4.25 acres of impervious (85%) and 0.75 acres pervious (15%). 3.40 acres of impervious area drains to a bioretention device. RECARGA gives a facility recharge depth of 8.2 inches.

Then:

R_F = 8.2 in * (3.40/4.25) = 6.6 in

P_p = 0.15

and,

R_{Post} = 6.6 in + (0.15 x 7.6 in) = 7.7 in

Figure 4 Example recharge calculations

RECARGA

The RECARGA model was developed to provide a design tool for evaluating the performance of bioretention facilities, raingarden facilities, and infiltration basins. The model is made available through the Wisconsin Department of Natural Resources (WI DNR) website, and can be downloaded free of charge. As with the use of any modeling software, it is important to understand the underlying principals and assumptions used to generate the model's results. Designers utilizing RECARGA modeling software are expected to read and understand the user manual prior to submitting plans that include modeling results. The following information is provided to supplement, not replace the information contained in the RECARGA user's manual. The guidance that follows is intended for permit applicants and designers submitting stormwater management plans to Dane County for review and approval.

Modeling Assumptions

Modeling the performance of stormwater infiltration practices require numerous assumptions be made about the contributing drainage area (tributary areas) and the characteristics of the infiltration practice and native soil conditions. In an effort to ensure proper use of modeling software and consistency in regulation, several modeling assumptions must be followed. Acceptable model input values are summarized in Table 1.

Table 1 Acceptable RECARGA modeling inputs for plans submitted to Dane County LCD

Model Input/Parameter	Acceptable Value
Engineered soil **hydraulic conductivity**	3.94 in/hr
Pervious CN	68*
Maximum **Ponding Zone** depth for bioretention basins	12 in
Maximum **Ponding Zone** depth for infiltration basins	24 in
Root Zone depth for infiltration basins	1 in
Storage Zone depth for infiltration basins	0 in

* unless justified by existing or proposed vegetation (i.e. 58 for prairie vegetation)

Table 2 Acceptable RECARGA modeling output results for plans submitted to Dane County LCD

Model Output/Parameter	Acceptable Value
Maximum **Hours Ponded**	< 96 hrs

In addition to following the acceptable modeling inputs and outputs, the following guidelines must be followed to accurately represent the site, infiltration practice, and native soil conditions:

- The WI DNR Technical Standard 1002 *"Site Evaluation for Stormwater Infiltration"* must be used for determining all design infiltration rates.
- All treatment areas must be removed from the tributary area for calculation purposes so they are not double counted as pervious surfaces.

FREQUENTLY ASKED QUESTIONS AND DEFINITIONS

Frequently Asked Questions

In late 2005, Dane County and City of Madison Staff met with DNR staff to discuss interpretation of NR 151 infiltration standards and related technical standards. County and City staff presented several specific questions concerning interpretations of sections of ch. NR 151, Wis. Adm. Code. Following the meeting, a memorandum was released to formalize the interpretive matters discussed at the meeting. The following text is taken directly from the memorandum dated January 20, 2006.

The Correct Approach toward Infiltration

The intent of the infiltration standard in ch. NR 151, Wis. Adm. Code, is to encourage infiltration of runoff. This requirement is tempered by a series of exemptions and exclusions for the purpose of minimizing the risk of groundwater contamination and addressing the practicality of implementation. These exemptions and exclusions were never intended to be evasive tools for developers and designers to avoid infiltration altogether.

Developers and designers need to seek practical and sometimes innovative methods to meet infiltration requirements. Where infiltration standards are unable to be fully realized, then developers and designers need to meet the standards to the Maximum Extent Practicable (MEP). MEP is a term that provides flexibility in meeting a standard (or requirement). However, there needs to be unique site-specific reasons why a project is unable to fully meet a standard. If full attainment of a standard is impractical due to unique site conditions, then the standard is to be achieved to the furthest degree practical. For example,

- If a portion of a site is not acceptable for infiltration due to poor soils or high groundwater, directing runoff via gravity flow to other areas of the site that are suitable needs to be considered.
- If a shallow layer of clay soil is underlain by sandy soils suitable for infiltration then excavation of the clay layer may be warranted.
- If the only area on a site suitable for an infiltration basin is located up-slope of proposed impervious areas and the impervious areas have no other reasonable location, the designers are not required to pump water to meet the infiltration requirements in NR 151. However, decentralizing infiltration practices and installing rain gardens or other smaller practices around the site must be considered as a viable alternative.

Proper implementation of NR 151 will require that some land or parcels will be needed for storm water management. The economic considerations regarding the loss of developable land are not a reasonable justification to prevent full attainment of a standard. The developer and designer shall not skew data or sampling methods to realize a predetermined outcome or rely on the exemptions and exclusions identified in ch. NR 151 to avoid infiltration, but rather they shall seek ways to maximize infiltration to the MEP.

DNR Caveat: Please note that many of these questions have come up while dealing with commercial sites that fall under the jurisdiction of the Department of Commerce or local ordinances. In these cases, DNR responses are based on DNR implementation of NR 151 and where other authorities are controlling, those authorities must be consulted.

Site Evaluation

- If the area that a developer proposes for infiltration is not on the best "infiltrating" area of the site and the best area is where the building is planned, is he/she required to re-site the facility to meet MEP?

Answer: The planning for infiltration, as indicated in the Site Evaluation for Stormwater Infiltration technical standard, must be done early in the site development process so that infiltration can be accommodated. If the submitted documentation suggests that the developer did not place the infiltration device(s) on the best infiltrating soils, for sites under DNR jurisdiction, DNR will not require that the site be redesigned. However, the developer or designer can not claim exemption from infiltration by placing impervious areas over all usable soils (soils not excluded from infiltration). If this occurs for sites under DNR jurisdiction, site redesign can be required.

- What are the infiltration requirements if the only area on the site that is not excluded is up-hill of the impervious areas or where the impervious areas are planned?

Answer: Pumping will not be required. However, other alternatives must be considered to achieve the infiltration goal. There are often several different infiltration options, so it is unlikely that pumping up-hill is the only alternative.

- If it is determined that with some excavation, a suitable soil layer may be reached, what is required in NR 151? If infiltration is required, to what depth is the developer required to excavate?

Answer: Although not specified by code, DNR believes that requiring excavation to a reasonable depth is acceptable. DNR supports the right of local administering authorities to select a minimum depth that they consider reasonable. Dane County and the City of Madison have adopted two feet as a minimum to define a reasonable excavation depth.

- What if a site doesn't have enough separation, but could be filled to meet the requirements? What level of filling would be required?

Answer: Just like excavation, if the intent is to encourage infiltration, asking the developer to bring in suitable fill material, when it is practical to do so, to meet the separation distance is a reasonable requirement. DNR supports the right of local administering authorities to select a minimum depth that they consider reasonable. Dane County and the City of Madison have adopted two feet of fill as reasonable, provided positive drainage can be maintained.

- Many sites are filled as part of construction. If the native soil was not exempt, but fill material was placed and compacted, is the area now exempt? This seems like it may be an easy way for developers to create an "exempt" site. In the same manner, commercial sites that had significant grading during the plat phase may have been compacted and may now infiltrate less than 0.6 inches/hour. Are these sites considered exempt just because they were graded? If so, wouldn't this be an incentive to compact the soil on a site before applying for a storm water permit?

Answer: Filling and compaction activities performed after implementation of NR 151 (October 2004) will not justify an exemption from the infiltration requirements. The infiltration requirements will be based on the native soils. Accordingly, these sites may be required to remove fill or mitigate compaction to meet the infiltration requirement. Where fill placement and compaction occurred prior to implementation of NR 151, the infiltration requirements will be based on both fill and native soil conditions. However, every effort must still be made to use infiltration practices, such as rain gardens for roof runoff.

Use of Infiltration Technical Standards

- With regards to the cap, are there any requirements or restrictions on how much of the site runoff is directed to a device or the placement of the device on the site to receive flows?

Answer: If the infiltration goals have been met and the infiltration area is at or below the cap, then there are no restrictions on placement of the device or requirements for flow diversion. If the infiltration goals are not realized by sizing a device to the cap, then all impervious surfaces should be routed through the infiltration device to maximize infiltration.

- Is a developer meeting the exclusion criteria if he/she says that the basin will be five feet deep and thus will not have proper separation from groundwater, even though the basin could be constructed shallower and meet the separation criteria?

Answer: The developer needs to have a good reason why the device has to be so deep. Even then, he/she can still be required to look at other infiltration options and practices. Not all the practices have the same design depth requirements.

- In regards to the separation distances, where are they measured from?

Answer: The separation distances are measured from the bottom of the infiltration device to the top of the seasonal high water elevation. The definition of bottom varies by device:

- *For infiltration basins, rain gardens, and swales the bottom of the infiltration device corresponds to the surface elevation of the device (invert of the depression storage).*
- *For bio-retention devices, the engineered soil can be credited toward the separation requirements, however the gravel storage layer (if present) can not. This means, to comply with the 3-feet separation distance, a bio-retention device with 3-feet of properly engineered soil meets the separation requirements. To meet the 5-feet separation requirement, a bio-retention device needs 3-feet of engineered soil and an additional 2-feet of suitable soil (below the gravel storage layer). If suitable soil is not present, the engineered soil depth can be increased to 5-feet. In all cases, the seasonal high groundwater elevation shall be below the bottom of the gravel storage layer to maintain proper functioning of the device.*
- *For rock filled trenches or subsurface infiltration devices, the bottom of the device corresponds to the top of the native soil layer.*

- What is the time frame for additional infiltration standards for swales, pervious pavement, and infiltration trenches? From a regulatory perspective this is a bit of a problem, since swales in SLAMM get too much credit.

Answer: Improvements in SLAMM and the proper application of the swale routine in SLAMM should have alleviated this concern. Additional standards will be made available as staff allocation allows.

- Porous pavement – Is the current means of addressing porous pavement not to treat it as an infiltration device (because an infiltration device requires pretreatment of parking lot runoff) but rather to allow the applicant to reduce the CN in the post developed situation or to treat it as pervious or open space? However, questions come up then in SLAMM if you direct rooftops to it. Does it count as being directed to a pervious or impervious surface? If using SLAMM, how is this treated - as an infiltration bed or as a large landscaped area? If using TR-55 what is the correct CN to allow for porous pavement? Also, are these areas given credit toward the cap?

Answer: Given the current level of understanding on how porous pavement functions, and its effectiveness, the DNR is not ready to address these questions. Additional information needs to be collected. However, we can at this time say that porous pavement should not be used as an infiltration device receiving runoff from sources other than what falls directly on it through precipitation. Areas dedicated to porous pavement cannot be counted toward the cap. For rain that falls directly onto porous pavement, there does not need to be pretreatment prior to letting it move through the porous pavement.

- Underground arch storage and infiltration devices - They look like a pipe cut in half with an open bottom and they are placed under the parking lot. Runoff is typically directed to them after being pretreated by another prefab device such as Stormceptor or Downstream Defender. Are these devices allowable? Do they need pretreatment? If so what amount and do you count these areas toward the cap?

Answer: The requirements for prefab subsurface infiltration systems are similar to infiltration basins with both requiring pretreatment and the area counted toward the cap calculated in the same manner. These devices are typically constructed at commercial development sites. The level of pretreatment for subsurface devices is currently established by Commerce in its plumbing code (s. COMM 82.365). Commerce must decide whether the pretreatment guideline in the infiltration basin technical standard can apply to subsurface infiltration.

- Previous discussion on this matter has indicated that the current SOC standard requirement of 2' or 24 hours draw down whichever is less is not needed, and that the 24 hour draw down would be the enforcement mechanism in more open soils. Is this still the case?

Answer: The 2-foot of depth or 24-hour draw down still applies to the depressional water quality storage volume. If peak flow control is combined with the device, the entire device must be drained within 72 hours.

- Is it true that applicants have a choice of using the design infiltration rates based on soil class or using in-field tested rates modified by the safety factors in the Site Evaluation for Stormwater Infiltration technical standard?

Answer: Yes.

Models for Infiltration

- Who is responsible for maintaining and providing support for RECARGA?

Answer: DNR currently does not have the ability to support individual models. DNR will attempt to contract with the UW or others through the use of grant money to make upgrades and provide support as needed.

- What is the design infiltration rate in RECARGA for engineered soils?

Answer: The default value currently used by RECARGA is 3.94 in/hr. Research has shown that the design infiltration rate of the engineered soils is generally not a critical factor in the proper design of a bio-retention device. If the designer is proposing a soil mixture that deviates from the soil mixture provided in the standard, testing may be warranted to establish an appropriate design infiltration rate.

TSS and Oil and Grease Control

- From the table under Considerations in the bio-retention technical standard, the sediment removal efficiency of a properly designed bio-retention device is purported to be 90%. Can this reduction be assumed if the bio-retention facility follows the design requirements of the technical standard? What if it is undersized due to the cap?

Answer: Whether the practice is fully sized or undersized to meet the cap, a model is needed to calculate the TSS removal efficiency of a bio-retention device. The bio-retention technical standard is for the construction of a device to meet the infiltration requirement. Even though filtration does occur, the Criteria in the standard were never intended to serve as a design tool for TSS reduction. The informational table in the technical standard represents monitored results for unique conditions and serves only as guidance. It was not intended for use as a filtration standard. We will consider removing the table in a future revision if it continues to be misinterpreted. The consultants need to run SLAMM to determine TSS removal efficiency. Alternatively, RECARGA can be utilized by calculating the water volume infiltrated and multiplying that by the average influent concentration of TSS for each unique source area (obtained from SLAMM). Both SLAMM and RECARGA credit TSS reduction through infiltration (basin stay-on) and not filtration. The DNR does not currently have a filtration technical standard and we are hesitant to predict treatment rates for flows passing through the engineered soils and out the under-drain without further research.

- How much oil and grease is being removed by a bio-retention facility?

Answer: Current research provides some guidance and indicates that bio-retention devices are effective in oil and grease removal for the portion of the runoff that is treated in the device. However, actual numbers are based heavily on site conditions. For subsurface infiltration, the pretreatment concentration requirement for oil/grease is specified by Commerce in its plumbing code. Commerce or its agent will have authority over these installations including determination of whether a bio-retention practice provides effluent of adequate quality for subsurface infiltration.

- Sweeping - if sweeping is used in an area - what type of credit do you want to use? SLAMM does not model parking lot sweeping, however shouldn't some credit be given?

Answer: Sweeping is not an allowed practice to meet TSS reduction requirements for sites requiring a Construction Site Permit. This applies to new development, in-fill areas, and redevelopment as defined in NR 151. Credit for street sweeping can only be claimed for existing urban areas under a Municipal Permit.

- SLAMM vs. Control of the 5 micron standard - I want to be certain that for TSS control these standards are interchangeable and that it is the applicant's choice on which method to use for satisfying both agencies.

Answer: The DNR uses the NURP particle size distribution and not the particle distribution for a silt loam soil and looks at TSS control on an average annual basis and not a design storm approach. Based on the NURP distribution, 80% control corresponds to between a 2 and 3 micron particle. SLAMM, P-8, or designs adhering to the technical standard (1001) are the best ways to show that the requirements are being met. Evaluation by Dane County of their design method that relies on a design storm approach and 5-micron particle size suggests that ponds sized using this method match well with the sizes obtained from the standard (1001), while SLAMM designs tend to have smaller surface areas. For now, both Dane County and DNR methods are acceptable.

Definitions

Bioretention - Bioretention is an upland water quality and quantity best management practice that uses the chemical, biological and physical properties of plants and soils to remove pollutants from stormwater runoff.

Continuous flow modeling - Modeling that accounts for continuous input of rainfall/runoff information and utilizes a water budget to track the common hydrologic parameters of a given system. Hydrologic parameters are estimated for an extended period of time, encompassing multiple rainfall events.

Event-based modeling - Modeling that predicts hydrologic parameters based on a single rainfall/runoff event, typically dealing with a time scale measured in hours.

SOURCES

1. Dane County Stormwater Infiltration Taskforce, Jim Lorman Chair. Report of the Dane County Stormwater Infiltration Taskforce. http://www.danewaters.com/pdf/2006StormwaterReport.pdf. July 2006.
2. Wisconsin Department of Natural Resources. For Sizing Infiltration Basins and Bioretention Devices to meet State of Wisconsin Stormwater Infiltration Performance Standards. http://dnr.wi.gov/org/water/wm/nps/stormwater/technote.htm . DNR Technical Notes. Last Update: July 2006.
3. Wisconsin Department of Natural Resources. Central Office Memorandum, NR 151 Questions and Answers. January 20, 2006.