

Grass Swale Infiltrometer Testing Report

For The
TOWN OF NEENAH'S
STORMWATER MANAGEMENT PLAN



Prepared For The
TOWN OF NEENAH
WINNEBAGO COUNTY, WISCONSIN

October 26, 2012
PTK

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ENGINEERS ARCHITECTS

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**TOWN OF NEENAH'S
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Prepared For The
TOWN OF NEENAH
WINNEBAGO COUNTY, WISCONSIN

Prepared By
McMAHON
NEENAH, WISCONSIN

October 26, 2012
McM. No. N0003-900379.00

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Grass Swale Infiltrometer Testing Report

For The

TOWN OF NEENAH'S STORMWATER MANAGEMENT PLAN

Prepared For The

TOWN OF NEENAH WINNEBAGO COUNTY, WISCONSIN

Prepared By

McMAHON
NEENAH, WISCONSIN

October 25, 2012
McM. No. N0003-900379.00

I. INTRODUCTION

In 2008, the Town of Neenah developed a Stormwater Management Plan to assist in complying with their WPDES Municipal Stormwater Discharge Permit. The 2008 Stormwater Management Plan identified grass swales as a best management practice (BMP) that provide water quality credits to the Town. In 2008, the Town's grass swales were evaluated using the best available information, including WDNR guidance documents, NRCS soil survey maps, and design soil infiltration rates. At that time, the design soil infiltration rates were selected from Table 2 of WDNR Conservation Technical Standard No. 1002 – Site Evaluation for Stormwater Infiltration.

On November 24, 2010, the WDNR issued a new guidance document that provides a basis for assessing and modeling grass swales for water quality credit. The 2010 guidance document outlines a procedure for measuring the soil infiltration rate of a grass swale in the field using a double-ring infiltrometer test. The soil infiltration rate is a required input variable within the WinSLAMM water quality computer model used to evaluate the water quality credits provided by a specific grass swale. Since the Town contains a good amount of well drained soils (HSG B), shallow depth to bedrock, and known karst features, it was thought that the measured soil infiltration rates may be higher than the design soil infiltration rates provided in Table 2 of WDNR Conservation Technical Standard No. 1002 – Site Evaluation for Stormwater Infiltration. Higher soil infiltration rates result in increased water quality credits provided by grass swales within

the WinSLAMM water quality model. The purpose of this report is to summarize the results of the double-ring infiltrometer tests and describe how this information was used to update the Town's Stormwater Management Plan. For reference, a copy of the 2010 WDNR grass swale guidance document can be found within Appendix B.

II. STUDY AREA

The study area contains approximately 5,122 acres or 8 square miles and is depicted in Figure 1 within Appendix A. It is of note that the double-ring infiltrometer tests were only performed along grass swales within the Town's developed urban area (urban planning boundary) within the Study Area. The urban planning boundary was developed using 2010 census urban maps and other WDNR guidance. For reference, the urban planning boundary is depicted in Figures 2 and 3 within Appendix A.

III. SOILS

Soil information was obtained from the U.S. Department of Agriculture (USDA) / Natural Resources Conservation Service (NRCS) *Soil Survey of Winnebago County, Wisconsin*. The USDA / NRCS Soils information is depicted in Figure 2 within Appendix A. The USDA / NRCS has classified soil types into four hydrologic soil groups (HSG). The four hydrologic soil groups (i.e. A, B, C and D) are classified according to the minimum infiltration rate of the soil column. Group A soils have the highest infiltration rate or lowest runoff potential, whereas Group D soils have the lowest infiltration rate or highest runoff potential. The infiltrometer tests were performed along grass swales with various underlying hydrologic soil textures and HSG's in order to provide 'representative' soil infiltration rate results within the developed urban area.

IV. INFILTRMETER TESTING

The 2010 WDNR grass swale guidance document outlines a procedure for measuring the soil infiltration rate of a grass swale in the field using a double-ring infiltrometer test. Specifically, the 2010 WDNR grass swale guidance document allows for several modifications to the procedures in ASTM D3385. The purpose of these modifications is to provide a more cost-effective approach to obtaining a reasonable estimate of the soil infiltration rates within existing grass swales. For reference, the field test procedure for the double-ring infiltrometer tests are described in the 2010 WDNR grass swale guidance document found in Appendix B.

A total of 17 double-ring infiltrometer tests were performed along various existing grass swales within the Town's developed urban area. The locations of test sites are depicted in Figure 2 within Appendix A.



Double-Ring Infiltrometer Test – Location 6

Per the 2010 WDNR grass swale guidance document, the lowest infiltration rate observed at each test location is considered the static soil infiltration rate. The static soil infiltration rate at each test site was then reduced by 50% to represent the dynamic soil infiltration rate. The dynamic soil infiltration rate is ultimately used to model a specific grass swale within the WinSLAMM water quality model. For reference, the infiltrometer test results and photos for each test location are included in Appendix C.

V. RESULTS

The results from the 17 individual double-ring infiltrometer tests are summarized below in Table 1.

**Table 1
Infiltrometer Test Results**

Test No.	Landuse	NRCS/USDA Soil Symbol	HSG	¹WDNR Design Dynamic Soil Infiltration Rate (in/hr)	²Measured Dynamic Soil Infiltration Rate (in/hr)
1	SUBR	CeC2	B	0.24	15.00
2	LDR	LzB	C	0.07	10.31
3	LDR	We	B	0.24	1.88
4	LDR	WhB	B	0.24	4.13
5	LDR	MtA	C	0.07	20.63

Test No.	Landuse	NRCS/USDA Soil Symbol	HSG	¹ WDNR Design Dynamic Soil Infiltration Rate (in/hr)	² Measured Dynamic Soil Infiltration Rate (in/hr)
6	LDR	HmB	B	0.24	0.94
7	MDR	OmB	C	0.07	2.25
8	MDR	WnB	C	0.07	5.63
9	SUBR	UoA	C	0.07	5.63
10	MEDI	Ph	A	1.63	1.69
11	LIGHTI	WhB	B	0.24	3.00
12	MEDI	YaA	C	0.07	0.47
13	MEDI	OmB	C	0.07	0.88
14	CSTRIP	NhA	C	0.07	0.09
15	CSTRIP	NhA	C	0.07	7.50
16	CSTRIP	NhA	C	0.07	1.31
17	FREE	NhA	C	0.07	0.75

¹Per Table 2 from WDNR Conservation Technical Standard No. 1002 - Site Evaluation for Stormwater Infiltration

²Determined by selecting the lowest infiltration rate measured at each test location and reducing it by 50%.

As shown in Table 1, the measured dynamic soil infiltration rates are much higher than the WDNR design dynamic soil infiltration rates. In addition, several test locations had very high measured dynamic soil infiltration rates (> 3.6 in / hr). Table 2 of WDNR Conservation Technical Standard No. 1002 – Site Evaluation for Stormwater Infiltration lists 3.6 in/hr as the design dynamic infiltration rate for a sandy soil. In order to provide more appropriate and representative results, it was determined that any measured dynamic soil infiltration rate that was greater than 3.6 in / hr should be removed from the data set. As such, Table 2 summarizes the remaining test results after removing any measured dynamic soil infiltration rate higher than 3.6 in / hr.

Table 2
Infiltrometer Test Results – Final Data

Test No.	Landuse	NRCS/U Soil Symbol	HSG	¹ WDNR Dynamic Soil Infiltration Rate (in/hr)	² Measured Dynamic Soil Infiltration Rate (in/hr)
10	MEDI	Ph	A	1.63	1.69
3	LDR	We	B	0.24	1.88
6	LDR	HmB	B	0.24	0.94
11	LIGHTI	WhB	B	0.24	3.00

Test No.	Landuse	NRCS/U Soil Symbol	HSG	¹ WDNR Dynamic Soil Infiltration Rate (in/hr)	² Measured Dynamic Soil Infiltration Rate (in/hr)
7	MDR	OmB	C	0.07	2.25
12	MEDI	YaA	C	0.07	0.47
13	MEDI	OmB	C	0.07	0.88
14	CSTRIP	NhA	C	0.07	0.09
16	CSTRIP	NhA	C	0.07	1.31
17	FREE	NhA	C	0.07	0.75

¹Per Table 2 from WDNR Conservation Technical Standard No. 1002 - Site Evaluation for Stormwater Infiltration

²Determined by selecting the lowest infiltration rate measured at each test location and reducing it by 50%.

The remaining measured dynamic soil infiltration rates were then sorted and averaged based on the HSG. Since there were no infiltrometer tests performed along a grass swale with an underlying HSG D soil, the average measured dynamic soil infiltration rates from the other data was compared to each HSG's representative pervious curve number (CN) to project a result for HSG D soils. Table 3 summarizes the average measured dynamic infiltration rate for each HSG.

Table 3
Average Measured Dynamic Infiltration Rates

HSG	Average Measured Dynamic Soil Infiltration Rate (in/hr)	Pervious CN
A	1.69	39
B	1.94	61
C	0.96	74
D	0.48	80

Figure 3 within Appendix A depicts the measured dynamic soil infiltration rates (based on the HSG) across the urban planning boundary. Ultimately, this information will be used to calculate the average measured dynamic soil infiltration rate for a particular grass swale based on the acreage of the underlying HSG(s). This information will be input to the WinSLAMM water quality model to evaluate the water quality credits provided by the Town's grass swales.

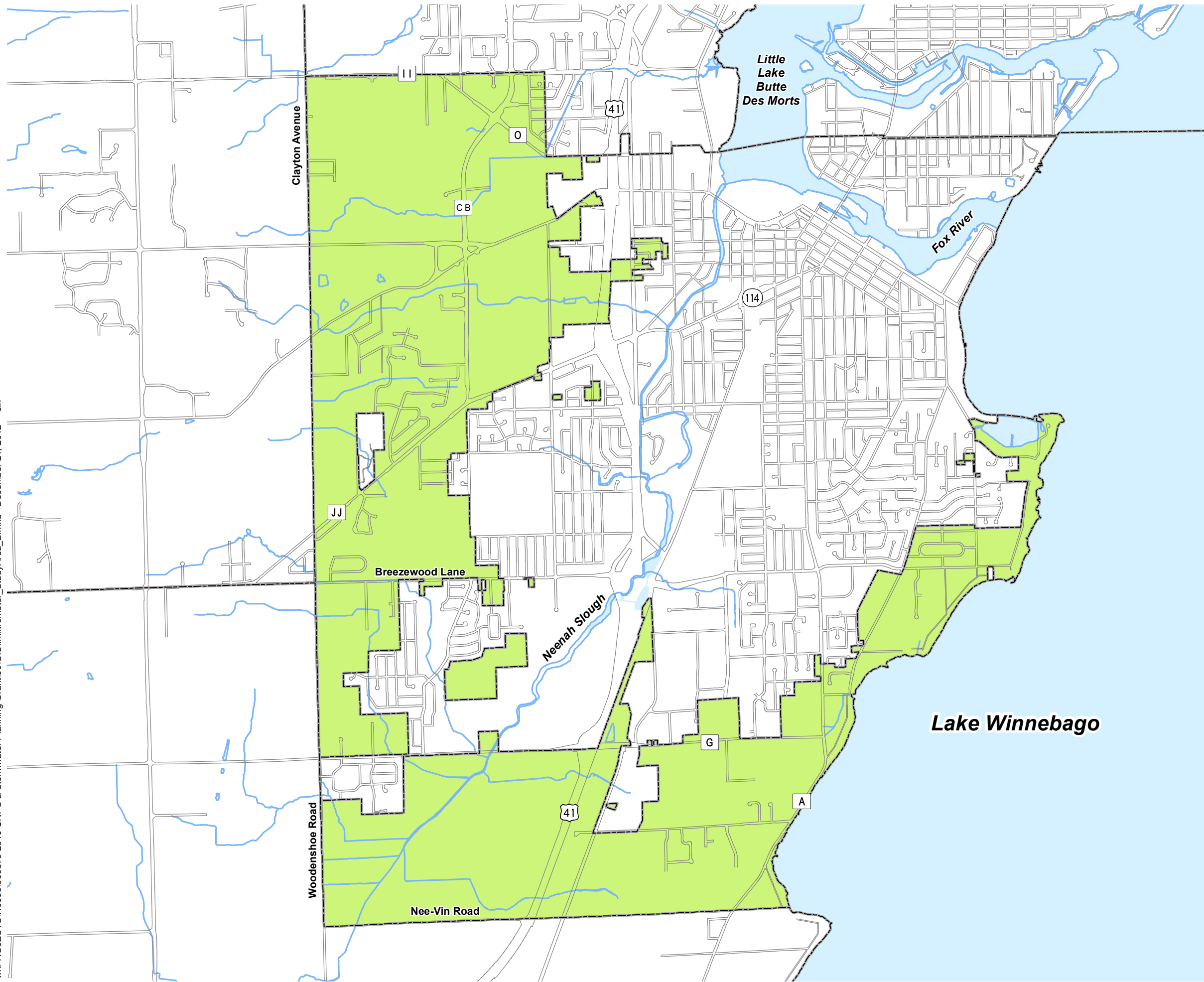
VI. SUMMARY

In summary, the double-ring infiltrometer tests have provided a basis for determining the representative dynamic soil infiltration rates for grass swales within the Town. The dynamic soil infiltration rates determined from this report will be used to update the Stormwater Quality section of the Town's Stormwater Management Plan. Specifically, the average dynamic soil infiltration rates will be used to evaluate the water quality credits provided by the Town's grass swales.

APPENDIX A

FIGURES

w:\PROJECTS\N0003\900379 2010 UNPS & Stormwater Planning Grant\00\GIS\Infiltrometer_StudyArea_B.mxd December 21, 2012 slh



- Town of Neenah
- Other Mapped Features
 - Right-of-Way
 - Municipal Boundary
 - Stream
 - Surface Water

Sources: Winnebago County, 2009-2012.

Disclaimer: The property lines, right-of-way lines, and other property information on this drawing were developed or obtained as part of the County Geographic Information System or through the County property tax mapping function. McMAHON does not guarantee this information to be correct, current, or complete. The property and right-of-way information are only intended for use as a general reference and are not intended or suitable for site-specific uses. Any use to the contrary of the above stated uses is the responsibility of the user and such use is at the user's own risk.

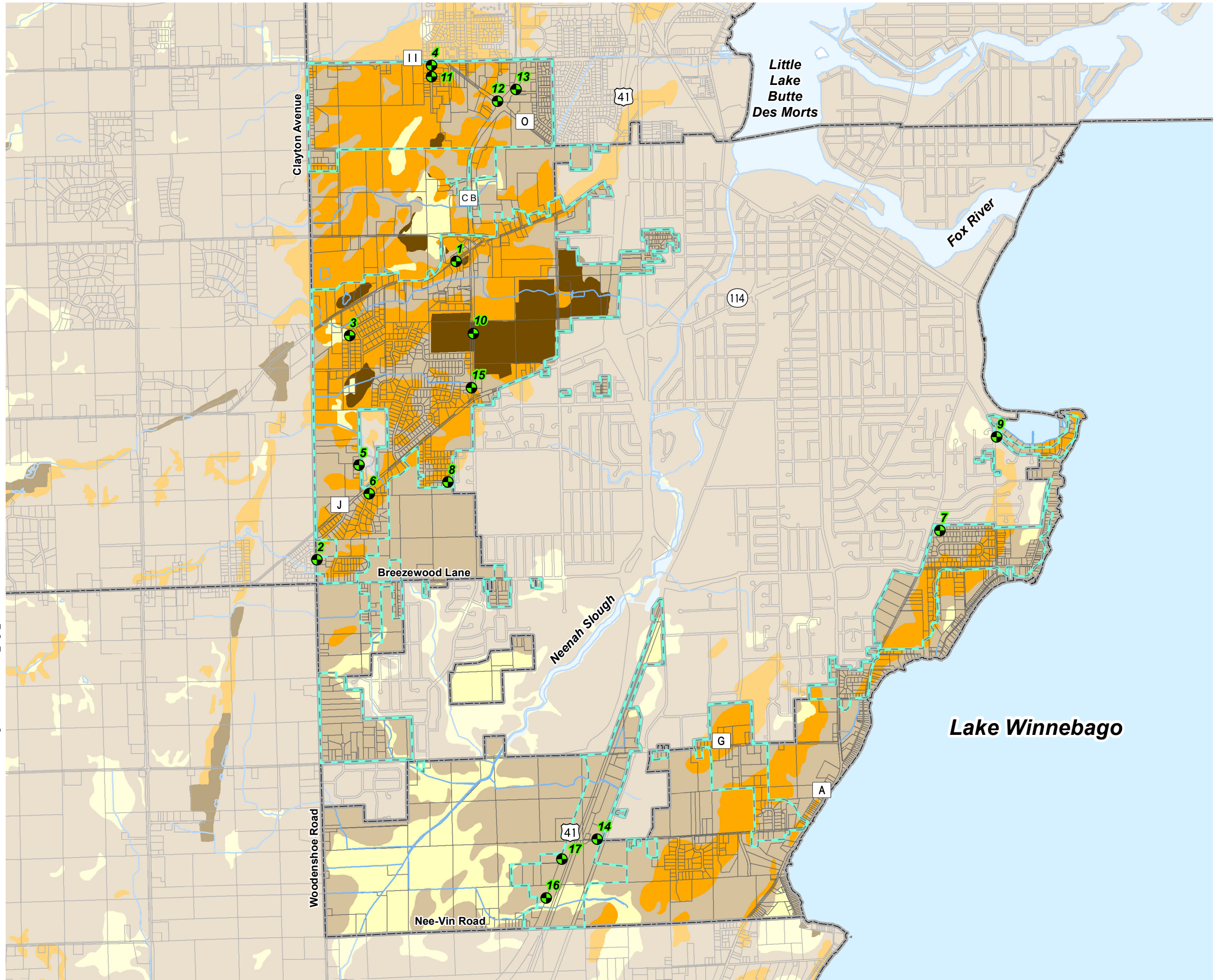


0 3,000 6,000
Feet

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FIGURE 1
STUDY AREA
GRASS SAWLE
INFILTROMETER TESTING
TOWN OF NEENAH
WINNEBAGO COUNTY, WISCONSIN

w:\PROJECTS\N0003\900379 2010 UNPS & Stormwater Planning Grant\00 GIS\Soils_Fig2_B.mxd December 21, 2012 slh



Hydrologic Soil Group (HSG)

- A
- B
- C
- D

Other Mapped Features

- 5 Infiltrometer Test Location and ID
- Urban Planning Boundary
- Parcel or Right-of-Way Line
- Municipal Boundary
- Stream
- Surface Water

Sources: Winnebago County, 2009-2011; USDA, 2011.

Disclaimer: The property lines, right-of-way lines, and other property information on this drawing were developed or obtained as part of the County Geographic Information System or through the County property tax mapping function. McMAHON does not guarantee this information to be correct, current, or complete. The property and right-of-way information are only intended for use as a general reference and are not intended or suitable for site-specific uses. Any use to the contrary of the above stated uses is the responsibility of the user and such use is at the user's own risk.

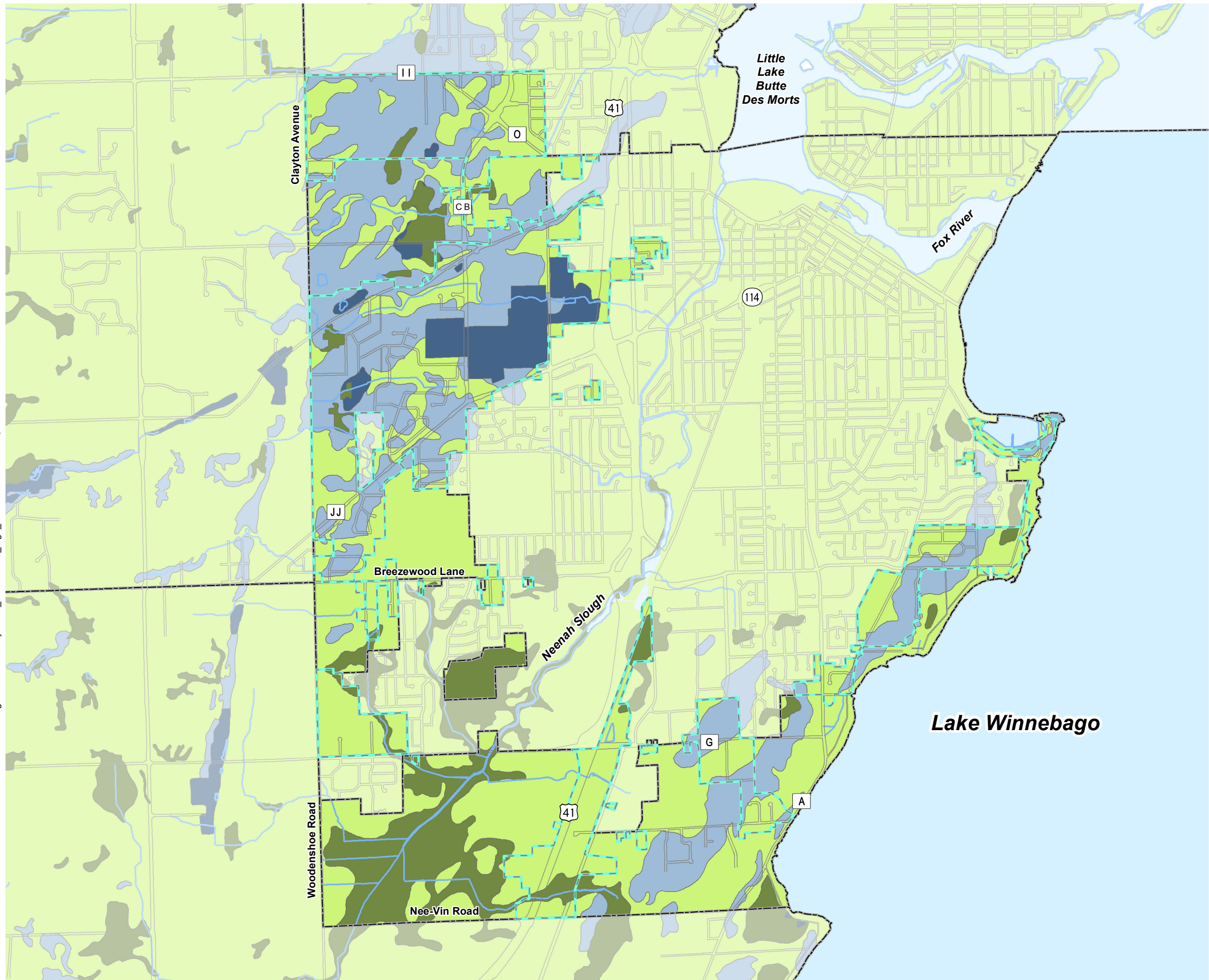


0 3,000 6,000 Feet

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FIGURE 2
SOILS AND TEST LOCATIONS
GRASS SWALE
INFILTROMETER TESTING
TOWN OF NEENAH
WINNEBAGO COUNTY, WISCONSIN

w:\PROJECTS\N0003\9000379 2010 UNPS & Stormwater Planning Grant\00\GIS\Dynamic_Infiltrometer_Fig3_B.mxd December 21, 2012 slh



**Dynamic Infiltration Rates
(Inches Per Hour)**

0.48
0.96
1.69
1.94

Other Mapped Features

- Urban Planning Boundary
- Parcel or Right-of-Way
- Municipal Boundary
- Stream
- Surface Water

Sources: Winnebago County, 2009-2012.

Disclaimer: The property lines, right-of-way lines, and other property information on this drawing were developed or obtained as part of the County Geographic Information System or through the County property tax mapping function. McMAHON does not guarantee this information to be correct, current, or complete. The property and right-of-way information are only intended for use as a general reference and are not intended or suitable for site-specific uses. Any use to the contrary of the above stated uses is the responsibility of the user and such use is at the user's own risk.

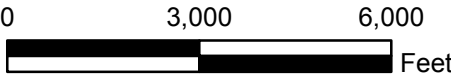


**FIGURE 3
DYNAMIC INFILTRATION RATES
GRASS SWALE
INFILTROMETER TESTING
TOWN OF NEENAH
WINNEBAGO COUNTY, WISCONSIN**

APPENDIX B

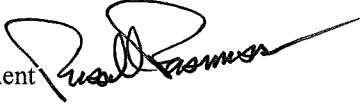
2010 WDNR GRASS SWALE GUIDANCE DOCUMENT

CORRESPONDENCE/MEMORANDUM

State of Wisconsin

DATE: November 24, 2010

TO: Regional Water Leaders, Basin Leaders and Experts
Storm Water Permit Staff (via email)

FROM: Russ Rasmussen, Director, Bureau of Watershed Management
DNR Storm Water Permit Engineers 

SUBJECT: Process to Assess and Model Grass Swales for ss. NR 151.13(2) and NR 216.07(6), Wis. Adm. Code
- Total Suspended Solids Reduction

*This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts. **This guidance document supersedes the guidance document on Dated April 24, 2008 and subsequent erratas dated August, 2008 and April, 2009.***

Issue

Under s. NR 151.13(2), Wis. Adm. Code, a municipality subject to the municipal storm water permit requirements of s. NR 216.07(6), Wis. Adm. Code, must implement a 20% reduction in total suspended solids (TSS), by March 10, 2008 or 24 months from coverage under the Municipal Separate Storm Sewer System (MS4) general permit, and a 40% TSS reduction by March 10, 2013. This memorandum provides DNR staff with guidance to advise affected municipalities and their consultants on how to evaluate grassed swales in the developed urban area for water quality credit. (This guidance does not address design of grassed swales to serve new development. The Vegetated Infiltration Swale, Interim Technical Standard, No. 1005 provides information on construction of new grassed swales.)

Discussion

To meet the requirements of the MS4 permit and the TSS reduction goal of s. NR 151.13(2), Wis. Adm. Code, a municipality must assess existing best management practices (BMPs) for TSS control and propose additional BMPs if the performance standard cannot be met with existing practices. One BMP available to many permitted municipalities is the grassed swale. This guidance provides a basis for assessing and modeling swales for TSS reduction to foster consistent application of this practice in all permitted municipalities. The goals of this guidance are to:

- Determine which water quality swales in the MS4 are eligible to receive TSS reduction credit, and
- Identify a typical swale geometry that can be considered representative. (It may be appropriate to develop more than one typical swale geometry if the swale characteristics in the MS4 are highly variable.)

DNR Guidance

Step 1. Identify which swales in the municipality can be considered water quality swales for the purpose of meeting the 20% and 40% TSS reduction goal.

The following apply to all swales in the developed urban area if they are to be considered water quality swales:

- A. Swales are not required to have pretreatment swales or equivalent pretreatment.
- B. The longitudinal slope must be less than 4% unless slope interruption devices are installed in the swales to ensure low flow velocities. Slope interruption devices must be consistent with Ditch Check Technical

Standard, No. 1062. Swales with slope interruption devices will be evaluated using a modified longitudinal slope of 1%.

- C. The Department is concerned about channel scouring and re-suspension of previously settled particles in swales that are being used for MS4 pollutant removal credit. To address this concern, all swales should be inspected for visual evidence of scour. Swales with visual evidence of scour, such as channel cuts in the bottom or areas of bare soil, can not be included.

There are two ways of identifying water quality swales within an MS4:

- A. If swale survey data is available, determine the locations of water quality swales and arrive at typical swale geometry based on statistical methods.
- B. In the absence of survey data, a desktop and field survey would be appropriate. The desktop and field procedure is as follows:
1. Identify potential water quality swale areas by using available topographic, land use and soil information.
 2. Based on results of the desktop evaluation, select a representative number of typical swale locations in the MS4 by conducting a field survey. A minimum of five locations should be selected. At each location:
 - Measure the width of the swale bottom using a tape measure.
 - For side slopes, measure the vertical drop over the level length using a carpenter's level and tape measure.
 - Select at least three cross-sections of the swale and average the results to determine the bottom width and side slopes.
 - Determine longitudinal slope using 2-ft contour mapping or other available topographic information.
 3. Use the typical swale geometry that best represents each drainage area.

Step 2. Model the swales identified in **Step 1.** using a model such as SLAMM or P8.

When modeling swales in SLAMM or P8 the following must be considered:

How should drainage basins with a mix of swale and storm sewer conveyance systems be evaluated?

Drainage basins with a combination of swales and storm sewer should be subdivided by conveyance system type and the subdivisions modeled separately. In SLAMM, swales need to be modeled separately because drainage system type (e.g., swale vs. storm sewer) cannot be assigned to individual source areas.

Where swale density varies within a modeled area, the swale density should be an area weighted average across the model area. For example, if a 100 acre modeled area has 90 acres of residential land use with an average swale density of 359 ft/acre and 10 acres of strip commercial with an average swale density of 412 ft/acre then the area weighted average across modeled area is $[(90 \times 359) + (10 \times 412)] / 100 = 364$ ft/acre.

Table 1 identifies the average swale density used in the standard land use files from SLAMM version 9.2. It is recommended that rather than using these averages, the municipality should identify the actual swale density for each of the representative areas.

TABLE 1

<u>Land use</u>	<u>Swale Density (ft/acre)</u>
Low density residential	238
Medium density residential	359
High density residential	385
Strip commercial	412
Shopping centers	92
Industrial	265
Freeway (Shoulder only)	1309
Freeway (Shoulder and Center)	1964

Note: These average swale density figures are from the SLAMM version 9.2 Standard Land Use files available on the USGS website at: <http://wi.water.usgs.gov/slammm/>

Should swales be modeled using the “wetted perimeter” or “typical swale geometry” option?

The typical swale geometry option must be used. Both SLAMM and P8 calculate wetted perimeter from the geometry for each storm event, which is more accurate than a user selected defined wetted perimeter.

What Manning’s “n” should be used for the typical swale geometry¹?

A Manning’s “n” value of 0.30 or less is recommended, based on type of vegetation, mowing height and depth of flow. Supporting documentation should be provided if Manning’s “n” values greater than 0.30 are used

How should the infiltration rate be determined?

The guidance provided in the Site Evaluation for Stormwater Infiltration Technical Standard, No. 1002 should be followed. The swale infiltration rate should be determined based on the representative soil texture identified in the NRCS soil survey or other soil data if available. When the representative soil texture has been determined, the appropriate design infiltration rate should be selected from Table 2 of the Technical Standard, No. 1002. If the infiltration rate is measured in the field using a scientifically credible field test method, the measured value can be used for the static infiltration rate without using the correction factors in Table 3 of Technical Standard, No. 1002. **Prior to entering an infiltration rate in the model, the design infiltration rate from Table 2, or the measured infiltration rate must be reduced by 50%.** The SLAMM default “infiltration rate by soil type” values should not be used.

Existing language in Technical Standard 1002 V. Step C. 4.b indicates that a measured infiltration rate using a double-ring infiltrometer test must follow the requirements of ASTM D3385. While this may be appropriate for designing new swales, is there any flexibility for measuring an existing swale using a double-ring infiltrometer test?

To determine the static infiltration rate of existing swales using a double-ring infiltrometer the following modifications to procedures in ASTM D3385 are allowed:

While the dimension and materials used for the double-ring should be based on the requirements of ASTM D3385, the infiltration rate can be measured in a time frame of a minimum of 2 hours instead of 24 hours and the water level in both rings does not have to stay constant during the test. The following procedure is a more cost-effective

¹ SLAMM version 9.3 will adjust Manning’s “n” based on flow, swale geometry and vegetative retardance classifications

approach to obtaining a reasonable estimate of the infiltration rate of existing grass swales. For most soil types the infiltration rate measured by the procedure should represent the soils under more saturated conditions. Sandier soil types might not be represented by saturated conditions, but the higher infiltration rate will probably represent reality for the duration of most storm events. The lowest infiltration rate observed is the one to be used for estimating the TSS reduction for the swales and is considered a static infiltration rate. The static rate should be cut in half to represent the dynamic infiltration rate in the model.

Field Test Procedure for Double-Ring Infiltrometer

1. Select a relatively flat test area so that the double-ring infiltrometer will not be placed at an angle.
2. Cut the grass to a height of between two to four inches.
3. Gently drive the infiltrometer into the ground.
4. Inspect the soil seal around each ring to make sure that it is even and smooth.
5. Pour clean water into the inner chamber and allow it to overflow and fill up the outer ring. Maintain a level in the outer ring approximately equal to the level in the inner ring.
6. Add more water to both rings when the level in the inner ring has dropped a measurable amount. For most soil types this should be less than an inch.
7. Repeat this step until the rate the water level drops begins to decline.
8. When the rate of decline begins to slow, bring the water level up to the top and start timing the decrease in water level.
9. Record the start time.
10. Stop timing when the water level in the inner ring has gone down a measureable level (the ASTM standard requires keeping the water level constant). Timing the rate of decline should probably be started almost immediately for more clayey soils, since it might be difficult to observe when the rate change has slowed.
11. Record the time, elapsed time, and change in water level.
12. Refill both rings and restart the timing.
13. Record the time, elapsed time, change in water level, and the elapsed time since the beginning of the first measurement.
14. Repeat the timing steps until the infiltration rate has become relatively constant or the test has been conducted for a minimum of two hours. (The ASTM standard requires 24 hours).
15. The measured rate of infiltration is considered a static infiltration rate. The dynamic infiltration rate is $\frac{1}{2}$ the static rate. Be aware some models, such as WinSLAMM, call for the dynamic rate for swales.

I have taken a number of measurements along a swale length and have several infiltration rates to average. How do I average the results of my in-field tests?

The geometric mean(s) of infiltration testing results should be used. However, equally important is to consider whether the measured infiltration rates should be 'grouped' in order to apply separate geometric means to different areas in order to provide representative TSS results across a municipality. Grouping of results might be done based on soil type, spatial reasons or simply done as a method to help provide representative results. For instance, if there are several relatively low infiltration rates measured and the geometric mean of the entire data set is quite high, it may be prudent to group the relatively low rates together and assign them to a representative area.

Note: In order to calculate a geometric mean, the data set of values must be greater than zero. Where the infiltration rate is too low to measure, a rate of 0.03 in/hr may be used to calculate a geometric mean of the data set.

Are velocity calculations required?

The swales that were not eliminated by visual inspection should be evaluated for scour and re-suspension using the results of velocity or shear stress calculations conducted at the representative swale locations

from **Step 1**. Velocity or shear stress calculations should be conducted based on the peak discharge rate for a 2-yr, 24-hr design event (or a reasonably equivalent event from the SLAMM or P8 rainfall file for the area) to verify that scour and re-suspension will not be a problem.

Do water quality swales need to meet the slope parameters identified in Vegetated Infiltration Swale, Interim Technical Standard, No. 1005?

If functioning as vegetated conveyance systems, swales with longitudinal slope less than 1% can be used. However, there is concern that swales with slopes less than 1% can clog. Where visual evidence indicates that the infiltration rate has been reduced (e.g., significant duration of ponded water or evidence of wetland vegetation), infiltration rates appropriate for clay soils should be used.

How do I model road runoff that sheet flows off the road and is dispersed with no apparent concentrated flow path?

For roads where runoff sheet flows off to the side of the road and is dispersed into adjacent pervious areas with no concentrated flow path in the vicinity, the roadway would be considered a disconnected impervious surface. Currently, SLAMM does not have the option of disconnecting a roadway, whereas rooftops and driveways can be disconnected. Therefore, an alternative method is needed to give treatment credit for such a system. If there is no concentrated flow path near the roadway and the runoff is dispersed as sheet flow across healthy vegetated areas, model this as a very broad, flat swale unless there is an option to model it as a vegetated filter strip.

Approved By:



Gordon Stevenson, Chief
Runoff Management Section

APPENDIX C

INFILTROMETER TEST RESULTS & PHOTOS

UNPS & SW Planning Grant
Swale Infiltrometer Testing Results
Town of Neenah, WI
McM No. N0003-900379.00

Test Site # 1 Oakridge Road, SE corner of Oakridge Pl.
Date: November 12, 2010

Time (min)	Drop (inches)	Permeability Rate (in./hr.)	Lowest Perm. Rate =	30.00
2	1.25	37.5	Dynamic Rate =	15.00
2	1.25	37.5		
2	1.125	33.8		
2	1.125	33.8		
2	1	30.0		
2	1	30.0		
2	1	30.0		
2	1	30.0		
2	1	30.0		
0.93	0.5	32.1		
0.92	0.5	32.7		
0.92	0.5	32.7		
0.92	0.5	32.7		
0.88	0.5	34.0		
0.92	0.5	32.7		
0.90	0.5	33.3		
0.95	0.5	31.6		
0.93	0.5	32.1		
0.90	0.5	33.3		
0.92	0.5	32.7		

Test Site # 2 Woodenshoe Rd., 300' south of Woodcrest Dr.
Date: November 12, 2010

Time (min)	Drop (inches)	Permeability Rate (in./hr.)	Lowest Perm. Rate =	20.63
2	0.75	22.5	Dynamic Rate =	10.31
2	0.75	22.5		
2	0.75	22.5		
2	0.75	22.5		
2	0.75	22.5		
2	0.75	22.5		
2	0.6875	20.6		
2	0.6875	20.6		
2	0.6875	20.6		
2	0.6875	20.6		
2	0.6875	20.6		
2	0.6875	20.6		

Test Site # 3 North/south Harvard Drive, 150' south of BEND
Date: November 12, 2010

Time (min)	Drop (inches)	Permeability Rate (in./hr.)	Lowest Perm. Rate =	3.75
3	0.5	10.0	Dynamic Rate =	1.88
3	0.375	7.5		
3	0.375	7.5		
3	0.1875	3.8		
5	0.5	6.0		
5	0.4375	5.3		
5	0.5	6.0		
5	0.5	6.0		
5	0.5	6.0		

Lowest Perm. Rate = 8.25
Dynamic Rate = 4.13

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
5	0.875	10.5
5	0.875	10.5
5	0.875	10.5
10	1.5	9.0
10	1.5	9.0
10	1.375	8.3
10	1.375	8.3

Lowest Perm. Rate = 41.25
Dynamic Rate = 20.63

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
2	1.75	52.5
2	1.5	45.0
2	1.5	45.0
2	1.5	45.0
2	1.5	45.0
2	1.5	45.0
2	1.5	45.0
2	1.375	41.3
2	1.375	41.3
2	1.375	41.3

Lowest Perm. Rate = 1.88
Dynamic Rate = 0.94

		Permeability
Time (min)	Drop (inches)	Rate (in./hr.)
4	0.5	7.5
4	0.125	1.9
8	0.4375	3.3
8	0.375	2.8
8	0.375	2.8
8	0.375	2.8

Lowest Perm. Rate = 4.50
Dynamic Rate = 2.25

[illegible]

Test Site # 8 Hilltop Dr., 250' west of Nothatch Ln. Lowest Perm. Rate = 11.25
 Date: November 16, 2010 Dynamic Rate = 5.63

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
3	0.5625	11.3
3	0.5625	11.3
3	0.5625	11.3
5	1.25	15.0
5	1	12.0
5	1.0625	12.8
5	1	12.0
5	1	12.0

Test Site # 9 Limekiln Dr., 75' east of Bayview Rd. Lowest Perm. Rate = 11.25
 Date: November 18, 2010 Dynamic Rate = 5.63

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
5	1.25	15.0
5	1.0625	12.8
5	1.0625	12.8
5	1.0625	12.8
5	1.0625	12.8
5	1	12.0
5	1	12.0
5	0.9375	11.3
5	0.9375	11.3
5	0.9375	11.3
5	0.9375	11.3

Test Site # 10 CTH CB, 800' north of Radcliff Road Lowest Perm. Rate = 3.38
 Date: November 16, 2010 Dynamic Rate = 1.69

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
5	0.5	6.0
10	0.625	3.8
10	0.5625	3.4
10	0.5625	3.4
10	0.5625	3.4

Test Site # 11 S. Fieldcrest Dr., 400' south of CTH II Lowest Perm. Rate = 6.00
 Date: November 16, 2010 Dynamic Rate = 3.00

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
3	0.75	15.0
3	0.5	10.0
3	0.625	12.5
3	0.5	10.0
5	0.5	6.0
5	1	12.0
5	1	12.0
5	0.875	10.5
5	1	12.0
5	1	12.0
5	1	12.0

Test Site # 12 CTH O, 100' NW of CTH CB Lowest Perm. Rate = 0.94
 Date: November 15, 2010 Dynamic Rate = 0.47

Time (s.)	Drop (inches)	Permeability Rate (in./hr.)
40	0.625	0.9
20	0.3125	0.9
20	0.3125	0.9
20	0.3125	0.9

Test Site # 13 NE Corner of CTH CB & Strohmeyer Drive Lowest Perm. Rate = 1.75
 Date: November 15, 2010 Dynamic Rate = 0.88

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
15	0.4375	1.8
15	0.4375	1.8
15	0.4375	1.8
15	0.4375	1.8

Test Site # 14 Muttart Road, 100' west of Dixie Road Lowest Perm. Rate = 0.19
 Date: November 16, 2010 Dynamic Rate = 0.09

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
60	0.1875	0.2
20	0.25	0.8
20	0.5	1.5
20	0.1875	0.6

Test Site # 15 CTH CB, 200' north of CTH JJ Lowest Perm. Rate = 15.00
 Date: November 18, 2010 Dynamic Rate = 7.50

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
2	1.0625	31.9
2	0.9375	28.1
2	0.9375	28.1
2	0.875	26.3
2	0.875	26.3
2	0.875	26.3
2	0.8125	24.4
2	0.8125	24.4
2	0.75	22.5
2	0.75	22.5
2	0.75	22.5
2	0.75	22.5
2	0.75	22.5
10	2.625	15.8
10	2.625	15.8
10	2.625	15.8
10	2.625	15.8
10	2.625	15.8
10	2.5	15.0
10	2.5	15.0
10	2.5	15.0

Test Site # 16 W. Frontage Rd. (USH 41), 400' north of "Stars" Lowest Perm. Rate = 2.63
 Date: November 16, 2010 Dynamic Rate = 1.31

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
10	0.5	3.0
10	0.4375	2.6
10	0.4375	2.6
10	0.4375	2.6
10	0.4375	2.6

Test Site # 17 W. Frontage Road, 1000' North of CTH G (1649 Bergstrom Rd.) Lowest Perm. Rate = 1.50
 Date: November 16, 2010 Dynamic Rate = 0.75

Time (min)	Drop (inches)	Permeability Rate (in./hr.)
10	0.25	1.5
10	0.25	1.5
10	0.25	1.5
10	0.25	1.5
10	0.25	1.5



Photo 1. Viewing west at Sample Point 1



Photo 2. Viewing south at Sample Point 2



Photo 3. Viewing south at Sample Point 3



Photo 2. Viewing north at Sample Point 4



Photo 5. Viewing south at Sample Point 5



Photo 6. Viewing west at Sample Point 6



Photo 7. Viewing east at Sample Point 7



Photo 8. Viewing east at Sample Point 8



Photo 9. Viewing east at Sample Point 9



Photo 10. Viewing south at Sample Point 10



Photo 11. Viewing north at Sample Point 11



Photo 12. Viewing northwest at Sample Point 12



Photo 13. Viewing north at Sample Point 13



Photo 14. Viewing east at Sample Point 14



Photo 15. Viewing north at Sample Point 15



Photo 16. Viewing north at Sample Point 16



Photo 17. Viewing north at Sample Point 17