Storm Water Quality Plan

NR216/NR151 TSS Reductions

City of Middleton, Wisconsin

MSA Project No. 120366

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Prepared by:

MSA Professional Services, Inc.
2901 International Lane, Suite 300
Madison, WI 53704

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1.0 EXECUTIVE SUMMARY

This report documents the findings of a study conducted for purposes of determining the City of Middleton's compliance with Total Suspended Solids reductions in accordance with NR216.07(6)(b) and NR151.13. The standards outlined within these two chapters require that regulated communities, including the City of Middleton, achieve a 20% reduction in total suspended solids in runoff that enters waters of the state as compared to no controls by 2008, and implement management practices to achieve a 40% reduction in total suspended solids in runoff that enters waters of the state as compared to no controls, by March 10, 2013.

The findings of this study are taken from a detailed WinSLAMM (Ver 9.2.1) water quality model of the City. The model was used to evaluate TSS reduction provided by 96 existing structural stormwater management facilities within the City's stormwater drainage system. The model was also used to evaluate the City's current street sweeping program. This study found the following:

TABLE 1
City of Middleton
Current Total Suspended Solids Reduction Performance

No Controls Annual Regulated Load	611.7 tons/yr
TSS Removed by Street Sweeping	15.3 tons/yr
Additional TSS Removed by Structural BMPs	202.0 tons/yr
Total TSS Removed	217.3 tons/yr
TSS Reduction Rate	**35.5%**

With its current management practices, the City of Middleton meets the 2008 20% TSS reduction requirement but falls short of the 2013 40% TSS reduction requirement. The WinSLAMM model was used to evaluate ten alternative street sweeping programs and 11 potential alternative structural stormwater management practices in order to develop a plan for compliance with the 2013 40% TSS reduction requirement. Presented in Table 2, below, are the four most likely alternatives that could be implemented to reach the 40% TSS reduction requirement.

Purchase of a high efficiency vacuum street sweeper is estimated at $200,000. It is anticipated that it will be necessary to purchase two vacuum sweepers to accommodate the sweeping schedule proposed in some of the alternates. It is recommended that the City develop a plan for optimal use of vacuum sweepers to determine if two sweepers are in fact required. There will also be some incidental costs associated with implementation of a parking-restriction ordinance and posting no-parking signs.

TABLE 2
City of Middleton
Proposed BMPs for compliance with NR151 TSS Reduction Requirements

Alternative	Description	Total Annual TSS Reduction	Estimated Capital Cost
1	• Increase Mechanical Sweeping Program to Once-per-Week Schedule, No Parking Controls • Construct Structural BMPs 200.01, 300.01, 1200.01	40.1%	$330,000[1]
2	• Implement High-Efficiency Street Sweeping Once-per-Week with Parking Controls	40.3%	$400,000[1]
3	• Implement High-Efficiency Street Sweeping At Current Frequency, No Parking Controls • Construct Structural BMPs 200.01, 300.01, 1200.01, 1100.01	40.2%	$615,000[1]
4	• Maintain Current Sweeping Program • Construct Structural BMP 100.01	43.0%	$880,000

1. Does not include amortized incremental increased cost of street sweeping.

2.0 INTRODUCTION

The City of Middleton is required to obtain a Wisconsin Pollution Discharge Elimination System (WPDES) Phase II permit to discharge stormwater runoff from the City's Municipal Separate Storm Sewer System (MS4) and comply with the standards specified in Wisconsin rules NR151 and NR216. NR216.07(6)(b) and NR151.13(2)(b) collectively require regulated municipalities to achieve a 20% reduction in total suspended solids in runoff that enters waters of the state as compared to no controls by 2008, and to achieve a 40% reduction in total suspended solids in runoff that enters waters of the state as compared to no controls, by March 10, 2013. This report documents the findings of a modeling study conducted for purposes of determining the City of Middleton's compliance with TSS reductions standards.

3.0 WATER QUALITY MODELING

The findings of this study are taken from a detailed WinSLAMM (Version 9.2.1)Urban Catchment Model of the City's stormwater management system. WinSLAMM is a Wisconsin Department of Natural Resources (WDNR) approved model recommended for use in determining TSS removal rates from stormwater management practices for assessment of compliance with WPDES requirements (see notation NR216.07(6)(b) – "The department believes that computer modeling is the most efficient and cost effective method for calculating pollutant loads. Pollutant loading models such as SLAMM, P8 or equivalent methodology may be used to evaluate the efficiency of the design in reducing total suspended solids.") 'WinSLAMM' abbreviates "Source Loading and Management Model [for Windows]."

SLAMM was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality. It has been continually expanded since the late 1970s and has been revised to include a wide variety of source area (runoff and pollutant generators) and outfall control practices (runoff and pollutant management practices). SLAMM is based on actual field observations and has minimal reliance on theoretical processes.

Input data required by WinSLAMM for each model application includes a number of data files that describe local meteorological and hydrological conditions and pollutant loading characteristics. These files are prescribed for use in the WinSLAMM model by the USGS Wisconsin Water Science Center and include parameter files for rainfall, pollutant distribution, runoff coefficients, particulate solids concentrations, and pollutant delivery data.

3.1 RAINFALL DATA

The USGS has evaluated rainfall data collected across the state of Wisconsin for many years and has identified annual rainfall records for five locations in the state that are felt to be representative of a 'typical rainfall year'. For Middleton, the closest rainfall record recommended for use in water quality modeling is the Madison rainfall record for 1981. When simulations are executed for a typical rainfall year it is necessary to eliminate the winter season where precipitation falls as snow or ice. The SLAMM model cannot accommodate snowfall and runoff from snowmelt events. The range of winter dates applicable to the Madison rainfall data run from December 2 to March 12. Thus, the single-year simulation runs from March 12 to December 2.

It has been determined by the USGS and WDNR that a single year's simulation does not fairly represent the impact of street sweeping. Accordingly, a second rainfall record consisting of five consecutive years data must be used for street sweeping analyses. For Middleton, the rainfall gauge was again the Madison rainfall gauge.

3.2 WinSLAMM POLLUTANT LOADING FILES

Pollutant loading files required by the WinSLAMM model include a *Pollutant Probability Distribution File, Runoff Coefficient File, Particulate Solids Concentration File, Particulate Residue Reduction File, and a Street Delivery Parameter File.*

The *Pollutant Probability Distribution File* describes the pollutant loading from different source areas (land use types). This data is based upon actual pollutant loading collected from the study area or region.

The *Runoff Coefficient File* describes parameters specific to different source areas (land use types) that determine the runoff volumes resulting from rainfall events of different depth.

The *Particulate Solids Concentration File* contains parameters allowing the WinSLAMM model to determine the weight of particulate solids loadings resulting from runoff events of different volumes. The particulate solids concentration file includes data measured by the USGS from source areas including residential, commercial, and industrial rooftops;

residential lawns; residential driveways; residential, commercial and industrial streets; commercial and industrial parking lots; freeways; and undeveloped areas.

The *Particulate Residue Reduction File* describes the fraction of total particulates that remains within the drainage system after rainfall events and so do not reach the system outfall.

The *Street Delivery Parameter File* contains data describing the fraction of total particulates that do not reach the outfall during a rain event, for different rain depths and street textures

3.3 MODEL PARAMETER FILES

The following model parameter files were entered into the WinSLAMM model(s) for evaluation of the City of Middleton's stormwater management system.

Rainfall Files -	***WisReg - Madison WI 1981.RAN***
	WisReg - Madison Five Year Rainfall.ran
Pollutant Probability Distribution File -	***WI_GEO01.ppd***
Runoff Coefficient File -	***WI_SL06 Dec06.rsv***
Particulate Solids Concentration File -	***Wi_avg01.psc***
Particulate Residue Delivery File -	***Wi_dlv01.prr***
Street Delivery File:	
Residential/Other -	***WI_Res and Other Urban Dec06.std***
Institutional/Commercial/Industrial -	***WI_Com Inst Indust Dec06.std***
Freeway -	***Freeway Dec06.std***

3.4 WATERSHEDS, LAND USES, SOURCE AREAS, AND SOIL TYPES.

Watersheds are the sources of runoff and pollutants simulated by the program. WinSLAMM is capable of modeling only one watershed at a time containing up to six discrete *land uses*; residential, institutional, commercial, industrial, freeway, and other urban areas. Each land use contains specific runoff and pollutant *source areas* including roofs, paved parking/storage areas, unpaved parking/storage areas, playground, driveways, sidewalks/walks, street areas, landscaped areas (small and large), undeveloped areas, isolated/water body area, other pervious areas and impervious areas (directly connected and indirectly connected). Each source area is further categorized by *soil type*, including sand, silt, and clay soil types. It is necessary to manually enter surface area (acres) for each source area within each land use within the watershed to be evaluated.

3.5 WATER QUALITY MANAGEMENT PRACTICES

WinSLAMM allows for assignation of water quality management practices for individual source areas within a land use type, land use types within a single watershed, within the drainage system serving the watershed, or at the point of discharge of the watershed. Each structural management practice must be defined according to its specific geometry, including storage volume, outlet configuration, infiltration rate, etc. Non-structural management practices such as street sweeping must be defined according to the type and frequency of activity.

The WinSLAMM modeling completed for this study included two types of management practices, street sweeping and ‘end-of-pipe’ structural management practices. Street sweeping is a management practice applied at the *land use* level within the WinSLAMM model and so was the only management practice evaluated in the WinSLAMM model itself. Structural management practices were modeled using the WinSLAMM expansion module called WinDETPOND. This was necessary because when WinSLAMM is solved using *standard land use files* it is impossible to route the output from the model to an end-of-pipe treatment device. However, WinDETPOND can model these output provided a certain amount of manual data handling is completed. Additional discussion of the application of WinDETPOND is included in the following section.

4.0 APPLICATION OF WATER QUALITY MODELS

The WDNR has provided very specific guidance in the application of water quality models for the assessment of compliance with the TSS reductions required by NR151 and NR216. This guidance is documented in a June 16, 2005 memorandum from Gordon Stevenson and Eric Rortvedt, titled, “Developed Urban Areas and the 20% and 40% TSS Reductions.” This memorandum is included in its entirety in the appendix of this report and documents several key issues regarding the determination of regulated *Land Uses* within the corporate limits of a regulated municipality. Several key statements from the guidance memo are reproduced below:

“The total suspended solids control requirements of s. NR 151.13(2)(b)1.b. and 2., Wis. Adm. Code, may be achieved on an individual municipal basis. Control does not have to apply uniformly across the municipality.”

“Areas Required to be Included in the Calculations
A municipality must include the following areas when calculating compliance with the developed urban area standard (s. NR 151.13, Wis. Adm. Code):

1. *Any developed area that was not subject to the post-construction performance standards of s. NR151.12 or 151.24, Wis. Adm. Code, that went into effect October 1, 2004 and that drains to the MS4 owned or operated by the municipality.*
2. *…*
3. *Any undeveloped (in-fill) areas under 5 acres. These areas must be modeled as fully developed, with a land use similar to the properties around them.*
4. *…*
5. *…*
6. *…*
7. *…”*

The language under item #1 above refers to the need to include all land areas NOT regulated by the standards of NR151.12 or NR151.24 developed prior to October 1, 2004. While it is not specifically stated here, subsequent information made available by the WDNR has clarified this statement to also mean that all development which has occurred on or after October 1, 2004, and was regulated by

NR151.12 or NR151.24 must NOT be included in the calculations.

"Areas Prohibited from Inclusion in the Calculations
Areas and loadings that shall not be included:

1. *Lands zoned for agricultural use and operating as such.*
2. *Pollutant loadings from an upstream MS4*
3. *Any internally drained area with natural infiltration.*
4. *Undeveloped land parcels over 5 acres within the municipality. These areas will be subject to s. NR 151.12 or 151.24, Wis. Adm. Code, when developed"*

Item #2 above refers to pollutant loadings, and not runoff. It is necessary to account for stormwater runoff from areas outside a regulated municipality that flow into the municipality so that the effect of the hydraulic loading from these areas that passes into a management practice (detention pond, etc.) is properly accounted for (i.e. effects on pollutant removal efficiency). Similarly, runoff, but not pollutants, from areas within the regulated municipality that are prohibited from inclusion in the calculations must be accounted for. *Note that a reader might not infer the previous requirement from reading the guidance in the June 16, 2005 memo. MSA has discussed this specific issue with the WDNR and was given this direction.*

"Optional Areas to Include in the Calculations
Areas a municipality may, but is not required to, include in the developed urban area load calculation:

1. *Property that drains to waters of the state without passing through the permittee's MS4.*
2. *Any area that discharges to an adjacent municipality's MS4 without passing through the jurisdictional municipality's MS4.*
3. *Industrial facilities subject to a permit under subch. II of ch. NR 216, Wis. Adm. Code."*

Areas draining directly to a water of the state without passing through the City's storm sewer system (item #1 above) were not included in the WinSLAMM modeling. These specifically include those areas draining directly to Lake Mendota, Black Earth Creek, Pheasant Branch Creek downstream of the Confluence Pond, Esser Pond, Stricker Pond, Tiedeman Pond, and Graber Pond. Developed land uses within these areas were reclassified as exempt. Similarly, those areas draining out of City limits without passing through part of the City's MS4 were likewise excluded.

The City of Madison is regulated by its own WPDES permit and, in part, drains into the City of Middleton. However, there is no intergovernmental agreement in place regarding Madison's runoff and Middleton's existing BMPs, so all areas outside the Middleton City limits have been excluded from this evaluation.

No Industrial WPDES permit sites were identified in this study, so the language described under #3 above was not applied.

MODEL STUDY LIMITS

For this study, watershed areas draining to existing or proposed structural management practices were delineated using the GIS program ArcMap. Delineation of watersheds was completed using two-foot contour interval topographic maps overlaid with storm sewer and surface drainage system maps. The water quality modeling study area includes the entire city limits and those areas outside the city limits that drain to an existing or proposed structural water quality management practice within the City. The figure titled 'City of Middleton Project Study Limits' included in the appendix of this report identifies the limits of the study area.

MODEL LAND USE

WinSLAMM can analyze an urban drainage area with up to six different land uses with 14 source areas per land use. Each source area (such as turf, roofs, parking, playgrounds, streets) is further classified according to their runoff behavior (for example, whether roofs are flat or pitched, and whether they drain directly to the drainage system or drain onto sandy or clayey soils).

Since data with this level of specificity is not typically available at a municipal or watershed scale, the WinSLAMM model comes with *Standard Land Use Files* (SLU files) which describe the distribution of source areas within a particular land use type. These files have been prepared by the authors of the WinSLAMM model based on studies of Wisconsin communities. The Standard land use files listed in the table below have been approved by the WDNR for use in Wisconsin with WinSLAMM version 9.2.1.

TABLE 3
WDNR APPROVED SLAMM STANDARD LAND USE FILES

Land Use Class	Standard Land Use File
Residential	• Duplex • High density residential with alleys • High density residential without alleys • High rise residential • Low density residential • Medium density residential • Mobile homes • Multi-family residential • Suburban residential
Commercial	• Downtown commercial • Strip commercial • Office park
Industrial	• Light industrial • Medium industrial
Institutional	• Hospital • School • General institutional
Other Urban	• Cemetery • Airport • Open • Parks
Freeways	• Freeways

The land use classifications in the land use map provided by Dane County did not correspond directly with the available WinSLAMM standard land use files. To accommodate this it was necessary to complete a series of data manipulation processes.

Land use for each parcel was determined by linking the City's parcel shape file to the City's assessor database and assigning each parcel a land use based on its zoning class. The resulting database is referred to as *original existing land use* and is shown on the figure in the appendix titled 'Original Existing Landuse Map (City Limits)'. Since the assessor database categories are broader than what is needed for SLAMM modeling, and in some cases assessor parcel information was missing or inaccurate, each parcel was individually reviewed, and refined/revised as appropriate based on land use discerned from aerial photos, and/or other additional information provided by the city.

SLAMM standard land use files include adjacent roadway areas. However, since the original parcel data did not include roadway right-of-way, it was necessary to add right-of-way polygons to the land use data and categorize right-of-way according to the land use of the adjacent parcels. Where the land use differed on either side of a roadway, the right-of-way was split down the middle and each side was assigned the land use of the adjacent parcel on that side. The only rights-of-way where this approach was not taken was for that of US Highway 12. *Freeway* land use is treated as a separate land use in the WinSLAMM model and defined as limited access roadways, typically divided.

After completing the individual parcel and right-of-way review, the *original land use* data was reduced by combining land uses of similar types to match the standard land use categories accommodated in the WinSLAMM model. Table 4, one the following page, summarizes how land uses were reduced and combined for this study.

For purposes of complying with the June 16, 2005 memorandum documenting model prohibitions the model land use map was further altered to identify 'excluded' areas. These included areas where new development or redevelopment had occurred since October 2004 that was also regulated by NR151.12 or 151.24. The WDNR provided a list of all construction activities (through mid-June 2006) that the WDNR had permitted under NR151.12 and NR151.24. No data was available from the Department of Commerce identifying areas permitted under Comm 21.126. Those parcels, or portions of parcels, covered by permits were coded within the model land use map as 'excluded' areas and are shown on the figure in the appendix labeled 'Exempt Area Map (City Limits.' Note, that while not shown on the exempt area figure, all areas within the study area limits but outside of the City limits were coded as 'exempt' also, in compliance with the June 16, 2005 guidance document.

It is worth repeating to note that excluded land uses were included in the WinSLAMM model for purposes of properly accounting for the volume of stormwater runoff generated in these areas so that the efficiency of downstream treatment devices could be properly evaluated. TSS loads from excluded land uses were artificially reduced to zero.

TABLE 4
City of Middleton
WinSLAMM Standard Land Uses

Original Land Use (Assessor Category)	WinSLAMM Modeling Land Use Files
Single Family	Residential, Single Family
Multi-Family	Residential, Multi-Family
Commercial	Commecial
Exempt Developed	Institutional
Exempt Developed Special	
Agriculture	Other Urban, Open Space
Vacant Land	Other Urban, Undeveloped
Industrial (Airports)	Industrial, Light
Industrial	Industrial, Medium
Parks/Greenway	Other Urban, Parks
Golf	
Transportation	Other Urban, Highway
County	Other Urban, Developed
	Other Urban, Undeveloped

SOIL CLASSIFICATIONS

Each land use was further sub-categorized according to the underlying soil type. WinSLAMM requires that the soil for all land uses be classified as *sand, silt, or clay*. Table 5 on the following page identifies the soil texture that each soil series identified in the Dane County Soil Atlas was assigned within the WinSLAMM model. A map of the distribution of soil textures within the study area is shown on the figures in the appendix titled, 'Soil Map.'

The size (area) and characteristics of each source area within each land use type was entered into the model according to the distribution within each standard land use file. Land use types were entered into the model according to the total area within each watershed corresponding to each land use and each soil texture. For instance, a watershed may consist of residential land use built atop sandy and silty soils; land use for residential – sand and residential – silt were separately entered into the model according to the total area of each land use and soil type within the watershed.

TABLE 5
City of Middleton
WinSLAMM Soil Classifications

Soil Symbol	Soil Name	Soil Texture	Soil Symbol	Soil Name	Soil Texture
Ad	ADRIAN MUCK	CLAY	Md	MCHENRY SILT LOAM	SILT
Bb	BATAVIA SILT LOAM	SILT	Mh	MILITARY LOAM	SILT
Bo	BOYER SANDY LOAM	SILT	Or	ORION SILT LOAM	SILT
Ch	CHASEBURG SILT LOAM	SILT	Os	ORION SILT LOAM	SILT
Co	COLWOOD SILT LOAM	SILT	Pa	PALMS MUCK	CLAY
Cu	CUT AND FILL LAND	SILT	Pn	PLANO SILT LOAM	SILT
Dn	DODGE SILT LOAM	SILT	Po	PLANO SILT LOAM	SILT
Do	DODGE AND KIDDER SOILS	SILT	Ra	RADFORD SILT LOAM	SILT
Dr	DRESDEN LOAM	SILT	Rn	RINGWOOD SILT LOAM	SILT
Ds	DRESDEN SILT LOAM	SILT	Ro	ROCKTON SILT LOAM	SILT
Du	DUNBARTON SILT LOAM	SILT	Rp	RODMAN SANDY LOAM	SILT
Ed	EDMUND SILT LOAM	SILT	Sa	SABLE SILTY CLAY LOAM	CLAY
Eg	ELBURN SILT LOAM	SILT	Sc	ST. CHARLES SILT LOAM	SILT
Ev	ELVERS SILT LOAM	SILT	Sh	SALTER SANDY LOAM	SILT
Gn	GRANBY LOAMY SAND	SAND	So	SOGN SILT LOAM	SILT
Gs	GRAYS SILT LOAM	SILT	St	STONY AND ROCKY LAND	CLAY
Gw	GRISWOLD LOAM	SILT	Tr	TROXEL SILT LOAM	SILT
Ha	HAYFIELD SILT LOAM	SILT	Vr	VIRGIL SILT LOAM	SILT
Ho	HOUGHTON MUCK	CLAY	Vw	VIRGIL SILT LOAM	SILT
Kd	KIDDER LOAM	SILT	W	WATER	CLAY
Ke	KEGONSA SILT LOAM	SILT	Wa	WACOUSTA SILTY CLAY LOAM	CLAY
Kr	KIDDER SOILS	SILT	Wr	WARSAW SILT LOAM	SILT
Ma	MADE LAND	SILT	Wt	WATSEKA LOAMY SAND	SAND
Mb	MARSH	SILT	Wx	WHALAN SILT LOAM	SILT
Mc	MARSHAN SILT LOAM	SILT			

STREET SWEEPING

The WinSLAMM model is capable of modeling both mechanical and high-efficiency (vacuum) street sweeping. Sweeping intervals may be altered and sweeping may be evaluated with and without parking restrictions. Parking restrictions assume that cars are not allowed to park on streets on days when sweeping is to occur.

Street sweeping frequency data was provided by the City of Middleton Engineering Department. Sweeping of the streets begins after spring thaw and continues until the ground freezes. In residential areas, street sweeping occurs once every 4-weeks with a mechanical broom sweeper. In institutional, commercial and industrial areas, street sweeping occurs once every 2 weeks. Parking density was assumed to be medium in residential areas and light in non-residential areas. There are no street sweeping parking controls enforced by the City.

The WNDR and USGS have provided the following guidance on their website regarding application of street sweeping to water quality models:

> *"For developed urban areas under s. NR 151.13, permitted municipalities must reduce the TSS load by 20% in 2008 and 40% in 2013. Again, this should be reported on an average annual basis. However, there are no identified rainfall years for the developed urban area performance standards in NR 151.13. Since a single year did not fairly represent the impact of street cleaning, a series of rainfall files (5 consecutive years) must be used..."*

The reason for this requirement is that it was found that identical street sweeping programs provided substantially different TSS reduction rates depending on the annual rainfall record selected for the simulation. It is speculated by the authors of the WinSLAMM model that this is the result of interactions between the randomness of rainfall events and the fixed schedule of sweeping. For example, if one rainfall record has comparatively more rainfall events on Mondays while street sweeping occurs consistently on Tuesdays then many of the pollutants that would be captured by the sweeper will have been washed off by the previous day's rainfall. On the other hand, if rainfalls occur more commonly at the end of the week, then the Tuesday sweeping schedule will capture comparatively more sediment, as there will be more 'dry' days of accumulation prior to the sweeping event. By running five years of rainfall data through the model it was felt that the impact of the randomness of rainfall occurrences would be reduced.

STRUCTURAL BMPs

There are currently 96 structural stormwater quality management devices within the City of Middleton's storm water management system. The City's engineering department provided construction plans for most devices documenting necessary geometric data such as storage volume and outlet device configuration. Those BMPs where plan information was not available were visually inspected and necessary geometry data was estimated. The location of each BMP was identified in GIS and the drainage area tributary to each device was delineated. The land use and soil characteristics of each BMP drainage area were determined by intersecting the land use-soil type and BMP drainage area shapefiles in GIS, and summing the area of each land use and soil type within each drainage area. This information was used to create a unique WinSLAMM model of each BMP drainage area. Output from the WinSLAMM model of each drainage area was consolidated and entered into a WinDETPOND model for the corresponding BMP. WinDETPOND results showed that the cumulative effect of existing structural BMPs and the improved street sweeping program described in the previous section were still insufficient for meeting the City's 40% TSS reduction requirement. As a result it was necessary to evaluate alternative street sweeping practices and/or identify additional structural BMPs.

Locations for eleven potential additional structural BMPs were selected according to recommendations made in previous studies and through interviews with City staff. Alternative BMPs were assumed to be wet detention ponds with permanent pool depths of three feet and live storage depths equal to three feet plus the diameter of the existing storm sewer pipe that will serve the basin. It was assumed that pond outflows would be restricted by an outlet structure consisting of a low-flow orifice with a minimum size of four inches. It also was assumed that each pond would have a weir overflow outlet at an elevation one-half foot below the top of the live storage maximum depth.

WinDETPOND MODELING

When standard land use files are used to create a WinSLAMM model, the model drainage area may be comprised of only one land use type in each of the following broad land use classes: residential, institutional, commercial, industrial, open, and freeways. Furthermore, only one soil type per land use is allowed. Although the *WinSLAMM Planning File Editor* partially overcomes this limitation by allowing the user to simulate pollutant load and runoff volume from a watershed with any number of standard land use types and soil textures, the Planning File Editor output cannot subsequently be routed through an end-of-pipe treatment device such as a detention pond. It was therefore not possible to create a stand-alone WinSLAMM model that would accurately represent watershed pollutant loading and structural BMP pollutant reduction.

Structural management practices were modeled using the WinSLAMM companion module called WinDETPOND. To accomplish this, the separate WinSLAMM output ('.OPR') files from each standard land use type within the watershed of the BMP being evaluated were combined manually to form a single WinDETPOND input file. ORP files consist of three columns of information: the rainfall event number, the runoff volume at the outfall for that rainfall event, and the particulate loading at the outfall for that rainfall event. ORP data was combined manually by importing each ORP file into MSExcel and summing the runoff volume and particulate loading values for each rainfall event. The resulting output was saved as a comma delimited text file and was renamed to have the necessary 'ORP' extension.

A detailed, bullet list explanation of how WinSLAMM standard land use files were used and how the WinSLAMM output was imported into WinDETPOND is included in the appendix of this report.

5.0 FINDINGS AND DISCUSSION

5.1 MODEL RESULTS

The table below demonstrates the significance of applying the various exemptions and exclusions documented in the WDNR modeling guidance memorandum.

TABLE 6
City of Middleton
Baseline Annual Total Suspended Solids Loads

Description	**Area**	**Annual TSS Load**
Study Area	14,714 ac	1084.5 tons/yr
City Limits	5,189 ac	678.9 tons/yr
Regulated Areas within City	3,670 ac	611.7 tons/yr

The table below documents the estimates performance of the City's stormwater management system at removing TSS from the regulated areas within the City.

TABLE 7
City of Middleton
Current Total Suspended Solids Reduction Performance

Description	**Annual TSS Load**
No Controls Annual Regulated Load	611.7 tons/yr
TSS Removed by Street Sweeping[1]	15.3 tons/yr
Additional TSS Removed by Structural BMPs	202.0 tons/yr
Total TSS Removed	217.3 tons/yr
TSS Reduction Rate	**35.5%**

1. TSS removal determined by applying reduction rate from 5-yr evaluation to 1-yr TSS loading values. See section 5.5.

With its current management practices, the City of Middleton meets the 2008 20% TSS reduction requirement but falls short of the 2013 40% TSS reduction requirement.

5.2 STREET SWEEPING EFFICIENCY

WinSLAMM modeling results showed much greater TSS reductions for high-efficiency sweepers relative to mechanical sweepers; modeling also shows greater TSS reductions for sweeping practices when parking controls are in effect. The following table compares the relative efficiencies of several street sweeping scenarios for the City of Middleton. *Note that per WDNR guidance the model results show the annual summary of an evaluation of five years' of rainfall records. As a result the annual TSS load (by weight) determined by the model does not match that for tables presenting single-year loads. The TSS reduction reported in the table below was applied to single-year loads by using the percent-reduction values.*

TABLE 8
City of Middleton
Alternative Street Sweeping Programs
TSS Reduction Performance

Description	**Annual TSS Reduction**		
	Current Sweeping Schedule	**All Areas Swept Once per Week**	**All Areas Swept Twice per Week**
Mechanical, No Parking Controls	2.5%[1]	5.3%	6.7%
Mechanical, With Parking Controls	3.7%	7.5%	N/A[2]
Vacuum, No Parking Controls	5.2%	10.9%	15.1%
Vacuum, With Parking Controls	7.1%	14.2%	N/A[2]

1. Reflects the City's current street sweeping program
2. Twice-per-week sweeping with parking controls was not evaluated because it is felt to be infeasible to ban parking twice per week for street sweeping activities.

5.3 STRUCTURAL BMP PERFORMANCE AND STREET SWEEPING

WinSLAMM modeling results of the 96 existing structural BMPs show that individually, the ponds are capable of removing 34.5% of the City's regulated annual TSS load. *However, this total removal rate does not account for the fact that street sweeping will occur within the drainage areas tributary to each alternative BMP.* For example, under the City's existing street sweeping program 2.5% of the annual regulated load is captured by sweeping activities. Street sweeping occurs throughout the City and so occurs within drainage areas tributary to existing structural BMPs. Because the sediment collected by street sweeping is not available to be captured by a structural BMP the efficiency of each BMP must be reduced by 2.5% to account for the TSS already captured by street sweeping. *Note that it is admitted that this approach is not entirely valid, especially given that street sweeping frequency varies throughout the City, however, it is the best that can be accomplished given the limitations of the WinSLAMM model. Additional discussion of model limitations is provided in the following section.* Table 9 documents a few example cases of the effects of street sweeping on the reported efficiency of the existing structural BMPs.

WinSLAMM modeling results of the 11 alternative structural BMPs show that individually, the ponds are capable of removing between 0.1% and 7.5% of the City's regulated annual TSS load. Cumulatively, the 11 ponds could remove an additional 14.4% of TSS in runoff from the City's regulated load. However, depending on the street-sweeping program implemented, the effective cumulative reduction provided by all 11 BMPs could be as low as 10.6%

TABLE 9
Effective Structural BMP TSS Reduction Performance
Under Various Street Sweeping Programs

Description	Frequency	TSS Reduction by Street Sweeping	TSS Reduction by Existing Structural BMPs	Total Reduction	
No Street Sweeping	N/A	0.0 tons/yr	211.1 tons/yr	211.1 tons/yr	34.5%
Mechanical No Parking Controls[1]	Current	15.3 tons/yr	202.0 tons/yr	217.3 tons/yr	35.5%
Mechanical W/Parking Controls		22.6 tons/yr	197.7 tons/yr	220.3 tons/yr	36.0%
Vacuum No Parking Controls		31.8 tons/yr	192.2 tons/yr	224.0 tons/yr	36.6%
Vacuum W/Parking Controls		43.4 tons/yr	185.3 tons/yr	228.7 tons/yr	37.4%
Mechanical No Parking Controls	Once per Week	32.4 tons/yr	191.9 tons/yr	224.3 tons/yr	36.7%
Mechanical W/Parking Controls		45.9 tons/yr	183.9 tons/yr	229.8 tons/yr	37.6%
Vacuum No Parking Controls		66.7 tons/yr	171.6 tons/yr	238.3 tons/yr	39.0%
Vacuum W/Parking Controls		86.9 tons/yr	159.9 tons/yr	246.7 tons/yr	40.3%
Mechanical No Parking Controls	Twice per Week	41.0 tons/yr	186.6 tons/yr	227.8 tons/yr	37.2%
Vacuum No Parking Controls		92.4 tons/yr	156.7 tons/yr	249.0 tons/yr	40.7%

1. Reflects the City's current street sweeping program

The tables included in the appendix of this report document the TSS reductions achieved by each of the individual existing and proposed structural BMPs.

5.4 WinSLAMM MODEL LIMITATIONS

It is important to make note of several limitations of the WinSLAMM model that affect the results and recommendations in this report. Specifically, these limitations required application of the WinSLAMM model according to the protocols described below.

Each BMP (structural and street sweeping) is modeled independently. Specifically, each BMP is modeled assuming that there are no other BMPs within its entire tributary area (ignoring upstream BMPs which discharge to the BMP being evaluated). This is due to WinSLAMM's inability to model BMPs in series.

The cumulative effectiveness of the BMPs is determined algebraically by applying the highest efficiency of any downstream BMP in series with the BMP being considered. This is due to WinSLAMM's inability to track the particle distribution (and hydrograph attenuation) being discharged from any single BMP.

Citywide cumulative TSS reduction estimates are the result of an algebraic exercise whereby the efficiency of successive downstream BMPs are compared to the efficiency of the BMP in question. If the downstream BMP's efficiency is greater than the BMP of concern the higher efficiency is applied to the TSS loading for the watershed directly tributary to the BMP of concern. For example: BMP 1 is upstream of BMP 2. BMP 1 has a TSS removal efficiency of 60% and BMP 2 has an efficiency of 80%. In this case an efficiency of 80% is attributed to both watersheds (the downstream BMP receives all the flow and TSS from both watersheds). If the efficiency of BMP 1 was 90% then 90% would be attributed to its direct watershed while 80% would be attributed only to the watershed tributary to BMP 2.

Note that this approach introduces several unquantifiable errors in the modeling. The first is that the attenuation of an upstream BMP may reduce the hydraulic demand on a downstream BMP, effectively increasing its residence time and increasing the downstream BMP's TSS removal efficiency. This would tend to make the model results conservative. However, what is more likely, is that the upstream pond will remove some of the more 'settleable' solids, that would then be unavailable for settling within the downstream BMP, reducing the TSS load to the downstream BMP, and subsequently the BMP's TSS removal efficiency.

5.5 RECENT RESEARCH AND CURRENT REGULATORY REQUIREMENTS

NR151.13(2)b(1) contains the following note:

> *"Note: It is expected that the municipality will be able to achieve the 20% reduction by municipal street sweeping, using either conventional or high efficiency sweepers, regular catch basin cleaning, de−icer management, and education to change human behavior toward reducing pollution."*

NR151.13(2)b(1) contains the following note:

> *"Note: It is expected that the municipality will be able to achieve the 40% reduction through the use of high efficiency street sweeping or structural BMP retrofit practices. The stage 2 requirements may include application of BMPs to privately owned lands, such as shopping centers."*

The implications of these notations is that the WDNR did not anticipate drastic changes in a municipalities operations to meet the 2008, 20% TSS reduction standard, and only anticipated relatively minor retrofit practices to meet the 2013, 40% standard. Recently, the USGS and the WDNR completed research on the efficacy of various street-sweeping practices. The findings of this research showed street sweeping to be much less effective than previously anticipated. As a result, plans for meeting the 20% and 40% TSS requirements will require additional structural management practices to account for the reduction in street sweeping performance.

The APWA Wisconsin Chapter has recently issued a letter to the WDNR requesting that the standard thresholds (primarily the 40% TSS reduction standard) and the applicable timeline for each threshold (2008 and 2013) be reviewed and revised to reflect a more reasonable standard given the recent research results. The WDNR's response to this issue, if there is one, may bring to the forefront the issue of 'maximum extent practicable.' If a community can demonstrate that they are achieving the maximum extent practicable through existing and proposed actions while not incurring disproportionate costs, it may be possible for the community to establish a lower TSS removal level than those identified in NR151.

The APWA sent their letter to the WDNR on June 15, 2007. As yet there is no response from the WDNR. A copy of the letter is included in the appendix of this report.

6.0 RECOMMENDATIONS

With its current management practices, the City of Middleton falls short of the 2013 40% TSS reduction requirement. The WinSLAMM model was used to evaluate ten alternative street sweeping programs and 11 potential alternative structural stormwater management practices in order to develop a plan for compliance with the 2013 40% TSS reduction requirement. There are several combinations of street sweeping programs and structural BMPs that could be implemented to reach the 40% TSS goal. The table below summarizes a few of the likely options:

TABLE 10
City of Middleton
Proposed BMPs for compliance with NR151 TSS Reduction Requirements

Alternative	Description	Total Annual TSS Reduction	Estimated Capital Cost
1	• Increase Mechanical Sweeping Program to Once-per-Week Schedule, No Parking Controls • Construct Structural BMPs 200.01, 300.01, 1200.01	40.1%	$330,000[1]
2	• Implement High-Efficiency Street Sweeping Once-per-Week with Parking Controls	40.3%	$400,000[1]
3	• Implement High-Efficiency Street Sweeping At Current Frequency, No Parking Controls • Construct Structural BMPs 200.01, 300.01, 1200.01, 1100.01	40.2%	$615,000[1]
4	• Maintain Current Sweeping Program • Construct Structural BMP 100.01	43.0%	$880,000

1. Does not include amortized incremental increased cost of street sweeping.

Purchase of a high efficiency vacuum street sweeper is estimated at $200,000. Note that to achieve the maximum-modeled TSS reduction under the City's current sweeping schedule it may be necessary to purchase two vacuum sweepers. It is recommended that the City develop a plan for optimal use of vacuum sweepers to determine if two sweepers are required for those scenarios where two sweepers are anticipated. There will also be some incidental costs associated with implementation of a parking-restriction ordinance and posting no-parking signs.

Appendix A

Figures

<u>Appendix B</u>

Tables

Appendix C

WinSLAMM Batch Processing
Work Breakdown Structure

Appendix D

WDNR Modeling Guidance

Appendix E

APWA Correspondence

Appendix F

Alternative Structural BMPs

Concept Designs
&
Cost Estimates