FDM 10-25-1 Stormwater Control Measure Selection

October 22, 2012

1.1 Introduction

The purpose of this section is to give designers guidance in meeting Federal and State stormwater quality discharge laws and regulations (refer to FDM 10-1-2).

The objective of this section is to provide designers with the tools to reduce pollutants via the removal of sediment from stormwater, as most targeted pollutants attach themselves to sediment. In addition, though many pollutants are derived from sources beyond WisDOT's right-of-way and control, the primary focus of these practices should be to control pollutants generated by WisDOT facilities only.

Areas where WisDOT projects have the potential to impact outstanding resource waters (ORW), exceptional resource waters (ERW), exceptional wetlands, trout waters, 303d waters, or impact other unique public waters may be where the designer incorporates such measures. Any questions regarding stormwater quality should be directed to WisDOT's regional stormwater engineer or to WisDOT's Bureau of Technical Services Stormwater Engineer, Central Office.

1.2 Determining Project Water Quality Objective Goals

The department has developed a post-construction stormwater management program based upon Federal regulations, TRANS 401, the FDM, and the Maintenance Manual.

The designer should use the guidelines below to determine the water quality objectives for a project. Consult with the region stormwater engineer or the central office stormwater engineer if there are questions or concerns about the appropriate objectives.

To determine what the specific goal for a project is, see the flowchart in Attachment 1.1. Each transportation facility that meets these post-construction program applicability requirements must address the following post-construction stormwater management issues.

1.2.1 Total Suspended Solids

The total suspended solids (TSS) reduction goal for a project will be 0%, 40% or 80% depending upon the project characteristics.

1. New transportation facilities (roadways, airports, park and rides, etc). Annual total suspended solids loadings from a new facility must be reduced by 80% (or to the maximum extent practicable (MEP)), based upon an average annual rainfall year, when compared to no runoff management controls.
2. Reconstruction projects. Annual total suspended solids loadings from a reconstruction project must be reduced by 40% (or to MEP), based upon an average annual rainfall year, when compared to no runoff management controls.
3. Projects within TMDL drainage basins may have different TSS and other pollutant reduction requirements. Work with you r regional Stormwater Engineer to determine if your project has any TMDLs to meet.

Some projects may transition from, for example, a new alignment with a rural cross section to a curb and gutter cross section that was formerly a rural cross section, but on the same alignment. Each of these segment types will have a different TSS reduction goal. If this occurs, the project may be segmented with different water quality objectives for each type of condition. There are three possible segment types:

- Rural or urban cross sections on new alignments,
- Rural or urban cross sections on existing alignments, and
- Rural cross sections to urban cross sections.

Each of these segment types may have a different TSS reduction goal. The overall water quality TSS reduction goal for the project is the area-weighted sum of the TSS reduction objectives from the three different segment types.

1.2.2 Peak Discharge

Peak discharge rates for the 2-year design storm for a new project shall remain at pre-development levels, to

MEP.

1.2.3 Infiltration

WisDOT will not design stormwater control practices to infiltrate runoff from highway projects. Non-highway transportation projects that are near;

- karst features,
- where the seasonal high water table is within three feet of the infiltration device bottom,
- within 400 feet of a community water well,
- within 100 feet of a non-community or private well,
- or that meet other requirements described in TRANS 401.106(5)(d) will also not infiltrate.

If none of these criteria apply to a project, then the department shall infiltrate enough runoff volume so that the post construction infiltration volume is at least 60 percent of the annual pre-construction infiltration volume. However, no more than 2 percent of the project area is required as an effective infiltration area. If direct infiltration to groundwater occurs, pre-treat the runoff to reduce the TSS loading by 80% or to MEP.

1.2.4 Buffer Areas

Post construction stormwater control measures must be applied to any project that constructs a roadway within a buffer area as defined in TRANS 401.106(6). The Department will not construct projects within buffer areas adjacent to streams, lakes, or wetlands except when reasonably necessary and done in consultation with the Department of Natural Resources. If construction within a buffer occurs, adequate and appropriate vegetation must be established within the buffer areas. Transportation facilities that cross or access surface waters, such as boat landings, bridges and culvert, are exempt from this requirement (TRANS 401.106(6)(b)(4)(b)).

1.2.5 Timing

All stormwater control practices will be installed before the project has undergone final stabilization. The Department may use the water quality practices listed in the DOT Facilities Development Manual in its projects, but may use other control practices as appropriate to reduce stormwater runoff and pollutants from highway facilities. Biofiltration devices should be completed after project site permanent stabilization.

1.2.6 Swales

The Department may use grass swales to meet all rural post-construction stormwater requirements provided that the swales:

1. Are vegetated (unless riprap or check dams are employed to reduce erosion)
2. Are at least 200 feet in length and
3. Carry a flow velocity of no more than 1.5 ft/sec based upon a 2-year design storm (or the flow velocity is reduced to the maximum extent practical).

The Department will encourage the placement of swales in urban projects if they are appropriate for the project.

1.3 Stormwater Report Development

The stormwater report is a spreadsheet that, along with accompanying documentation if needed, provides a framework to calculate and document not only a project's hydrologic and hydraulic analysis but also any potential project runoff quality impacts. It should be used throughout the project to assist the engineer with the development of appropriate and cost effective stormwater treatment practices. Though the stormwater report must be submitted at the end of the project, it may also be submitted at the following times:

1. At the project planning level,
2. At the 30% submittal, to reflect stormwater and drainage coordination with all stakeholders,
3. At the 60% submittal, to include as much drainage and stormwater design information as is available,
4. At PS&E, the final, complete stormwater report should be submitted.

The transportation facility designer or planner should use the water quality matrix (Attachment 1.2) as described below to develop a conceptual stormwater plan, which normally should be completed prior to the Design Study Report (DSR). This conceptual plan should be submitted to the region stormwater engineer for review and DNR concurrence. As the design progresses, the designer or planner should use the stormwater report and other tools described in this section of the FDM to develop the final calculations and pollutant removal rates for the project. This process is described in more detail in FDM 10-35-3. Submit the final plan to the region stormwater engineer and the project manager for review.

The project manager can use the stormwater report to assist with negotiations for any cost sharing of stormwater control practices from offsite runoff with local communities because the stormwater report specifically distinguishes between on-site and offsite runoff and pollutant loading.

1.4 Stormwater Quality Matrix

The stormwater quality matrix, as shown in Attachment 1.2, was developed to simplify the planning and design process for WisDOT highway project stormwater quality control practice selection. The first column lists the standard stormwater quality control practices described in this section of the FDM. The second column is a list of the planning level percent TSS reduction values allowed for each of the control practices. This column is applied when the planning check box is checked when describing the design stage for the project (Line 13 on the Drainage – Summary worksheet). Use these values in the Stormwater Report water quality sections to determine, on a planning level, what control practices may be necessary for a project. The percent reduction values assume that all practices are designed and installed according to the appropriate design standard, and that they are properly maintained.

The third column is the design percent TSS reduction values allowed for each control practice. The values that are either in this column or determined by modeling or design are developed for the design phase (30% complete, 60% complete, 90% complete, or final design) of the project. Both grass swales and biofilters have an assigned 80% reduction rate, assuming that the practices are designed, constructed, and maintained according to the appropriate standard. Use the design method described in each section of the FDM to determine the final TSS reduction rate for the other control practices, and enter those values in the Stormwater Report to determine your overall project TSS reduction rate.

1.5 Stormwater Technical Standard and Procedure Links

Below is a list of Wisconsin post construction stormwater management technical design standards and references for water quality analysis. Refer to these standards in addition to the sections in FDM 10-35 for additional guidance, if needed;

- Bioretention for Infiltration Tech Note,
- Proprietary Storm Water Sedimentation Devices,
- Infiltration Basin Tech Note,
- Site Evaluation for Stormwater Infiltration,
- Swales (Updated 5/10/2007),
- Wet Detention Pond.

To view the standards, go to the WDNR Storm Water Management Technical Standards web site: http://dnr.wi.gov/topic/stormwater/standards/postconst_standards.html.

1.6 Stormwater Retrofit Projects

The SAFETEA-LU section 6006 allows states to participate in stand-alone retrofit projects to address water pollution or environmental degradation caused 'wholly or partially by a transportation facility.' Use of Surface Transportation Program (STP) and NHS funds may be used voluntarily for this purpose. To view guidance on whether this is the appropriate action for your project see FHWA guidance on 23 USC 328 (http://www.fhwa.dot.gov/hep/envrestore.htm).

LIST OF ATTACHMENTS

Attachment 1.1	Post Construction Stormwater Quality Management Goals
Attachment 1.2	Treatment Efficiencies for WisDOT Stormwater Control Practices as Required for Highway Facilities Covered Under TRANS 401

FDM 10-25-5 The Effects of Urbanization on Stormwater Quality

October 22, 2012

5.1 Introduction

This procedure has been developed in order to help planners and designers understand the potential storm water quality impacts that urbanized areas may have on WisDOT facilities. This knowledge is beneficial when working with local planners or municipalities. However, it is not WisDOT's position to assume responsibility for pollutants discharged from sources other than WisDOT facilities.

5.2 Urbanization

There are two main reasons why urbanization increases pollutant loads in runoff:

1. The runoff is more contaminated due to the surfaces and activities occurring in the developed areas, and
2. The amount (and rate) of runoff is greater, resulting in greater amounts of pollutant discharges.

Although stormwater pollutants frequently impact the quality of surface water, groundwater quality can also be adversely affected. The greatest potential for groundwater contamination comes from pollutants that are soluble in water and not readily trapped or treated by the soil during percolation.

5.3 Hydrologic Changes

When an undeveloped area changes to support urban land uses, drastic changes in the local hydrology result. As land is covered with roads, buildings, and parking lots, the amount of rainfall that can infiltrate into the soil is reduced. The increases in the impervious covers and in compacting the soils results in substantially increased runoff volumes from the watershed. Typical impervious cover percentages for different land uses are shown below:

Typical Impervious Area Covers

Land Use	***Percent Impervious Cover***
Business District or Shopping Center	95-100
Residential, High Density	45-60
Residential, Medium Density	35-40
Resident, Low Density	20-40
Open Areas	0-10

Besides the increased volumes of runoff associated with the impervious covers, the flow rate of the increased runoff also increases, exasperating the hydrologic effects of urbanization. When an urban area is developed, natural drainage patterns are modified as runoff is channeled into road gutters, storm sewers, and paved channels. These modifications increase the velocity of runoff, which decreases the time required to convey it to the mouth of the watershed. This results in higher peak discharges and shorter times to reach peak discharges. Also, water that once seeped through the upper layers of soil as *interflow* now runs off the surface. The loss of this shallow groundwater is significant because it supplies much of the *baseflow* in streams between storms.

In many development projects, grading changes the slopes of the land surface to provide better drainage. Developers fill low spots and wetlands to provide more "buildable" land. These natural detention areas no longer collect stormwater for gradual release after a storm. Instead, storm sewers or ditches are built to improve drainage capacity by carrying runoff directly to lakes and streams.

Stormwater runoff problems continue after builders complete construction. Water runs off hard surfaces covered by buildings, streets, and parking lots, picking up speed and pollutants along the way. In some places, however, spreading top soil and planting trees and grass allows the land to regain some of its ability to soak up stormwater.

Higher flow rates can cause flooding and have adverse effects on natural streams. Under natural conditions and at bankfull capacity, studies have shown that streams can handle a flow approximately equal to about the 1- to 2-year frequency peak discharge. After urbanization, increased flows can cause bank-full flow to be exceeded several times each year, preventing regrowth of damaged vegetation during the high flows. In addition to frequent flood damage, this condition causes previously stable channels to erode and widen, damaging streamside infrastructure and the natural habitat. Sediment from stream bank erosion also increases in-stream turbidity levels and can eventually become deposits in streams, rivers, and lakes, smothering benthic organisms.

Base flow in streams is also affected by changes in the hydrology from urbanization because a large part of the natural base flow is supplied by shallow infiltration. As shallow infiltration is reduced by increased impervious cover, the volume of water available for base flow in streams is reduced. These changes in hydrology, combined with increased pollutant loadings, can have a dramatic effect on the aquatic ecosystem in urban streams. Studies of streams affected by urbanization have shown that fish populations either disappear or are dominated by rough fish that can tolerate a lower level of water quality.

An early understanding of, and response to, the effects of urbanization on water quality can result in a much greater chance of cost-effectively minimizing those effects. Stormwater control practices (sometimes referred to as “Best Management Practices (BMP's) or “Stormwater Control Measures (SCM’s) that slow runoff and increase infiltration are recommended as a first approach to effective stormwater management. Conventional interception of untreated runoff by storm sewers directed to the nearest waterway results in substantial receiving water problems associated with the increased runoff volumes and flow rates, and pollutant discharges.

5.4 Pollutants

Although urban areas cover only a small part of the land in Wisconsin, they are responsible for significant water quality problems, flooding, and habitat destruction.

The major urban pollutants include:

1. Sediment
2. Nutrients
3. Oxygen demanding materials such as grass clippings
4. Bacteria
5. Trace metals
6. Pesticides
7. Toxic chemicals, such as Hydrocarbons and PCBs
8. Chlorides
9. Temperature

Each of these pollutants is discussed below.

5.4.1 Sediment

Sediment is considered to be one of the most damaging pollutants, and is the major pollutant by quantity in state surface waters. Urban runoff produces a unique mix of sediment that includes flakes of metal from rusting vehicles, particles from vehicle exhaust, bits of tires and brake linings, chunks of pavement and soot from residential chimneys and industrial smokestacks, along with eroding soils.

Generally, the concentrations of sediment in urban runoff is lower than in rural runoff (except in areas undergoing active construction), but because more water runs off impervious surfaces in cities, the total load of sediment for urban areas can be comparable to rural areas. Land uses that produce the highest sediment loads in existing (post development) urban areas are industrial and commercial areas, and freeways. Parking lots are the predominant source of sediment in industrial areas. In residential and commercial areas, streets surfaces are the primary sources of sediment.

Although existing urban areas are important sources of sediment, by far the highest loads of sediment (and the highest concentrations) come from areas under construction.

5.4.2 Nutrients

Runoff from urban and rural areas contains nutrients such as phosphorus and nitrogen. Phosphorus is the greatest concern in stormwater runoff because it usually promotes weed and algae growth in Wisconsin freshwater lakes and streams.

Because particulate phosphorus compounds attach themselves to sediment particles, land uses that produce high sediment loads also tend to produce high phosphorus loads. The phosphorus in runoff from existing urban areas, in both particulate and filterable forms, come from areas where excessive fertilizers have been applied, leaves and grass have been left on paved areas, and from vehicle exhaust.

Nitrogen is usually so abundant in Wisconsin lakes and streams that nitrogen in runoff does not usually increase weed and algae growth, as phosphorus is the limiting nutrient.

Nitrate forms of nitrogen are found naturally at low levels in most water bodies. However, drinking waters contaminated with high levels of nitrates are a health hazard. Nitrates are very soluble and do not attach to soil particles. This allows nitrates to readily leach into groundwater when nitrogen fertilizer application rates exceed plant needs. Septic systems are another common source of nitrate contamination in groundwater.

5.4.3 Oxygen Demanding Materials

Urban runoff carries organic material such as pet waste, leaves, grass clippings, and litter. As these materials decay, they use oxygen needed by fish and other aquatic life. The sudden increase, or "pulse," in oxygen demand after a storm can totally deplete oxygen in an urban lake or stream. Shallow, slow-moving waterways are especially vulnerable to fish kills caused by the oxygen demands of urban runoff. However, more commonly, long-term sediment oxygen demand associated with organic-enriched sediments from stormwater can drive the oxygen levels in the benthos to consistently very low levels, causing dramatic shifts in the benthic organism populations to more tolerant species (such as to sludge worms compared to more desirable fish food sources).

5.4.4 Bacteria

The levels of bacteria found in urban runoff frequently exceed by large margins the public health standards for water contact recreation such as swimming and wading. Generally, fecal coliform bacteria counts in urban runoff are 20 to 40 times higher than the health standard for swimming. Sources of bacteria in urban runoff include sanitary sewer overflows, but more commonly pets (especially dogs) and urban wildlife such as pigeons, rodents, raccoons, geese and deer.

5.4.5 Trace Metals

The greatest challenge in urban watershed stormwater pollution control is toxic pollution, particularly trace metals. Metals are the most understood toxic pollutants in urban runoff because they were excessively monitored as part of the National Urban Runoff Program (NURP) in the early 1980's. Data collected recently in Wisconsin cities verify that trace metals such as lead, zinc and copper contaminate runoff from small and large cities.

Lead is an "indicator" for other toxic pollutants because it is relatively easy to monitor. Lead is a problem for both human and aquatic life. According to recent monitoring, about 40 percent of the runoff samples from a primarily residential area, and 70 percent of the samples from a commercial area have lead levels that exceed acute toxicity standards for aquatic life. However, lead levels in urban runoff are much lower today than they were before the move to unleaded gasoline.

Zinc is another trace metal in urban runoff that commonly violates water quality standards. While zinc does not create human health problems, it can be toxic to aquatic life. Zinc levels in urban runoff are more likely than lead to violate acute toxicity standards for aquatic life. Common sources of zinc in urban areas include galvanized metals and tire wear, with roof runoff commonly having very high zinc concentrations (if galvanized rain gutters and flashings are used, or especially for galvanized roofing).

Copper concentrations in urban runoff frequently violate water quality standards. Like lead, copper is toxic to both human and aquatic life. Copper can also be high from roofing (used as an algaecide on asphaltic roofs), but the highest concentrations are usually found in runoff from paved parking areas and from industrial areas.

Cadmium is another trace metal commonly detected in urban runoff. Unlike zinc and copper, cadmium concentrations usually do not exceed acute toxicity standards. However, cadmium has a low standard level for chronic toxicity that is frequently exceeded by urban runoff. This means cadmium concentrations are seldom high enough to kill aquatic life, but are likely to have long-term health problems for people such as cancer and kidney damage.

Chromium is frequently detected in urban runoff but usually does not violate acute toxicity standards. Organisms can excrete chromium very quickly and keep it from building up in body tissues. One form of chromium (chromium IV) is considered highly toxic in humans.

These metals originate from galvanizing, chrome plating, and other metal sources in urban areas. Lead and zinc in urban runoff have also been associated with application of road sand and salt.

Another significant source of trace metals is runoff from rooftops. Many roofs have galvanized gutters and downspouts that contaminate stormwater with zinc. In industrial areas galvanized roofs and gutters are the leading source of zinc (60%). In residential, roofs are a less significant source of zinc (7%). This dramatic difference happens because most residential downspouts discharge onto lawns that filter out zinc while most industrial downspouts discharge directly into storm sewers. Another source of trace metals on some roofs is copper flashing. Runoff from these roofs carries high concentration of copper and lead.

In some cities, a significant source of trace metals is uncovered outdoor storage piles of scrap metals, coal and salt. According to the USGS monitoring, scrap metal piles are the primary source of mercury in the area surrounding the Milwaukee harbor. Scrap metal piles are also a source of arsenic. Coal piles are another source of arsenic while salt piles are a source of chromium and lead.

The list of other sources of trace metals is long, ranging from combustion to deteriorating metal and paint. For example, paints and plated metals commonly contain cadmium or chromium. Fishing weights, lead shot and paint sold before 1977 may contain lead. Air-borne emissions from burning coal, oil, or municipal waste may carry cadmium, copper, lead, or mercury. Wood used in outdoor construction may contain arsenic, chromium, copper or zinc to prevent rotting.

5.4.6 Pesticides

While much is known about the sources of trace metals in urban runoff, the sources of pesticides are a subject of some debate. Turf experts conducted tests that suggest properly applied pesticides are bound up in plants and soil so little runs off. However, monitoring data for Wisconsin shows urban runoff contains many pesticides.

Common lawn and garden insecticides, like diazinon and malathion, may not persist in the environment, but they are toxic to bees, fish, aquatic insects and other wildlife. Diazinon is toxic to birds and is banned on golf courses and sod farms because of waterfowl deaths in diazinon treated feeding areas.

Finding agricultural herbicides like alachlor, atrazine and cyanazine in urban stormwater may seem surprising since these herbicides are not used in lawn and garden compounds. However, studies in Minnesota suggest that concentrations of atrazine observed in urban stormwater are consistent with concentrations observed in rainfall. These herbicides apparently are transported by wind and rain from surrounding farm fields in the region.

Pesticides in Urban Runoff		
Regulated Insecticides	***Lawn & Garden Insecticides***	***Agricultural Herbicides***
Aldrin	Diazinon	Alachlor
Chlordane	Malathion	Atrazine
DDT	Cyanazine	
Endrin		
Heptachlor		
Lindane		
Toxaphene		

5.4.7 Other Toxic Chemicals

Other toxic chemicals found in urban runoff include organic compounds. Some of these chemicals are health hazards even in very small doses and therefore have water quality standards set in parts per billion (ppb). Because sampling for these chemicals can be difficult and costly, data are very limited. Monitoring suggests that polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are the two groups of chemicals present in large enough concentrations in urban runoff to be of concern.

Polycyclic aromatic hydrocarbons (also called polynuclear aromatic hydrocarbons) are a large group of about 10,000 different compounds. They are common by- products of incomplete combustion from vehicles, wood and oil burning furnaces, and incinerators. PAHs are used in ingredients in gasoline, asphalt and wood preservatives. The best known PAH is benzene, which is used both as a solvent and as an antiknock additive in gasoline. While benzene levels in Wisconsin stormwater do not exceed surface or groundwater standards, several other PAHs do exceed the standards. PAHs affect human health in a variety of ways, but they are of particular concern because of several of the most toxic carcinogens are PAHs. According to monitoring from Wisconsin cities, a significant percent of urban runoff samples violate human cancer criteria due to PAHs.

Petroleum-derived hydrocarbons are commonly found in urban runoff. These materials initially float on water and create the familiar rainbow-colored film. Hydrocarbons have a strong affinity for sediment and are quickly adsorbed. The hydrocarbons are then transported with sediment and settle out. Common sources of hydrocarbons are spillage at oil storage and fueling facilities, leakage from crankcases, and improper disposal of drain oil.

Polychlorinated biphenyls (PCBs) are a group of over 200 compounds. They are very stable compounds that do not easily degrade, burn or dissolve in water (or conduct electricity, a major reason that PCB's have been used for insulation in transformers and electrical capacitors for fluorescent light fixtures and appliances). They have also been used as coolants or lubricants. PCB's are of special concern because they remain in the environment for a long time. They can build up in the food chain, accumulating in the fatty tissues of animals and humans, and may eventually cause health problems. PCB production stopped in 1977, but most of Wisconsin's urban runoff samples still violate the human cancer criterion for PCBs.

5.4.8 Chlorides

In Wisconsin, a tremendous amount of salt is used each year to melt ice from roads, parking lots, and sidewalks. Because it is extremely soluble, almost all salt applied ends up in surface or ground waters. If the concentration of chlorides becomes too high, it can be toxic to many freshwater organisms. Normal applications of salt to roads for de-icing typically do not have significant impacts on large lakes or streams because of dilution. However, temporary toxic conditions due to elevated chloride levels have been found in surface waters associated with small streams or wetlands. In addition, high (greater than 10,000 mg/L) chloride groundwater concentrations have been measured in aquifers adjacent to highways.

5.4.9 Temperatures

Besides changes in water chemistry, urbanization changes the quality of waterways by raising their temperatures. Reasons for increased temperatures in urban lakes and streams include:

- Pavement and roof surfaces store heat from the sun. Rainfall that falls on these surfaces, and runoff that flows over these surfaces, are warmed from the stored heat.
- Shallow ponds and impoundments heat up between storms and release a pulse of warm water during a storm.
- Fewer trees along streams that shade the water.

Temperature is a critical factor in determining what species can live in a lake or stream since increases in water temperature affects waterways in several ways. At higher temperatures, water holds less oxygen, and many chemical and biological processes that consume oxygen increase at higher temperatures, further driving down the dissolved oxygen. Therefore, as water temperature rise, the demand for oxygen increases while the supply decreases.

5.5 References

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