MUSKEGON COUNTY
MICHIGAN
OFFICE OF THE DRAIN COMMISSIONER

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Muskegon County Site Development Rules with Procedures & Design Standards for Storm Water Management

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Nonpoint pollution from storm water runoff continues to be the nation's primary water pollution problem. This is also true for Muskegon County.

Muskegon County is rich with surface water; it has hundreds of miles of streams, thousands of acres of inland lakes, and its westerly boundary is defined by Lake Michigan.

Good surface water quality is paramount to Muskegon County's (and Michigan's) economy and quality of life.

Clean surface water is also an important part of Muskegon County resident's lifestyle.

The standards for storm water management found within this document are put forth to meet Michigan Department of Environmental Quality's storm water management permit requirements.

Left & above; examples of nonpoint water pollution.

Right & above; examples of good storm water management practices.

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PART 1: GENERAL PROVISIONS

I. PURPOSE

This manual was produced to update and unify site plan review procedures within Muskegon County. It is the purpose of these site development rules to establish a uniform set of minimum storm water management standards to be applied county-wide to meet the following objectives:

- Ensure storm water drainage systems and best management practices (BMPs) are adequate to address storm water management needs within a proposed development, and protect the drainage, property and water rights of landowners outside of the proposed development.
- Reduce flood damage due to poorly planned development.
- Minimize the degradation of existing watercourses.
- Control non-point source pollution.
- Maintain site hydrology to avoid detrimental changes in the balance between storm water runoff, groundwater recharge, and evapotranspiration.

A. Compliance with State Land Division Statute

The Land Division Act, formerly known as the Subdivision Control Act (Act 288 of the Public Acts of Michigan of 1967, as amended by Act 591 of the Public Acts of 1996), requires the County Drain Commissioner to publish rules governing the internal drainage of proposed subdivisions and outlets for drainage. The rules in this manual are intended to assist land developers by providing uniform procedures to be followed in the processing of preliminary and final plats, construction drawings, and establishment of county drains and their branches within and outside of these subdivisions.

B. Compliance with State and Federal Storm Water Mandates

The National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) General Permit requires the Drain Commissioner to adopt an ordinance or other regulatory mechanism to address post-construction storm water runoff from private, commercial and public development and redevelopment projects, including preventing or minimizing water quality impacts. County drains located within an urbanized area defined by the United States Environmental Protection Agency (US EPA) are considered MS4s. The Drain Commissioner is required to obtain a General Permit under Section 402 of the Federal Clean Water Act, as amended, and under Water Resources Protection (Part 31, Act 451, PA 1994) of the Michigan Natural Resource and Environmental Protection Act (NREPA), as amended. The MS4 General Permit requires among other things:

- *A water quality treatment performance standard to ensure specified reductions in total suspended solids.*
- *A channel protection performance standard to address resource impairments resulting from increases in bankfull flow rates and volumes.*
- *A review procedure for the evaluation of infiltration BMPs to meet water quality and channel protection standards in areas of soil or groundwater contamination.*
- *Measures to address associated pollutants in identified "hot spots," which include land uses with the potential for significant pollutant loading that could result in the contamination of surface water or groundwater, including public water supplies.*

- *A long-term operation and maintenance (O&M) plan and agreement allowing for the inspection of BMPs, including a mechanism for tracking the transfer of O&M responsibility and compliance.*

The standards in this manual adhere to the Post-Construction Storm Water Runoff Program requirements for new and redevelopments set forth in the 2013 Michigan Department of Environmental Quality (MDEQ) *Permit Application for Discharge of Storm Water to Surface Waters of the State from a Municipal Separate Storm Sewer System* under the NPDES program (Rev 10/2014).

The MS4 General Permit also requires identification and prioritization of actions to reduce pollutants in storm water discharges to make progress in meeting Total Maximum Daily Load (TMDL) Water Quality Standards. TMDL water bodies and for NPDES permit holders in the county are shown in the following table:

Table 1

TMDL Type	Unit of Government Affected	Pollutant(s) of Concern
Biota for Little Black Creek	City of Muskegon Heights City of Muskegon City of Norton Shores Muskegon County Road Commission	Sedimentation and Siltation
Biota for Black Creek	City of Muskegon Heights City of Norton Shores City of Muskegon Muskegon County Road Commission Muskegon County Drain Commissioner	Sedimentation and Siltation
Phosphorus for Bear Lake	City of North Muskegon Muskegon County Road Commission Muskegon County Drain Commissioner	Total Phosphorus
E. Coli for Ruddiman Creek	City of Muskegon Heights City of Norton Shores City of Roosevelt Park City of Muskegon Muskegon County Drain Commissioner	Human and wildlife pathogens, refuse, illicit discharges

C. Preferred Storm Water Management Strategies

It is the position of the Drain Commissioner to promote the following storm water management strategies:

Regional Storm Water Management (Off-site Mitigation). The management of storm water on a regional basis and is encouraged where practical. Offsite mitigation for channel protection is allowed in the MS4 General Permit where physical constraints of individual sties may preclude effective onsite treatment. Off-site locations may allow for the use of superior performing BMPs that require more space and can be sited strategically to address a known water quality issue.[2] Specific requirements for regional storm water management facilities are provided in Part 2 section “Regional Storm water Management Facility.”

Alternative Approach for Channel Protection. An alternative approach using extended detention is preferred over payment-in-lieu programs for sites where technical justification is

provided demonstrating that the full channel protection volume cannot be retained onsite. These standards provide specific criteria for determining the conditions under which the alternative approach will be approved for use. Payment-in-lieu programs are allowed in the MS4 General Permit, but have not been adopted by the Muskegon County Drain Commissioner.

Low Impact Development. The *Low Impact Development Manual for Michigan* (SEMCOG, 2008) was used to develop this manual. Further documentation of the impacts of development on land and water resources and the importance of storm water management can be found in Chapter 2 of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008).

A Low Impact Development (LID) approach provides multiple benefits in terms of preservation of natural areas and greenspace, meeting multiple storm water objectives (listed above), and doing so in a manner that often leads to increased property value and offers a potential cost savings.[1] Developers can reduce the size of storage facilities and storm water infrastructure by incorporating LID principles into a site design up front. This manual provides rules for the storm water "credits" allowed through the use of specific LID best management practices (BMPs). Guidelines for use of LID BMPs on storm water systems established as county drains are also provided.

[1] United States Environmental Protection Agency (December 2007). *Reducing Storm Water Costs through Low Impact Development (LID) Strategies and Practices*, EPA 841-F-07-006.

[2] Maupin, Miranda, and Wagner, Theresa (2003). *Regional Facility vs. On-site Development Regulations: Increasing Flexibility and Effectiveness in Development Regulation Implementation*, City of Seattle, Seattle, Washington.

LID screened inlet and domed riser for parking lot storm water management

Storm Water Management
Traditional Development versus Low Impact Development

Traditional Parking Lot Design

LID Parking Lot Design captures storm water

Traditional “Big Box” Site Layout

Equivalent LID Site Layout

II. LETTER OF INTENT

MUSKEGON COUNTY DRAIN COMMISSIONER

IT IS HEREBY ORDERED that the Muskegon County Drain Commissioner Site Development Rules, promulgated pursuant to Section 105 of Act 288 of the Public Acts of Michigan of 1967, as amended by Act 591 of the Public Acts of 1996, and NPDES MS4 General Permit No. MIG61051, are hereby adopted and shall be followed in the processing of all subdivision plats, and all other private, commercial and public land developments (e.g. condominiums, planned unit developments, manufactured housing communities, and other residential, commercial, industrial, or institutional developments) which impact established county or inter-county drains under the jurisdiction of the Muskegon County Drain Commissioner pursuant to the Michigan Drain Code (Act 40 of the Public Acts of 1956, as amended), or for which the Muskegon County Drain Commissioner's office provides plan review support to other state or county entities and site plan review support for storm water management to local units of government via resolution or the site plan review standards of their zoning ordinances.

IT IS HEREBY FURTHER ORDERED that the effective date of the following rules shall be the **1st day of June, 2016.**

Muskegon County Drain Commissioner

III. AUTHORITY

A. Land Division Act (formerly Subdivision Control Act)

All plats recorded with the Register of Deeds must conform to the Michigan Land Division Act (Act 591, PA 1996 and Act 288, PA 1967, as amended). Under this Act, the Drain Commissioner is responsible for ensuring that the storm water drainage system of a subdivision is adequate to address storm water management needs within the proposed subdivision and for protecting downstream landowners. The procedures and standards set forth in these rules are designed for these purposes.

In accordance with the provisions of The Land Division Act, the Drain Commissioner has the authority, through the subdivision review process, to require that county drains, both inside and outside of a plat, be improved to the standards established by the Drain Commissioner when necessary for the proper drainage of a proposed subdivision.

As specified in the Land Division Act, the Drain Commissioner may acquire jurisdiction over the drainage systems within subdivisions as deemed necessary for adequate operation and maintenance.

B. Mobile Home Commission Act

The standards set forth herein will be applied by the Drain Commissioner in review for plans for mobile home parks prepared under the Michigan Mobile Home Commission Act (Act 96, PA 1987.) The Drain Commissioner has jurisdiction to review and approve outlet drainage, and internal drainage only if the streets or drains are dedicated to the public.

C. Condominium Act

The standards set forth herein will be applied by the Drain Commissioner in review of site condominium and regular condominium plans prepared under the Michigan Condominium Act (Act 59, PA 1978, as amended). A notice of proposed action is required to be provided to the Drain Commissioner.

D. Drain Code

All developments that discharge directly to an established county or inter-county drain under the Michigan Drain Code (Act 40, PA 1956, as amended) shall conform to the requirements herein. A drain use permit may be required.

E. Review Authority Granted by Local Municipalities

All developments where review authority is granted to the Drain Commissioner by the local municipality (i.e. township, city, village) via resolution or site plan review conditions shall conform to the requirements herein. The Drain Commissioner's review of private drainage systems will focus on the discharge of storm water offsite, but will also include review of the internal drainage and the accommodation of surface water from upstream areas.

F. Provisions for Requirements in Addition to Minimum Standards

These rules provide minimum standards to be complied with by Proprietors and in no way limit the authority of the municipality in which the development is situated to adopt or publish and enforce higher standards as a condition of approval of the final plat or site plan. Proposed site plans shall complement any local storm water master plans that may exist and/or comply with any ordinance in effect in the municipalities where the site development is located.

The Drain Commissioner reserves the right to determine site-specific requirements other than those herein, based upon review of the plans.

Any deviations from these standards shall be subject to approval by the Drain Commissioner and will be done so with input from the affected municipality.

IV. APPLICABILITY

A. Review Required

These standards apply to private and public development projects.

The following types of developments shall be subject to review under these standards:

- Plats.
- Mobile Home communities with public streets.
- Site Condominiums with dedicated county drains.
- Sites discharging directly into a county drain.
- Sites that disturb at least one or more acres, including projects less than an acre that are part of a larger common plan of development or sale, discharging directly or indirectly into a regulated county MS4 (a county drain located within an urbanized area defined by the US EPA under the NPDES program). For the purpose of these rules, all county drains located within an urbanized area are considered an MS4 even if they are waters of the state. Except for the development types listed above, review authority must be granted to the Drain Commissioner by the local municipality.
- Other private developments requiring site plan review at the local level (may be less than 1 acre), at the request of the municipality.

B. Exemptions

The following development activities are exempt from these standards:

- Construction of individual single and two-family residential structures.
- Additions or modifications to existing single and two-family residential structures.

C. Redevelopment

Redevelopment and additions requiring site plan review at the local level shall comply with the current standards for the redeveloped or newly constructed portion of the site.

The Drain Commissioner reserves the right to require that the entire site be brought up to the current standards where there is, or may be significant impact to drainage or water quality off-site.

V. SEVERABILITY CLAUSE

If any part of these rules is found to be invalid, such invalidity shall not affect the remaining portions of the rules which can be given effect without the invalid portion, and to this end the rules are declared to be severable.

VI. PERMITS FOR WORK IN COUNTY DRAINS

A. Utilities. If any utilities are to be located within the drainage easement of the proposed development, the Design Engineer shall present plans detailing such utilities to the Drain Commissioner for approval as to location. Utility plans shall be presented at the same time as construction drawings so that all details of construction and location may be checked and properly oriented with each other. A sample application, checklist and permit for "Utility Work in a County Drain and/or County Drain Easement" is available upon request.

B. Encroachments. Permission is required to place an encroachment within an existing drain easement. A sample application and checklist for "Encroachment in County Drain Easement" is available upon request.

C. Crossings and Maintenance Work. A permit is required for maintenance to a county drain including installation of crossings, and shall be presented at the same time as construction drawings. A sample application, checklist and permit to "Perform Work in a County Drain and/or County Drain Easement" is available upon request.

D. Modifications. Agreements for modification (deepening, widening, straightening, relocating), tiling or adding a branch or extension to a county drain shall follow the procedures under "Section 425 Application and Petition."

E. Tapping. A permit shall be obtained from the Drain Commissioner prior to tapping any open or enclosed county drain and shall be presented at the same time as construction drawings. A sample application, checklist and permit for "Connection to a County Drain" is available upon request**.**

Footing Drains. Whenever building footing drains are required or utilized, footing drain leads shall be provided from a drainage structure (to the greatest extent practical) to service each lot. The Proprietor shall also provide a marker or monument indicating the location of the footing drain lateral access point.

Floor Drains. Floor drains shall be connected to the sanitary sewer system. Where this is not possible, the Drain Commissioner shall review and approve connection of floor drains to a county drain on an individual basis. In all cases, connection of floor drains will not be allowed without adequate pretreatment meeting spill containment criteria

Agricultural Tiling. GPS coordinates for discharge points into the drain shall be provided along with a drawing of approximate location of tile discharge points.

VII. FEES

The fees for reviewing a plat or site development under the provisions of the Muskegon County Drain Commissioner Site Development Rules are set forth in the Schedule of Fees.

SCHEDULE OF FEES

REVIEW**	
Subdivisions	$600.00
Condominiums	$600.00
Business/Building/Commercial Development	$600.00
Utility Drain Crossing	$350.00
Land Divisions	$350.00
Inspection Fee:	Based on hourly rate of inspector
**Submittal fees are considered a deposit for engineering review. Additional costs will be billed prior to final approval.	

DRAIN PERMITS	
A permit is required to locate a utility within a county drain easement, cross a county drain with utilities, roads, drives, etc., or connect to a county drain. Fees shall be paid with the permit application submittal prior to construction drawing approval. No fee is required for connecting storm water discharges to a county drain; however, the Drain Commissioner reserves the right to charge a fee for connection of discharges other than storm water runoff or tile drainage/footing drains.	
Utility Crossing	Permit required, plans must be submitted and approved.
Discharging private agricultural drain tiles directly into a county drain.	None; provided marking signs, GPS coordinates & height from the bottom of the ditch are provided for the outfall(s). Stabilization measures must also be provided.
Placing or replacing a culvert in a county drain	Equal to the cost of a surveyor to check grades & obtain coordinates. Engineer's inspection also required as culvert is set. $350.00 deposit required; remaining fee to be paid before final approval is given.
Placing a bridge of under six (6) feet in width over a drain; no disruption to the banks.	None; provided GPS coordinates are provided for bridge location, the bridge sits on top of the ditch banks, the banks are not disrupted to place the structure, & the structure would not aggravate flooding.
Dewatering into a Drain (tap fee)	$100.00 for up to 30 days, Best Management Practices must be utilized.

DEDICATION AGREEMENTS	
425 or 433 Agreement:	
Maintenance Fee (required by Michigan Drain Code):	Lesser of $2,500.00 or 5% of construction
Surety for Work Completed after Final Plat Approval, or for Regional Storm water Facility (Off-site Mitigation):	110% of uncompleted project
*Maintenance fee shall be paid prior to final plat approval and/or execution of the 433 Agreement. Surety shall be posted prior to final plat or site plan approval, and must be in the form of a cashier's check or irrevocable letter of credit.	
**Engineering services will be based on current hourly billing rates for actual time and reimbursable expenses. Charges are to be paid by the Proprietor within thirty (30) days of invoice by the Drain Commissioner. Payment of all fees is prerequisite to approval. Failure to make timely payment constitutes a violation, permits will be revoked, and the deposit will be forfeited. Development deposits will be returned to Proprietors of good standing upon receipt of construction record drawings (as-builts). No interest will be paid on deposit funds.	

PART 2: PROCEDURES FOR PLAN SUBMISSION AND APPROVAL

These procedures have been developed in the context of the plat requirements specified in the Land Division Act, which lays out a two-step submittal and approval process. A preliminary plat and final plat are required by statute. A pre-application review meeting may be requested by the Proprietor as stated in the statute for the purpose of an informal review of the concept plan for the preliminary plat. A site evaluation may also be requested.

For other categories of developments, including site condominiums, submittal of a preliminary site plan is recommended, but not required. Construction drawings are required for all developments.

Plats, site condominiums and other developments where the storm water system is to be established as a county drain, must also follow the additional procedures outlined for drains under the jurisdiction of the Drain Commissioner.

I. SUBMISSION AND APPROVAL

A. Submission

Submit the following for site plan review:

1. Application for Development Approval.
2. Drawings. Two (2) prints and one (1) electronic file (.pdf) of the preliminary plat, site plan, or construction drawings containing the information on the Plan Review Checklist.
   a. Preliminary plat: Prepared by a professional engineer or surveyor licensed in the State of Michigan.
   b. Construction drawings: Sealed by a professional engineer licensed in the State of Michigan.
3. Storm water calculations prepared by a professional engineer licensed in the State of Michigan and containing the information on the Site Plan Review.
4. Applicable fee (refer to Part 1 section “Fees”).
5. Other required documentation per these standards.
   a. A Submittal Checklist for Private Developments.
   b. A Submittal Checklist for County Drainage Systems.

Submit the following for final plat approval:

1. Evidence of preliminary plat approval. The preliminary plat must be approved by the municipal governing body in which the proposed development is located. Evidence of this approval shall be submitted to the Drain Commissioner's office with the final plat.
2. Final plat. The Land Division Act requires that one (1) true copy of the final plat be delivered to the Drain Commissioner for review. Final plats must be prepared in accordance with the requirements of the Land Division Act. Final plat mylars of the number and type are directed by the Michigan Department of Commerce. One (1) electronic file of the plat in .pdf format, and one (1) electronic copy meeting County Geographic Information Systems (GIS) digital submission requirements (refer to Site Plan Review Checklist shall be submitted to the Drain Commissioner.
3. Acceptable construction record drawings and post-construction certification from the Design Engineer must be submitted along with the final plat. A Proprietor who desires to expedite the formal platting procedure shall enter into an agreement with the Drain Commissioner and post surety for faithful performance of the agreement (refer to Part 2 section “Surety”).

B. Changes and Resubmission

Preliminary Plat. Approval of the preliminary plat by the local governing body is required under the Land Division Act. Further, the approval of federal and state agencies may also be required. Should the approval of the local unit of government, federal, or state agencies require changes to the proposed layout, such changes shall be incorporated in a new layout and a new preliminary plat or site plan shall be resubmitted for review by the Drain Commissioner's office.

If the Proprietor finds it advantageous to make changes in the preliminary plat or site plan, they shall be incorporated in the plan and a new preliminary plat or site plan shall be resubmitted for approval. Resubmission is required even though the original layout may have already been approved.

Construction Drawings. If the Proprietor finds it advantageous or necessary to make design changes, or if the information given to the Drain Commissioner does not represent the conditions as they exist on the ground, and revisions are required as a result, such revisions shall be made by the Proprietor and the drawings resubmitted to the Drain Commissioner for approval.

C. Approval

Payment of all fees is prerequisite to approval (refer to Part 1 section "Fees").

Preliminary Plat. The Drain Commissioner within thirty (30) days after receipt of the preliminary plat will approve it, approve it subject to conditions, or reject it. If the preliminary plat is approved, the Drain Commissioner will note its approval on the copy to be returned to the Proprietor, or by letter if the Proprietor does not need the preliminary plat to be returned. If the preliminary plat is approved subject to conditions or rejected, the reasons for rejection and requirements for approval shall be given in writing to the Proprietor and each of the other officers and agencies to which the Proprietor was required to submit the preliminary plat.

Construction Drawings. The Land Division Act gives no time limit in which final construction plans must be reviewed. The Drain Commissioner will approve or reject construction drawings in writing within thirty (30) days of receipt of a complete submittal.

Final Plat. Final plat review will be completed by the Drain Commissioner's office within ten (10) days of submission by the Proprietor. If the plat is not acceptable, written notice of rejection and the reasons therefore will be given to the Proprietor and the clerk of the related municipality. Upon approval, the Drain Commissioner will sign the plat, and the plat will be executed.

D. Expiration of Approval

Preliminary Plat. If the Proprietor does not present the final plat to the Drain Commissioner for approval within a period of two (2) years after receiving approval of the tentative layout, it will be necessary to resubmit the layout for review. The preliminary layout is no longer valid and a new submittal is required.

Construction Drawings. Approval of construction drawings by the Drain Commissioner's office is valid for two (2) calendar years. If an extension beyond this period is needed, the Proprietor shall submit a written request to the Drain Commissioner for an extension. The Drain Commissioner may grant one-year extensions of the approval and may require updated or additional information, if needed. Should modifications be made to the drawings, a new review may be required subject to the appropriate fees.

E. Staged Development

Should the Proprietor plan to develop a given area but wish to begin with only a portion of the total area, the original preliminary plat or site plan shall include the proposed general layout for the entire area. The first phase of the development shall be clearly superimposed upon the overall plat or site plan in order to illustrate clearly the method of development that the Proprietor intends to follow. Each subsequent plat or site plan shall follow the same procedure until the entire area controlled by the Proprietor is developed.

Final acceptance by the Drain Commissioner of only one portion or phase of a development does not ensure final acceptance of any subsequent phases or the overall general plat or site plan for the entire area; nor does it mandate that the overall general plat or site plan be followed as originally proposed, if deviations or modifications acceptable to the Drain Commissioner are proposed.

F. Submission of Construction Record Drawings ("As-builts")

One (1) electronic file of the construction record drawings in .pdf format, and one (1) electronic file meeting County GIS digital submission requirements shall be submitted to the Drain Commissioner with a letter of certification by the Design Engineer for all developments reviewed under these rules. Construction record drawings must be submitted prior to release of any review deposit. At a minimum, construction record drawings shall contain the information listed on the Site Plan Review Checklist**.** The Drain Commissioner shall have thirty days (30) to review construction record drawings.

II. STORM WATER DRAINAGE REQUIREMENTS

A. Site Plan

Drainage Patterns. Proposed drainage for the development shall conform to existing watershed boundaries, natural drainage patterns within the site, or any established county drainage districts.

Staged Development. Each phase shall be self-sufficient from the standpoint of drainage.

Location of Storm Water Facilities. Storm water facilities for private drainage systems with multiple land ownership shall be located on dedicated outlots, within road rights-of-way, or have separate easements granted to the appropriate governing body. As such, drainage easements and facilities at the rear of lots are discouraged.

Storm Water Discharge. The rate, volume, concentration, or constitution of storm water discharged from a site shall not create adverse impacts to downstream property owners and watercourses.

1. Post-development discharge shall not exceed the capacity of the existing infrastructure.
2. Post-development discharge shall not cause adverse impact to offsite property due to concentrated runoff or ponded water of greater height, area, and duration.
3. Discharge shall not cause downstream erosion.
4. For a downstream drainage system that is inadequate to handle the proposed design discharge from the site development, it is the Proprietor's responsibility to:
    a. Stabilize or upsize the existing conveyance system, or establish a county drain to provide the needed design level of flood protection.
    b. Obtain flooding easements for measurable increases in water levels determined to cause an adverse impact.
    c. Provide additional onsite storm water controls.

5. Additional impacts (such as increased temperature, pollutant load, or groundwater recharge) may also need to be mitigated.
6. It is the Proprietor's obligation to meet this standard. Should a storm water system, as built, fail to comply with the rules herein, it is the Proprietor's responsibility to have constructed at their expense, any necessary additional and/or alternative storm water management facilities. Such additional facilities will be subject to the Drain Commissioner's review and approval.

B. Regional Storm Water Management Facility

Regional storm water management facilities are designed to serve multiple developments or parcels and can provide water quality treatment, channel protection and flood control. Regional facilities shall be sited and designed to serve an identified area defined as a regional storm water management district. Sites located within a regional storm water management district would be approved for off-site mitigation to meet the channel protection standard and MS4 General Permit requirements (i.e. offsite mitigation is provided within the same jurisdiction and/or watershed/sewershed). The Drain Commissioner may pursue projects within a drainage district through the petition process to construct facilities to serve a particular storm water management district, or may approve facilities proposed to be constructed by individual Developers.

The regional facility should be constructed first when possible. When development or redevelopment occurs in a storm water management district prior to construction of the regional facility, temporary onsite measures must be installed and financial surety provided to ensure that the regional facility will be constructed within 24 months of the original project site construction.

The size of the regional facility shall provide for a 2:1 (offsite:onsite) treatment ratio to meet MS4 General Permit requirements for channel protection. (This provides for a factor of safety since a 1.5:1 ratio is acceptable if a minimum of 0.4 inches of storm water is managed onsite.)

A regional facility serving more than two individual parcels shall be dedicated as a county drain with associated easements granted to the drainage district to allow for operation and maintenance in perpetuity. Refer to Appendix 1 "Watershed Policy Statements" for special watershed considerations.

C. Restrictive Covenants

For plats and site condominiums, a copy of restrictive covenants or master deed language related to drainage shall be provided to the Drain Commissioner along with construction drawings for approval. Covenants and deeds shall be recorded prior to release of posted surety.

Block Grading Plan. A block grading plan shall be incorporated in the restrictive covenants of the plat or master deed to ensure proper drainage of individual lots. In addition, the Proprietor shall provide an electronic copy of the block grading plan to the Drain Commissioner and the municipality for their permanent files. The block grading plan shall include the Lowest Allowable Floor Elevation and Lowest Allowable Opening Elevation for each lot, and include the "basement type" for each lot (e.g. walkout, daylight, or standard basement) as indicated by the topography of each site and according to the approved design plans. The block grading plan shall state:

> *"The block grading plan shows the direction of flow for the surface drainage for all lots. It is the lot owner's responsibility to ensure that the final grading of the lot is in accordance with the block grading plan. During the final lot grading and landscaping, the owner shall take care to ensure that the installation of fences, planting, trees, and*

shrubs do not interfere with nor concentrate the flow of surface drainage. No changes will be made in the grading of any lot areas used for drainage which would later affect surface runoff drainage patterns without the prior written consent of the Drain Commissioner for all portions of the drainage system. Finish grading for home construction shall be completed in conformance with the master drainage plan for the development and in such a manner so as not to create the excessive ponding of storm water on the sites within the development."

Minimum Floor and Opening Elevations. Minimum building floor and opening elevations shall be established to eliminate the potential of structural damage and flooding of building interiors. Minimum floor and opening elevations shall be incorporated in the restrictive covenants of the plat or master deed, including bench mark references. Lots not impacted by high groundwater or potential flooding from a 100-year storm event as determined by the Design Engineer shall be so noted as well. A certification by the Design Engineer that the minimum floor and opening elevations do not pose a risk of flooding for up to the 100-year storm shall be provided for each development or phase of development prior to approval. Documentation to support allowable minimum floor and opening elevations shall be submitted with construction drawings.

Criteria for determining the Lowest Allowable Floor Elevation includes:

1. Proximity to detention/retention facilities due to groundwater mounding (which may not be apparent until after construction).
2. Groundwater elevations from monitor wells, test pits and/or soil borings including any soil mottling noted in the soil profile.
3. Regional and cyclical groundwater levels available online.
4. Hydro-geologic studies and groundwater modeling.

Criteria for determining the Lowest Allowable Opening Elevation includes:

1. Proximity to open drain or natural watercourse, pond or wetland and the 100-year flood elevation.
2. Proximity to detention/retention basin and design high water level.
3. Proximity to drainage swales and/or flood routes designed to convey the 100-year storm event runoff including overflows from detention/retention basins.
4. Proximity to an enclosed storm sewer system with open ends or catch basins that could surcharge during the 100-year storm event.
5. Type of building foundation (e.g. walkout, daylight, or standard basement) as dictated by the topography of each site.

It is the responsibility of the Proprietor to provide a sufficient number of bench marks (NAVD 88 datum) to use as a reference for establishment of minimum floor and opening elevations for all lots.

The restrictive covenant shall state:

"The lowest allowable floor elevations are set at 1-foot or more above the highest known ground water elevation. The lowest allowable floor and/or opening elevations are set 1-foot or more above the 100-year floodplain or design hydraulic grade line of the storm system. These elevations are set to reduce the risk of structural damage and the flooding of building interiors. A waiver from the set elevations may be granted by the Drain Commissioner following receipt of a certification for a professional engineer licensed in the State of Michigan demonstrating that the proposed elevation does not pose a risk of flooding. Minimum building floor and opening elevations and bench mark locations and elevations are indicated on the Block Grading Plan."

Footing Drains and Sump Pumps. Provide direction in the restrictive covenants of the plat or condominium master deed for footing drain and sump pump outlets. If proposed to be directed to the storm sewer system, the restrictive covenant shall state:

> *"Water from such sources as eave troughs and footing drains shall be directed to footing drain laterals provided for the lots. Water from footing drains shall be discharged to the lateral via a sump pump with check valve system, or a gravity system with a double flap gate valve for backflow prevention. If no lateral is provided, the lot owner shall discharge said water in such a manner as to not impact neighboring land or public streets."*
>
> *"Floor drains, laundry facilities or other similar features shall not be connected to a footing drain or sump pump system discharging to footing laterals and the storm sewer system. Laundry facilities and sewage lift pumps must discharge into the sanitary sewage disposal system."*

Easements for Side Yard and Surface Drainage. Private easements for enclosed yard drains and surface drainage are for the benefit of upland lots within the development or upland sites that currently drain across the proposed plat or site. Language shall be included within the restrictive covenants of the plat or condominium master deed that clearly notifies property owners of the location and purpose of private easements for side yard and surface drainage, as well as restrictions on use or modification of these areas. A separate, recordable easement form is not required. The restrictive covenant shall state:

> *"Private easements for side yard and surface drainage are for the benefit of upland lots within the subdivision and any improper construction, development, or grading that occurs within these easements will interfere with the drainage rights of those upland lots. Private easements for surface drainage are for the continuous passage of surface water and each lot owner will be responsible for maintaining the surface drainage system across their property. No construction is permitted within a private easement for side yard and surface drainage. This includes swimming pools, sheds, garages, patios, decks, or any other permanent structure or landscaping features. No dumping of grass clippings, leaves, brush or other refuse is allowed within a drainage easement. These items obstruct drainage, restrict flow and plug culverts. This can lead to higher maintenance costs and cause flooding situations."*

Soil Erosion and Sedimentation Control Permits. It is the responsibility of the Proprietor to contact the County Public Works Department (724-6411) to determine which lots if any need Soil Erosion and Sedimentation Control Permits. The restrictive covenant shall state:

> *"Each individual lot owner will be responsible for the erosion control measures necessary on their lot to keep loose soil from their construction activities out of the street, catch basins, and off of adjacent property. If any sedimentation in the street, catch basins, or adjacent lots results from construction for a particular site, it is the responsibility of that lot owner to have this cleaned up. This applies to ALL lot owners.*
>
> *A Soil Erosion and Sedimentation Control Permit must be obtained from the Department of Public Works Office prior to excavation for lots _____ through _____. All conditions set forth by permit shall be met throughout construction activity until permit is allowed to expire."*

Responsibility for Maintenance of Open Water Bodies. The restrictive covenant shall state:

> *"Lot owners are responsible for the management and maintenance of open water bodies for aesthetics, aquatic habitat, recreation and water quality, including liability and costs."*

D. Maintenance Plan and Agreement

For private developments, a legally binding maintenance agreement between the Proprietor and the municipality shall be required before approval is granted within the urbanized area. The maintenance agreement includes a maintenance plan and requires tracking of compliance. A copy of the recorded maintenance agreement must be presented to the Drain Commissioner prior to release of any review deposit.

III. DRAINS UNDER THE JURISDICTION OF THE DRAIN COMMISSIONER

A. Responsibility for Storm Water System Ownership and Maintenance

Plats. All plats shall be established as county drains under the jurisdiction of the Drain Commissioner.

Other Developments. Site condominiums and other multi-lot developments with public roads shall be established as county drains under the jurisdiction of the Drain Commissioner.

The Drain Commissioner may accept drainage jurisdiction over other multi-lot developments with private roads when a single private entity with responsibility for operation and maintenance does not exist.

Roadside Ditches. In general, the Drain Commissioner will not accept responsibility for roadside ditches. The County Road Commission maintains these if located within the right-of-way of a public road. When required by the County Road Commission, roadside ditches may be established as county drain.

Maintenance by Drain Commissioner. The Drain Commissioner shall be responsible for maintenance of all established county drains, including storm water BMPs dedicated as part of the county drain system. The costs for maintenance shall be assessed to the drainage district under the provisions of the Michigan Drain Code. A maintenance plan must be prepared by the Proprietor and delivered to the Drain Commissioner with the dedication agreement documents. A maintenance plan template is available from the Drain Commissioner's office.

The Drain Commissioner will not accept ownership and maintenance of any decentralized storm water BMPs (e.g. rain barrels for individual houses, green roofs, and pervious pavement) as part of the county drain system. All portions of a county drain system must have dedicated easements.

Maintenance Agreement. A maintenance agreement shall be submitted for property owner associations or corporate entities that desire to perform the routine maintenance required on the drainage system internal to the plat or development, which is established as a county drain. A maintenance plan shall be included with the executed maintenance agreement and recorded with the subdivision agreement or legally binding documents such as the property deed or condominium master deed. A maintenance plan template is available from the Drain Commissioner's office.

B. Easements

Existing Easements. The liber and page (or document number) reference of all recorded easements shall be shown on final plats and construction drawings. Drainage easements obtained prior to 1956 were not required by statute to be recorded. In this case, affidavits of easements may be employed. Therefore, it may be necessary to check the permanent record of the Drain Commissioner's office to see if a drain easement is in existence on the subject

property. Existing county drain easements (or release of rights-of-way) shall be indicated on the plans and designated with the name of the Drain.

Proposed Easements. An easement, not land ownership, is the approved method of providing access to, and protection of, public storm drainage facilities. Transfer of land ownership to an established drainage district is not allowed unless permitted in writing by the Drain Commissioner or other applicable authorities.

Within a Plat or Multi-Lot Site Development. All established county drains located within the plat or multi-lot site development, shall have granted easements. Private (exclusive) easements for drainage shall be granted to the appropriate drainage district and must be shown on the final plat or site plan. Related easement language shall be depicted on final plats and/or Exhibit B condominium drawings as follows:

> *"Easement for [Drainage] [Flooding] [Name of BMP] to the _____ Drain Drainage District."*

Separate, recordable easements must be provided in a form acceptable to the Drain Commissioner. Sample easement forms can be provided upon request. Recordable drainage easements shall be submitted to the Drain Commissioner prior to construction drawing approval and recorded prior to final plat approval and the sale of any lots which are to be encumbered by easements. If lots are sold prior to the Proprietor releasing an easement to the drainage district, the Proprietor shall obtain all necessary easements on said lots for completion of the project. Any lots sold on land contract must have the signature of both land contract vendor and vendee on the easement.

Outside the Plat or Site Development. Private (exclusive) easements shall be required downstream of a plat or site development when the discharge is to a watercourse or an open or enclosed drainage way that requires improvements and maintenance to continue to serve as a viable outlet for the plat or site development. A sample release of right-of-way form for county drains can be provided upon request. Recordable drain easements shall be submitted to the Drain Commissioner prior to construction drawing approval and recorded prior to release of surety. Easements will not be required through public rights-of-way (e.g. county roads).

Flooding Easements. When concentrated storm water is proposed to be discharged over, onto, or across private property (other than that owned by the Proprietor), and no watercourse or drainage way exists or is proposed to be constructed, an agreement between the owners must be executed relieving the drainage district of any and all responsibility for damage that might occur. A sample Flooding Easement form can be provided upon request. Such an agreement shall be submitted to the Drain Commissioner prior to construction drawing approval and recorded prior to release of surety.

Easement Width. Minimum easement widths for new storm water systems are provided below. These easements shall be situated in such a way as to allow maximum maintenance access (for example, by offsetting them from the centerline if required). In general, easement widths shall conform to the following:

Open Channels and Watercourses. Open channels shall have a minimum of 15 feet on each side of the top of bank and a total minimum width of 50 feet.

Open Swales. Open swales shall have a total minimum width of 30 feet.

Enclosed Drains. Easement widths for pipes shall conform to the following table:

Depth to Invert (feet)	Easement Width (feet)
0-7	20
7.1-12	30
12.1-17	40
>17	50

Detention and Retention (Infiltration) Basins. A minimum of 15 feet of open space outside the high water level and around the perimeter of a public detention/retention basin, and an easement over the temporary spoil disposal area must be granted to access and maintain the facility. Ingress and egress easements shall also be provided. For basins located adjacent to county drains, a minimum of 15 feet open, flat space between the basin and the county drain must be granted as a drainage easement for access and maintenance of both.

Other Storm Water BMPs. A minimum of 10 feet around the perimeter of storm water BMPs (e.g. bioswale/rain garden, infiltration trench) must be granted to access and maintain the BMP.

Exceptions. Generally, the above widths shall govern; however, if the Review Engineer determines that additional easement width is required for proper construction, or because of special circumstances, such facts shall be made known to the Proprietor upon review by the Review Engineer.

C. Surety

The Proprietor shall post a performance surety prior to construction drawing approval.

The performance surety shall consist of a cash deposit, a certified check or an irrevocable letter of credit drawn on a bank licensed in the State of Michigan in an amount equal to 110% of the uncompleted portion of the project, or $10,000, whichever is greater.

Valid existing contracts for construction of the storm water management system and soil erosion control measures executed between the Proprietor and Proprietor's contractor shall be the basis for establishing the portion of the contract to be covered by surety.

In the event the Proprietor has not contracted for the construction of the storm water management system (Proprietor is the contractor), the Design Engineer shall estimate the cost of said construction. The estimate of cost, as reviewed and approved by the Drain Commissioner, shall be the basis for the amount of surety.

Rebate. A rebate to the Proprietor may be made as the work progresses with approval by the Drain Commissioner. The amount of the rebate will be equal to the cost of the completed work minus a 10% retainage. In no case shall the surety amount be reduced to less than $10,000.

Release of Surety. Upon final inspection, completion of all punch list items, receipt of acceptable construction record drawings and post-construction certification from the Design Engineer, the Drain Commissioner will execute and agreement granting final approval of the plat and/or final acceptance of the county drain and shall subsequently release the balance of any surety deposit to the Proprietor. A sample Agreement for Drain Commissioner Approval of Development Infrastructure is available upon request.

If the Proprietor does not complete the approved drainage improvements as agreed, the Drain Commissioner will draw on the surety and proceed to fulfill the Proprietor's obligation at such

time and in such manner as the Drain Commissioner may determine appropriate.

D. Dedication Agreements

Developments proposed to have public drains must submit a completed Dedication Agreement. Two methods for establishing and dedicating drainage facilities are provided for by the Michigan Drain Code. Rules developed by the Drain Commissioner for each method are similar.

Section 433 Agreement. Section 433 of the Michigan Drain Code addresses enlargement of existing drainage districts and creation of new districts where none previously existed. A formal agreement is required between the Proprietor and the Drain Commissioner or intercounty drainage board on behalf of the affected drainage district. Owners of lands not owned by the Proprietor, who will be included in the drainage district, must also sign the agreement. The property of any adjoining landowner who refuses to sign cannot be included in the drainage district for assessment purposes. However, the Proprietor must accommodate surface and subsurface runoff from adjoining properties.

Submittals

1. Agreement. The Proprietor and all parties having legal interest in the plat or development, as well as adjoining landowners, whose properties will be included in the enlarged or new drainage district, shall enter into a formal agreement dedicating drainage facilities therein for public use. The agreement form will be completed by the Proprietor in coordination with the Drain Commissioner and stipulate conditions of transfer and responsibilities of parties. Sample Section 433 Agreement forms are is available upon request. The Drain Commissioner's legal council will help determine which agreement form will be necessary.

   The 433 Agreement shall be signed by an authorized representative of the Proprietor and Drain Commissioner and be submitted for recording at the County Register of Deeds prior to final plat approval and the sale of any lots in a plat or units in a site condominium. If property is sold on a land contract, both land contract vendor and vendee must sign the agreement. If more than one individual, corporation, partnership, or limited liability company has interest in the property, duly authorized representatives of each shall sign the 433 Agreement. Proprietor shall obtain on the 433 Agreement the signatures of all landowners or unit owners to whom lots are sold, if any.

2. Legal Descriptions.

   a. Route and Course. The Design Engineer shall provide centerline descriptions for each drain or branch to be dedicated.

   b. Drainage District. The Design Engineer shall provide a shape file of the drainage district boundary meeting County GIS digital submission requirements and a description of the contributing drainage district benefiting from such improvements. One (1) electronic file in .pdf format, and one (1) paper copy of a 24-inch by 36-inch drainage district map showing the drainage district boundary line, route & course of the drain, roads, lot and parcel lines with numbering, townships and sections, and other pertinent information shall be required. The Drain Commissioner may also require that adjoining drainage district boundaries changed by the dedication be described in their entirety for amending documents pertaining to those drains.

3. Certification. The Design Engineer shall include a sealed and dated statement attesting that 1) lands to be added to a drainage district naturally drain into the area served by the existing drain or that the existing drain is the only reasonably available outlet and attesting to the adequacy of existing receiving drains, or 2) that the outlet for the existing

drain is the only reasonably available outlet and attesting to the adequacy of the outlet. A certification form is available upon request.

4. Specifications for construction.

5. Copy of the Master Deed. A copy of the 433 Agreement shall be attached to the Master Deed, and the Master Deed shall state:

   _____ *DRAIN DRAINAGE DISTRICT*

   Attached as Exhibit __ is an Agreement establishing the ____ Drain Drainage District pursuant to Section 433 or Act No. 40 of the Public Acts of 1956 as amended. A copy of the 433 Agreement is recorded in the Muskegon County Register of Deeds at Liber ____ Page ____.

   When a 433 Agreement is accompanied by a maintenance agreement, the master deed shall also state:

   Attached as exhibit __ is a maintenance agreement outlining the maintenance responsibilities of the Association for the Drain. A copy of the maintenance agreement is recorded in the Muskegon County Register of Deeds at Liber __ Page __.

   Note: Exhibit A is typically by-laws and Exhibit B is typically condominium plans.

Maintenance Fee

The Michigan Drain Code requires that any person dedicating a drain for public use shall provide funding for initial maintenance operations. Contribution is calculated by taking the lesser amount of $2,500 or 5% of the cost of constructing the drain and its appurtenances. These funds shall be submitted to the Drain Commissioner prior to final plat approval and/or execution of the 433 Agreement. The funds are deposited in the account set up for the subject drain and are not refundable.

The $2,500 fee is based on a storm water system consisting solely of gravity components. Systems with non-gravity components are subject to fees above and beyond $2,500.

Section 425 Application and Petition. Section 425 of the Michigan Drain Code addresses the addition of branch drains to serve lands entirely within an existing drainage district and the enclosure or tiling of an existing drain. A Section 425 Agreement is required when a Proprietor wishes to relocate, improve and/or enclose a county drain on their own property at their expense. The Proprietor must petition the Drain Commissioner or intercounty drainage board for permission to construct or improve the additional drainage for public use.

Submittals

1. The Drain Commissioner's legal counsel will draft the agreement with the Proprietor responsible for all costs. A sample agreement is available upon request.
2. Legal Descriptions. The Design Engineer or surveyor shall provide the centerline (route & course) descriptions for the branch drain or extension.
3. Certification. The Design Engineer shall include a sealed and dated statement attesting to the adequacy of existing receiving drains. An acceptable certification form is available upon request.
4. Specifications for construction.

E. Construction

Documentation of Value. Governmental accounting standards (GASB Statement 34) require the County to report the value of their drain infrastructure. The Proprietor shall submit documentation relative to the contract covering the work to be performed including the cost of construction with an itemized breakdown.

Preconstruction Meeting. The Drain Commissioner may request a preconstruction meeting be held with all involved parties.

Inspections

Inspection Fee. The Proprietor shall submit an inspection fee (refer to Part 1 section "Fees").

By Proprietor. Upon request of the Drain Commissioner, the Proprietor shall retain a qualified inspector, supervised by the Design Engineer, to perform construction inspection of storm drains and appurtenances that will be the responsibility of the Drain Commissioner to operate and maintain to assure construction according to Drain Commissioner approved plans. Inspection activities shall be documented by written daily reports acceptable to the Drain Commissioner. Daily inspection reports shall be bound and submitted to the Drain Commissioner for review prior to final acceptance.

By Drain Commissioner. The Drain Commissioner may employ an inspector on behalf of the drainage district should it appear that the installation fails to meet minimum requirements. Spot inspections by the Review Engineer are to verify the proper construction of the drainage system. Inspection by the Drain Commissioner or the Review Engineer shall not relieve the Design Engineer or the municipal engineer of their obligations.

Final Inspection. The Drain Commissioner will complete a final inspection jointly with the County Road Commission. The Drain Commissioner will issue a letter to the Proprietor upon final acceptance.

Post-Construction Certification. A post-construction letter of certification from the Design Engineer that certifies construction of the county or intercounty drains in accordance with the approved construction drawings shall be submitted to the Drain Commissioner. An acceptable certification form is available upon request.

Construction Record Drawings ("As-builts"). Construction record drawings shall be submitted by the Proprietor to the Drain Commissioner in accordance with the submission requirements (refer to Part 2 section "Submission of Construction Record Drawings").

PART 3: STORM WATER MANAGEMENT REQUIREMENTS

I. SUMMARY

The following storm water management requirements comply with the county NPDES MS4 General Permit and shall apply to all new development and redevelopment in Muskegon County:

1. Protection: The design process shall begin by identifying environmentally sensitive areas located on the site and laying out the site to maximize protection of the sensitive areas.

2. Runoff Reduction: Non-structural BMPs are required for protection of environmental sensitive areas on the site, and may also be used to reduce the amount of storm water runoff routed to a collection system.

3. Storm water Management: Storm water shall be managed using minimum standards to protect both water resources and real property. Storm water standards are summarized ***Table 2***.

4. Regional Storm water Management Facilities: Regional storm water management facilities are encouraged, particularly where site constraints preclude effective onsite treatment of storm water. Regional facilities may be used to provide off-site mitigation to meet channel protection performance standards at a 2:1 (offsite:onsite) mitigation ratio. Regional facilities serving more than two parcels must be dedicated as county drain.

5. Watershed Policy Statements: Specific storm water management criteria (e.g. regional storm water management, no-detention zones, higher treatment standards) have been determined beneficial for certain identified watersheds and geographic areas of the county, and are required to be met in addition to these minimum standards, as identified in the Watershed Policy Statements of Appendix 1.

6. Groundwater: The highest known groundwater elevation and extent of mounding from infiltration BMPs shall be determined to ensure no adverse impacts internal and external to the development.

7. Soils: Soil borings are required for most structural BMPs to determine soil classification, depth to groundwater and the presence of other site constraints. Field permeability testing is not generally required, but may be conducted to allow the use of a higher infiltration rate for design, or may be required in certain cases to confirm field infiltration rates.

8. BMP Design: BMPs must be designed to meet the minimum criteria provided. BMPs selected to meet the water quality treatment standard must also be shown to reduce total suspended solids in storm water runoff by at least 80% or to a concentration of no greater than 80 mg/L (refer to ***Table 3***).

The following additional requirements apply to storm water systems established as county drains, including but not limited to plats, site condominiums and other multi-lot developments dedicated by agreement under Section 433 of the Michigan Drain Code, and county drain extensions, branches or modifications performed by agreement under Section 425 of the Michigan Drain Code:

9. Easements: Easements are required for county drains and associated BMPs accepted by the Drain Commissioner.

10. Maintenance Agreement: A maintenance agreement between the Developer and the Drain Commissioner is required for storm water systems established as county drains when a private entity or organization wishes to conduct the maintenance. (A maintenance agreement between the Developer and the local municipality may also be required for private storm water management systems in urbanized areas that discharge to an MS4.)

Table 2 - Minimum Required Storm Water Standards

Standard / Where Required	Criteria
Water Quality "first flush" All sites.	Treat the runoff generated from 1 inch of rain over the project site (i.e. the 90% annual non-exceedance storm). Treatment may be provided through settling (permanent pool or extended detention), filtration or infiltration, absorption, or chemical/mechanical treatment.
Channel Protection Surface water discharges; except Muskegon and Mona Lakes.	Retain onsite the increase between the pre-development (defined as meadow and/or woods) and post-development runoff volume and rate for all storms up to and including the 2-year, 24-hour rainfall event; OR where site conditions preclude infiltration, an alternative approach may be allowed after all other onsite retention options are exhausted: Extended Detention of runoff from the 2-year, 24-hour storm for a period of 24 hours with a drawdown time no greater than 72 hours.
Flood Control All sites; unless exception is allowed.	Collection and Conveyance: Design storm sewers and swales for the 10-year storm, and open channels for the 25-year storm. Detention: Store runoff from the 25-year storm with a maximum release rate of 0.13 cfs/acre. If retention of the total channel protection volume is provided, the maximum release rate may be increased to the pre-development 25-year peak runoff rate; OR Retention: Store and infiltrate runoff from the 25-year storm. Emergency Overflow Routes: Identify overland flow routes and the extent of high water levels for the 100-year flood to ensure no adverse impacts offsite or internal to the site. Where overland flow routes do not exist, detention/retention basins shall be shall be increased in size to store a total of 2 times the flood control volume. Adequate Outlet: The design maximum release rate, volume or concentration of storm water discharged from a site shall not exceed the capacity of the downstream storm water infrastructure or cause impairment to the offsite receiving area.
Pretreatment Refer to Table 4.	Forebay: Minimum volume equal to 15% of water quality volume (required for detention/retention basins). Vegetated Filter Strip: Minimum 5-foot width; maximum 2% grade; no more than 6 times filter strip width for upstream flow length. Vegetated Swale: Minimum 20-foot length; maximum 2% grade. Water Quality Device.
Hotspot Industrial and commercial land uses in Table 3; Part 201 and Part 213 sites.	Isolate transfer and storage areas to minimize need for treatment. Pretreatment BMP with impermeable barrier above groundwater and provisions for the capture of oil, grease, and sediments. Minimum spill containment volume: 400 gallons.
Coldwater Streams	Incorporate strategies to promote groundwater recharge and/or reduce temperature of surface discharge water.

II. DESIGN PROCESS

The storm water site design process is summarized in the steps below. This process is intended to minimize negative impacts from development sites that could be avoided through proper planning.

A. Identify Sensitive Areas

Identify existing environmentally sensitive areas on the site plan that may require special consideration or pose a challenge for storm water management. For the purpose of these rules, sensitive areas include:

- Waterbodies (lakes and ponds)
- Rivers and streams
- Floodplains (and flood prone areas)
- Riparian areas
- Wetlands
- Woodlands
- Sand dunes
- Natural drainage ways
- Soils and topography (erodible, steep)
- Susceptible groundwater supplies
- Threatened and endangered species habitat

Sensitive areas are determined on a site-specific basis through site survey, delineation, aerial photographs, or maps. Sensitive areas must be shown on the site map or on the drawings. The total acreage of protected areas must also be indicated. The Developer must demonstrate a good faith effort to maximize protection of sensitive areas.

B. Minimize Storm Water Runoff

Nonstructural BMPs are required to meet sensitive area protection requirements, and may be used to reduce the size of the collection and conveyance system and other storm water controls necessary for the site.

C. Determine Standards

Adequate storm water runoff controls are required to meet pollutant removal goals, reduce channel erosion, maintain groundwater recharge, and prevent overbank flooding. Minimum standards are given in ***Table 2***.

Manage storm water onsite by meeting all of the following standards:

- Water Quality
- Channel Protection
- Flood Control

Identify any additional standards required for the site. Additional standards are required for:

- Pretreatment
- Hot Spots (refer to ***Table 3***)
- Coldwater Streams
- Watershed Policy Statements

D. Confirm an Adequate Outlet

The design criteria specified in this manual is generally protective of the receiving waterbody. However, the Developer must always demonstrate an adequate outlet exists downstream of the development to receive the design rate, volume, and concentration of the post-development site runoff. Discharge from the site, including discharge from emergency overflow spillways and pipes, must not cause adverse impact to downstream properties or infrastructure (refer to Part 2 section "Storm water Discharge Requirements").

E. Select Best Management Practices (BMPs)

Select appropriate storm water BMPs to meet minimum required pollutant reduction, volume and peak rate requirements. A list of common BMPs their associated treatment ability is given in ***Table 4***. The BMP or combination of BMPs selected must be designed in accordance with the calculation methods and design criteria provided in Part 4 of this manual. BMPs proposed for use, but not included in this manual will be evaluated on an individual basis.

III. STANDARDS

A. Water Quality

Where Required. Treatment of the water quality volume is required for all sites to capture and treat the "first flush" of storm water runoff that typically carries with it the highest concentration of pollutants.

Note: A majority of these pollutants build up and wash off from the surface of roadways, driveways, and parking areas. Directly connected disturbed pervious surfaces (primarily lawns) can also contribute pollutant load (e.g. nutrients due to overuse of fertilizer; nutrients and bacteria due to overuse by wild/domestic animals).

Standard. Capture and treatment of the runoff from the 90% annual nonexceedance storm is required for the project site. This storm is approximately equivalent to 1 inch of rain (1.00 inch for Michigan Climatic Zone 8 per MDEQ memo *90 Percent Annual Nonexceedance Storms* dated March 24, 2006). Treatment of this volume with properly designed BMPs has been found to generally meet MDEQ pollutant load targets of:

- 80% decrease in total suspended solids (TSS); or
- discharge concentrations of TSS less than 80 mg/L.

Natural areas of the site left undisturbed and BMPs that provide water quality treatment need not be included in the calculations. This effectively results in the directly connected impervious areas and disturbed pervious areas of the site being used to calculate the water quality volume.

Treatment BMPs. Water quality volume can be provided through one of the following methods:

- Permanent Pool
- Extended Detention
- Filtration
- Infiltration
- Absorption
- Chemical/Mechanical Treatment

Permanent Pool: The volume of a permanent pool incorporated into a storm water BMP can be counted as water quality volume. This is the volume below the ordinary static water level (also known as dead storage).

Extended Detention: The storage volume provided by extended detention can be counted as water quality volume. Extended detention is defined as holding the storm water runoff volume and releasing it gradually over a period of 24 hours with a drawdown time no greater than 72 hours.

Filtration: The volume of storm water runoff routed through a BMP that provides filtration (i.e. an under drained BMP) can be counted as water quality volume. In the case of a vegetated filter strip or grassed swale, the filtering area must meet minimum standards.

Infiltration: The volume of storm water runoff infiltrated into the ground through a storm water BMP can be counted as water quality volume.

Absorption and Chemical/Mechanical Treatment: The volume of storm water runoff routed through a proprietary water quality device can be counted as water quality volume on sites where a maintenance agreement between the Developer and the local municipality is provided.

MS4.38 Selected BMPs must meet the 80% TSS reduction target either alone or in combination. Pollutant (TSS) removal efficiencies for BMPs are provided in ***Table 4***.

B. Channel Protection

Where Required. Channel protection is required for discharges to natural watercourses either directly or by a storm sewer or ditch. Channel protection is not required for Mona and Muskegon Lakes and Lake Michigan.

Standard. The post-development runoff rate and volume shall not exceed the pre-development rate and volume for all storms up to and including the 2-year, 24-hour storm. Onsite retention of the volume increase is required.

Note: The 2-year storm was selected since 95% or more of the annual average runoff volume will be controlled, including the bankfull event (typically between a 1- to 2-year frequency.) It is these smaller, more frequent events that have the greatest impact on the stability of headwater streams which are most susceptible to erosion.

Retention can be provided through infiltration, evapotranspiration, or reuse.

Pre-development is defined as meadow or woods (if woods presently exist) in good condition.

Note: Using this definition of pre-development in lieu of “the last land use prior to the planned new development or redevelopment” (i.e. existing conditions) as defined in the MS4 General Permit is necessary to protect sensitive streams and improve hydrologic conditions for channels that have already experienced degradation due to changes associated with development.

Alternative Approach. Where site constraints limit infiltration, an alternative approach may be allowed after all other onsite retention options are exhausted. A Storm water Worksheet signed by the Design Engineer must be submitted for approval before the alternative approach can be used.

Site constraints that limit the use of infiltration may include:

- Poorly draining soils (<0.24 inches per hour, typically hydrologic soil groups C and D).
- Bedrock.
- High Groundwater, or the potential of mounded groundwater to impair other uses.
- Wellhead protection areas.
- Brownfield sites and areas of soil or groundwater contamination.

The alternative approach shall consist of extended detention of the 2-year, 24-hour storm for a period of 24 hours with a maximum release rate no greater than the existing 2-year peak discharge, and a drawdown time no greater than 72 hours.

Note: An extended detention discharge no greater than the existing 2-year discharge will meet the MS4 general permit requirement of not exceeding the pre-development discharge rate for all storms up to and including the 2-year storm.

If the allowable opening size from an extended detention basin becomes too small for practical design, an underdrained bioretention BMP (e.g. bioretention/rain garden, planter box, water quality swale) may be used to protect the orifice.

Note: Various studies by universities and monitoring by municipalities have shown that underdrained biofiltration BMPs provide a significant percentage of volume reduction (25% or more) and a large percentage of rate reduction (80% or more), although performance may vary somewhat between types of BMPs, BMP design, and time of the year.[1,2,3]

C. Flood Control

Where Required. Flood control is required for all sites. Exceptions may be allowed for direct discharges to large lakes or rivers when the site is located in a designated non-mandated detention zone, and the Developer demonstrates that the receiving waters possess capacity to convey the increased flows safely and with no negative downstream impacts due to increased flow rates, water levels or velocities. In addition, the peak flow of the (larger) receiving waters cannot be increased by the proposed development.

Standard. Detention or retention of the 25-year storm with a maximum release rate of 0.13 cfs per acre is required.

Note: The 25-year storm is selected to balance flood risk management with economics based on federal studies comparing the cost of flood damage to storm return interval.[4] The release rate of 0.13 cfs per acre is selected to be generally protective of floodplains in downstream watercourses and is based on result found in previous hydrologic studies on West Michigan streams.[5] Where volume control is not provided, an extremely low release rate is required to prevent an increase in peak flow rates in downstream watercourses or storm sewers. The increased volume and prolonged duration of runoff from multiple detention basins can have a cumulative effect to increase peak flow rate and duration in downstream reaches.

When retention of the channel protection volume is provided, the maximum release rate may be increased to the pre-development 25-year peak rate. This approach is effective in maintaining peak flow rates and floodplain levels in downstream watercourses, since it better mimics the pre-development hydrology of a site and eliminates the large volume increases associated with increased flooding.

Emergency Overflow Routes. Emergency overflow flow routes and the extent of high water levels for the 100-year storm (extreme flood) shall be identified for all sites. Provisions shall be made to ensure no adverse impacts offsite or internal to the site.

Note: The intent of the extreme flood criteria is to prevent flood damage from large but infrequent storm events by identifying and/or designing overland flow paths that are clear of structures and have grades below the lowest openings of structures.

Overflow routes may include floodplains along open channels, overbank areas along vegetated swales, curb jumps in drives and parking lots, and other flow paths flood waters will take to reach an outlet, whether overland or underground.

Where acceptable overflow routes do not exist, detention/retention basins shall be increased in size to store a total of 2 times the flood control volume.

D. Pretreatment

Where Required. Pretreatment is required for detention basins, retention basins, infiltration practices, bioretention/rain gardens, constructed filters and water quality swales to preserve the longevity and function of the storm water BMP. Pretreatment may also be needed for other BMPs such as storm water reuse systems.

Treatment BMPs. Pretreatment provides for the removal of fine sediment, trash and debris. Methods of pretreatment include:

- Forebays (including spill containment cells and level spreaders)
- Vegetated filter strips (including buffers and green roofs)
- Vegetated swales (including natural flow paths)
- Water quality devices

Standard. A minimum pretreatment volume equivalent to 15% of the water quality volume is required for sediment forebays using gravity.

Note: This is a conservative approximation of results given by the Hazen Equation for sediment basin sizing using a 50% settling efficiency for a 50-micron particle (silt) and a 1-year peak inflow.

Vegetated filter strips and vegetated swales must meet minimum length, slope, and vegetated cover requirements to be accepted.

E. Hot Spots

Where Required. Sites considered to be storm water hot spots are identified in ***Table 3***. Industrial and commercial land use activities on these sites involve the production, transfer, and/or storage of hazardous materials in quantities that pose a high risk to surface and groundwater quality (those exceeding 55 gallons aggregate for liquids and 440 pounds aggregate for dry weights), as defined in Part 5 Rules: Spillage of Oil and Polluting Materials, under Water Resources Protection (Part 31, Act 451, PA 1994). Sites of soil or groundwater contamination under Part 201 Environmental Remediation and Part 213 Leaking Underground Storage Tanks (Act 451, PA 1994) are also included in ***Table 3***.

Standard. The spill containment volume is equivalent to the pretreatment volume with a minimum of 400 gallons required. The minimum volume provides a reasonable capture size (e.g. a standard liquid propane truck has a hauling capacity of 1,000 gallons) that can be accommodated with a 6-foot diameter water quality device.

Spill containment facilities must have an impermeable barrier between the treated material and the groundwater and have provisions for the capture of oil, grease, and sediments.

Treatment BMPs. Infiltration BMPs will be reviewed to meet performance standards in areas of soil or groundwater contamination to ensure a site design that does not exacerbate existing conditions. Specific storm water management strategies for areas of existing contamination and hotspots include the following:

- Isolate transfer and storage areas from permeable surfaces and reduce exposure to storm water.
- Identify opportunities for use of infiltration BMPs in other areas of the site.
- Where storage and transfer areas exposed to storm water cannot be avoided:
  - Infiltration of runoff from parking lots and road surfaces is discouraged in favor of a surface water discharge.
  - Porous pavements that infiltrate into the groundwater are not permitted because they do not allow for any pretreatment or spill containment.
  - Perforated pipes for infiltration are not permitted because of the difficulty in isolating an accidental spill.

Table 3 - Storm Water Hot Spots

2012 North American Industry Classification System (NAICS)	
31 - 33	Manufacturing
44 - 45	Retail Trade (441 Motor Vehicle and Parts Dealers, 444 Building Material and Garden Equipment and Supplies Dealers, 447 Gasoline Stations, 454 Non-store Retailers (e.g. fuel dealers))
48 - 49	Transportation and Warehousing
71	Arts, Entertainment, and Recreation (79393 Marinas)
81	Other Services (8111 Automotive Repair and Maintenance, 8113 Commercial and Industrial Machinery and Equipment Repair and Maintenance, 8123 Dry Cleaning and Laundry Services, 8129 Other Personal Services (e.g. photofinishing laboratory))
	Salvage Yards and Recycling Facilities
	Sites classified under Part 201 Environmental Remediation and Part 213 Leaking Underground Storage Tanks (Act 451, PA 1994) of the Michigan compiled laws.
	Areas with the potential for contaminating public water supply intakes and other land uses and activities where there is a high probability for an accidental spill of petroleum products, chemicals, or other polluting materials due to quantity of use, storage or waste products generated as determined by the Drain Commissioner (e.g. floor drains)
Many of these sites will also be regulated under the EPA NPDES Industrial Storm water Program. A detailed list of NAICS industries can be found at: http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012	

F. Coldwater Streams

Where Required. Coldwater streams require an adequate and stable base flow to maintain their designation and support a cold-water fishery. In Muskegon County, Cedar Creek, a tributary of the Muskegon River, is a coldwater stream. See also maps provided on the Michigan Department of Natural Resources (MDNR) website:

http://www.michigan.gov/dnr/0,4570,7-153-10364_63235-211883--,00.html

Treatment BMPs. Development practices that increase surface water temperature or eliminate groundwater recharge should be avoided. The following strategies apply to developments located within a watershed of a designated trout stream that also propose a surface water discharge to the coldwater stream. Strategies must be identified on the site plan and/or submittal package.

- Protect riparian buffers.
- Storm water disconnection.
- Incorporate heat-reducing BMPs such as green roofs and re-forestation.
- Implement structural BMPs that control volume through infiltration.
- If detention ponds are used, detention times must be limited to a maximum of 12 hours.
- Wet ponds should draw water from near the pond bottom to maintain a cooler discharge water temperature.

G. Watershed Policy Statements

Specific storm water policies have been adopted by the Drain Commissioner for Cedar Creek and Ruddiman Creek Watersheds. These policy recommendations have resulted from hydrologic and hydraulic analysis and/or monitoring performed during engineering studies. The policy statements identify specific storm water management standards and the areas where these standards must be used to meet resource protection goals. If the site is located within one of the identified watersheds, the storm water management plan for the site must also comply with the policy statements included in ***Appendix 1***.

[1] Carpenter, Donald D. and Hallam, Laura (2009). *Influence of Planting Soil Mix Characteristics on Bioretention Cell Design and Performance,* Lawrence Technological University.

[2] University of New Hampshire Storm water Center (2007). *2007Annual Report*.

[3] City of Portland, Oregon, Environmental Services (December 2010). *2010 Storm water Management Facility Monitoring Report Summary.*

[4] Johnson, William K. *Significance of Location in Computing Flood Damage.* ASCE Journal of Water Resource Planning and Managmeent. January 1985.

[5] Camp, Dresser and McKee, Inc. (1991). *Buck and Plaster Creek Storm water Management Masterplan, prepared for the Kent County Drain Commissioner*.

[6] Fraley-McNeal, L. (September 2007). *National Pollutant Removal Performance Database, Version 3*, Center for Watershed Protection.

[7] Rowe, Amy A., Borst, Michael, and O'Connor, Thomas P. (2007). *Pervious Pavement System Evaluation*, United States Environmental Protection Agency, Office of Research and Development.

[8] State of Maryland, Department of Environment (October 2000, Revised May 2009).*Maryland Storm water Design Manual*.

Table 4 - Storm Water BMP Matrix

Storm water BMP	Treatment			
	Requires Pretreatment	Provides Water Quality	Provides Pretreatment	Provides Spill Containment
Non-Structural BMPs				
Minimize Soil Compaction				
Protect Natural Flow Paths			X	
Protect Sensitive Areas				
Native Revegetation			X	
Storm water Disconnection				
Structural BMPs - Conveyance and Storage				
Storm Sewer				X
Culvert or Bridge				
Open Channel				
Detention Basin (dry)	Yes	X (71)		
Detention Basin (wet)	Yes	X (88)		
Detention Basin (wetland)	Yes	X (86)		
Retention Basins	Yes	X (96)		
Structural BMPs - LID and Small Site				
Infiltration Practices	Yes	X (96)		
Bioretention/Rain Garden	Yes	X (80)		
Constructed Filter	Yes	X (92)		X
Planter Box		X (74)		
Pervious Pavement		X [50]		
Pervious Pavement (lined)		X [84]		
Capture Reuse		X (*)		X
Vegetated Roof		X (*)	X	
Water Quality Device		X (*)	X	X
Sediment Forebay		X (88)	X	
Spill Containment Cell		X (88)	X	X
Water Quality Swale	Yes	X (87)	X	X
Vegetated Swale		X (87)	X	
Vegetated Filter Strip		X (87)	X	
Level Spreader			X	

Yes = This BMP requires pre-treatment of storm water prior to entering BMP.
X = This BMP may be used to meet treatment criteria.
Blank Cell = This BMP does not provide treatment.
( ) = 75 Percentile TSS Removal Efficiency in percent.[6]
(*) = Submit manufacturer's certified test results.
[ ] = Average TSS Removal Efficiency in percent.[7]

Notes: Design criteria in Part 4 of this manual is provided to meet the 75 percentile TSS removal efficiency. Bioretention results in database appear biased by under-sized or poorly designed facilities; 80% removal can be achieved with current design criteria.[8]

PART 4: STORM WATER DESIGN CRITERIA

I. SOILS INVESTIGATION

A. Qualifications

Soils investigation by a qualified geotechnical consultant is required for retention and detention basins, infiltration practices, bioretention/rain gardens, constructed filters, planter boxes, and pervious pavement to determine the site soil infiltration characteristics and groundwater level. The geotechnical consultant shall be a professional engineer, soil scientist, or professional geologist.

B. Background Evaluation

An initial feasibility investigation shall be conducted to screen proposed BMP sites. The investigation involves review of the following resources:

- County Soil Survey prepared by the NRCS and USDA Hydrologic Soil Group (HSG) classifications.
- Existing soil borings, wells, or geotechnical report on the site.
- Onsite septic percolation testing.
- Cyclical groundwater levels (http://waterdata.usgs.gov/mi/nwis/gw.)

C. Test Pit/Soil Boring Requirements

A test pit (excavated hole) or soil boring shall be used for geotechnical investigation. Test pits may typically be selected for shallower investigations in locations where groundwater is sufficiently low. The minimum number of test pits or soil borings shall be determined from ***Table 5***:

Table 5 - Minimum Number of Soil Tests Required

Type of BMP	Test Pit/Soil Boring	Depth of Test Pit/ Soil Boring	Field Permeability Test
Retention basin Infiltration bed Rain garden Pervious pavement	1 soil boring per 5,000 square feet of bottom area; 2 minimum	10 feet below proposed bottom	1 test per soil boring
Infiltration trench Bioswale	1 soil boring per 100 linear feet of BMP; 2 minimum	10 feet below proposed bottom	1 test per soil boring
Dry well Planter box	1 soil boring minimum	5 feet below proposed bottom	1 test per soil boring
Detention basin	1 soil boring per 10,000 square feet of bottom area; 1 minimum	5 feet below proposed bottom	Not Applicable

Excavate a test pit or soil boring in the location of the proposed BMP.

At each test pit or soil boring, the following conditions shall be noted and described, referenced from a top-of-ground elevation:

- Depth to groundwater. The groundwater elevation shall be recorded during initial digging or drilling, and again upon completion of drilling.

- Depth to bedrock or hardpan.
- Depth and thickness of each soil horizon including the presence of mottling.
- USDA soil texture classification for all soil horizons.

Test pit reports and soil boring logs shall include the date(s) data was collected and the location referenced to a site plan.

D. Highest Known Groundwater Elevation

The highest known groundwater elevation shall be determined by adjusting the measured groundwater elevation using indicators such as soil mottling and regional water level data. It should also take into consideration local conditions that may be temporarily altering water levels at the time of measurement. Such conditions could include, but not be limited to: dewatering, irrigation well or large quantity withdrawals in the area, or areas of groundwater infiltration (such as a nearby retention basin).

E. Field Permeability Testing

Field permeability testing is not required, but may be performed to determine if a design infiltration rate higher than indicated in ***Table 6*** may be used. The Drain Commissioner reserves the right to request field permeability testing be performed on questionable sites. Acceptable field tests include:

- Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers (ASTM D3385).

The minimum number of field permeability tests shall be determined from ***Table 6.***

Tests shall be conducted in the location of the proposed BMP at the proposed bottom elevation. The Drain Commissioner may allow an alternate testing depth if material is identical and groundwater is not an issue.

Tests shall not be conducted in the rain or within 24 hours of significant rainfall events (>0.5 inch) or when the ground is frozen.

Field permeability testing reports shall include the date(s) data was collected and the location referenced to a site plan.

F. Design Infiltration Rates

A conservative value for the infiltration rate is used to calculate the storage volume of infiltration BMPs due to the uncertanty the soil will infiltrate at the design rate during the time the basin is filling.

The infiltration rate determined from field permeability testing shall be divided by a factor of 2 to calculate the design infiltration rate, up to a maximum design infiltration rate of 10 inches per hour.

Where field permeability testing is not performed, the design infiltration rates provided in ***Table 6*** shall be used to calculate the storage volume and minimum infiltration area of the BMP necessary to drain in the allotted drawdown time.

The least permeable soil horizon within 4 feet below the proposed BMP bottom elevation shall be used to select the design infiltration rate.

Table 6 provides design values of the infiltration rate and effective water capacity (void ratio) for soils based on their textural classification. The soil textural classes shown in ***Table 6*** correspond to the soil textures of the USDA Soil Textural Triangle included as ***Figure 1***.

Note: *Infiltration* is the process by which water on the ground surface enters the soil. *Infiltration rate* is a measure of the rate at which soil is able to absorb rainfall or irrigation in inches per hour. The rate decreases as the soil becomes saturated. The design infiltration rate assumes saturated conditions and closely approximates the *hydraulic conductivity* (typically given in feet per day) of the near-surface soil.

Note: The *effective water capacity* of a soil is the fraction of the void spaces available for water storage measured in inches per inch.

Table 6 - Design Infiltration Rates by USDA Soil Texture Class

Soil Texture Class	Effective Water Capacity[1] (inches per inch)	Design Infiltration Rate[2] (inches per hour)	HSG[1]
Gravel	0.40	3.60	A
Sand	0.35	3.60	A
Loamy Sand	0.31	1.63	A
Sandy Loam	0.25	0.50	A
(Medium) Loam	0.19	0.24	B
Silty Loam / (Silt)	0.17	0.13	B
Sandy Clay Loam	0.14	0.11	C
Clay Loam	0.14	0.03	D
Silty Clay Loam	0.11	0.04	D
Sandy Clay	0.09	0.04	D
Silty Clay	0.09	0.07	D
Clay	0.08	0.07	D

[1]Source: Maryland Department of Environment (2000). *Maryland Storm Water Design Manual*, Appendix D.13, Table D.13.1 (Rawls, Brakensiek and Saxton, 1982).

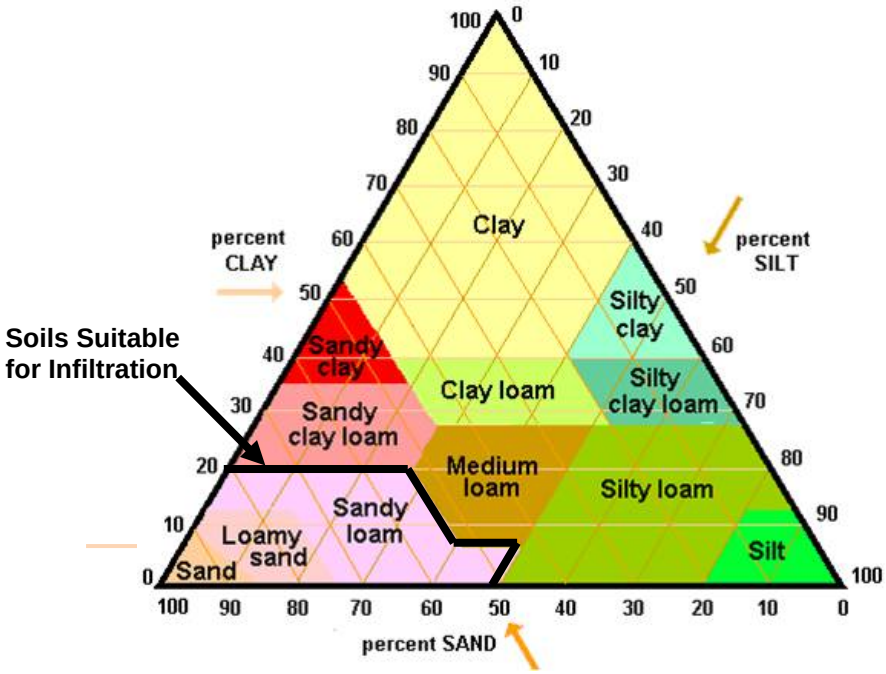
[2]Source: Wisconsin Department of Natural Resources (2004). *Site Evaluation for Storm Water Infiltration (1002),* Table 2 (Rawls, 1998). Note: Values are reduced by approximately a factor of 2 from those given in Table D.13.1.

G. Minimum Allowable Infiltration Rate

Soil textures with design infiltration rates less than 0.50 inches per hour are deemed not suitable for infiltration BMPs.

Soils with design infiltration rates as low as 0.24 inches per hour (Medium Loam) may be used for LID and Small Site BMPs if suitable supplemental measures are included in the design. Supplemental measures may include subsoil amendment, or underdrain placed at the top of the storage bed layer.

Figure 1 - USDA Soil Textural Triangle



****see also page 4-16 regarding a storm water calculator****

II. CALCULATION METHODOLOGY

The Rational Method and the NRCS Runoff Curve Number Method are typically used to calculate storm water runoff, peak discharges and runoff volumes for design of storm water conveyance and storage systems. The NRCS method is presently the only acceptable method to calculate the channel protection volume. The Small Storm Hydrology Method is used to calculate runoff volumes from the smaller rainfall amounts used for water quality treatment.

A. Calculating Runoff

1. **The Rational Method** may be used to calculate storm water runoff volumes and peak discharges to size conveyance and storage systems for contributing drainage areas of 40 acres or less. The peak runoff rate is given by the equation:

$$Q = CIA \qquad (4.1)$$

where:
Q = peak runoff rate (cubic feet per second).
C = weighted runoff coefficient of the drainage area.
I = average rainfall intensity for a storm with a duration equal to the time-of-concentration of the drainage area (inches per hour). Use rainfall amounts from ***Table 11*** and divide by the duration in hours to obtain the average rainfall intensity (I).
A = drainage area (acres).

Runoff coefficients sizing conveyance systems shall be selected from ***Table 7***.

Table 7 - Rational Method Runoff Coefficients (5- to 10-year rainfall frequencies)

Character of Surface	Runoff Coefficients
Asphalt and Concrete Pavement	0.70 to 0.95
Brick Pavement and Gravel Surface	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil Flat 2%	0.05 to 0.10
Lawns, Sandy Soil Average 2% to 7%	0.10 to 0.15
Lawns, Sandy Soil Steep 7%	0.15 to 0.20
Lawns, Heavy Soil Flat 2%	0.13 to 0.17
Lawns, Heavy Soil Average 2% to 7%	0.18 to 0.22
Lawns, Heavy Soil Steep 7%	0.25 to 0.35
Source: American Society of Civil Engineers and the Water Pollution Control Federation (1969). *Design and Construction of Sanitary and Storm Sewers*. Note: Gravel Surface added.	

Runoff coefficient for sizing detention/retention basins, which are designed for higher rainfall frequencies, shall be selected from ***Table 12***.

Time-of-concentration for the Rational Method is the sum of overland flow and channel flow. A minimum of 15 minutes shall be used.

Overland flow time may be calculated using the following formula:

$$t_o = \left(\frac{2Ln}{3\sqrt{s}} \right)^{0.4673} \quad (4.2)$$

where:
t_o= time of overland flow (minutes).
L = length (feet); the distance from the extremity of the subcatchment area in a direction parallel to the slope until a defined channel is reached. Overland flow will become channel flow within 1,200 feet in almost all cases.*
n = surface retardants coefficient (from ***Table 8***).
s =slope (feet per foot); the difference in elevation between the extremity of the subcatchment area and the point in question divided by the horizontal distance.

Table 8 – Surface Retardants Coefficients

Type of Surface	Coefficient (n value)
Smooth impervious surface	0.02
Smooth bare packed soil	0.10
Poor grass, cultivated row crops, or moderately rough bare surface	0.20
Pasture or average grass	0.40
Deciduous timberland	0.60
Conifer timberland, deciduous timberland with deep forest litter, or dense grass	0.80
Source: Formula, coefficients and empirical observations from W.S. Kerby, J.M. Asce. Servis, Van Doren & Hazard Engineers, Topeka, Kansas. "Time of Concentration for Overland Flow" as included in ENGINEER'S NOTEBOOK.	

Channel flow shall be calculated using Manning's equation:

$$V = \frac{An}{1.49R^{\frac{2}{3}}S^{\frac{1}{2}}} \quad (4.3)$$

where:
V = velocity (feet per second).
A = wetted area (square feet).
n = Manning's roughness coefficient (from ***Table 13***).
R = hydraulic radius (feet).
S = slope (feet per foot).

The time-of-concentration is then:

$$Tc = t_o + \frac{L_c}{60V} \quad (4.4)$$

where:
Tc = time-of-concentration (minutes).
t_o = time of overland flow (minutes).
L_c = length of channelized flow (feet).
V = velocity of channelized flow (feet per second).
60 = factor to convert seconds to minutes.

2. The Runoff Curve Number Method developed by the NRCS may be used to calculate storm water runoff volumes and peak discharges to size conveyance and storage systems. This method must be used when it is necessary to calculate runoff volumes for channel protection. The formulas are as follows:

$$Q_v = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (4.5)$$

where:
Q_V = surface runoff (inches). Note: Qv=0 if P ≤ 0.2S
P = rainfall (inches).
S = potential maximum retention after runoff begins (inches).

and where:

$$S = \frac{1000}{CN} - 10 \quad (4.6)$$

Surface runoff (Qv) is calculated separately for impervious and pervious areas. Total runoff volume can then be calculated by the formula:

$$Vt = (Qv_{perv}A_{perv} + Qv_{imp}A_{imp}) \times 3630 \quad (4.7)$$

where:
V_t = runoff volume of the design storm (cubic feet).
Qv= surface runoff (inches); separate for pervious and impervious surface.
A = contributing site area (acres).
3630 = factor to convert acre-inches to cubic feet.

Curve Number (CN) values are taken from Technical Release No. 55 (TR-55), and provided in ***Table 9***.

The Michigan Modified Unit Hydrograph formula shall be used with the Runoff Curve Number Method to generate peak storm water runoff rates.

Note: This formula was developed by the MDEQ for use with Bulletin 71rainfall data, and uses an SCS Type II rainfall distribution. Updates to the formula to account for the changes in Atlas 14 are anticipated. The formula shall be used in its present form in the interim:

$$Qp = 238.6(A)(Qv)(Tc^{-0.82}) \quad (4.8)$$

where:

Qp = peak runoff rate (cubic feet per second).
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors.
A = drainage area (square miles).
Qv = surface runoff (inches) calculated separately for pervious and impervious surfaces and then summed.
Tc = time-of-concentration (hours).

Note: Times-of-concentration less than 1 hour will tend to overestimate peak runoff rate with this method.

Table 9 - Curve Numbers (CNs) from TR-55

Land Use Description		Curve Number[1]			
Cover Type	Condition[2]	Hydrologic Soil Group			
		A	B	C	D
Cultivated land	Poor	72	81	88	91
	Good	62	71	78	81
Pasture or range land	Poor	68	79	86	89
	Fair*	49	69	79	84
	Good	39	61	74	80
Meadow	Good	30	58	71	78
Orchard or tree farm (50% woods /50% pasture)	Poor*	57	73	82	86
	Fair*	43	65	76	82
	Good*	32	58	72	79
Woods	Poor	45	66	77	83
	Fair*	36	60	73	79
	Good	30*	55	70	77
Open spaces (grass cover)	Poor*	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Paved parking lot, roof, driveway		98	98	98	98
Gravel		76	85	89	91
Dirt		72	82	87	89

Source: U.S. Department of Agriculture Soil Conservation Service (1986). *Urban Hydrology for Small Watersheds*, *Technical Release No. 55*.

[1]Antecedent moisture condition II and $I_a = 0.2S$

[2]Good Condition: cultivated land with conservation treatment; pasture, meadow or open space with 75% or more grass cover; woods with good cover of trees protected from grazing with litter and brush over soil
Fair Condition: pasture or open space with 50% to 75% grass cover; woods are grazed with some litter over soil
Poor Condition: cultivated land without conservation treatment; pasture or open space with less than 50% grass cover; woods with litter and brush destroyed by heavy grazing or burning

* SEMCOG (2008). *Low Impact Development Manual for Michigan.*

Time-of-concentration for the Runoff Curve Number Method shall be calculated using NRCS TR-55 methodology as outlined below. A minimum of 0.1 hour (6 minutes) shall be used.

The flow path is split into three sections - sheet flow, shallow concentrated flow, and open channel flow. The travel time is computed for each flow regime. The time-of-concentration is then the sum of the travel times:

$$Tc = t_1 + t_2 + t_3 \tag{4.9}$$

(1) For sheet flow the travel time (t_1) in hours is given as:

$$t_1 = \frac{0.007(nL)^{0.8}}{P_2^{0.5} s^{0.4}} \tag{4.10}$$

where *n* is Manning's roughness coefficient from ***Table 13***, *L* is the flow length (feet), P_2 is the 2-year, 24-hourprecipitation depth from ***Table 11***, and *s* is the slope (feet/foot).

(2) Shallow concentrated flow velocities are calculated for paved and unpaved surfaces. The velocities are given as:

$$v = \begin{matrix} 16.1345 s^{0.5} & Unpaved \\ 20.3282 s^{0.5} & Paved \end{matrix} \tag{4.11}$$

where *s* is the slope (feet/foot) and *v* is the velocity in feet per second.

The flow length (feet) is then divided by the velocity (feet per second) and a conversion factor of 3600 to obtain travel time (t_2) in hours:

$$t_2 = \frac{L}{3600v} \tag{4.12}$$

(3) Open channel flow uses Manning's equation to calculate the velocity based on slope, flow area, and wetted perimeter (refer to Equation 4.3). The flow length (feet) is then divided by the velocity (feet per second) to obtain travel time (t_3) in hours (refer to Equation 4.12).

BMP residence time shall be calculated as the storage volume divided by the 10-year peak flow rate.

3. The Small Storm Hydrology Method is used to calculate the water quality treatment volume. The method was developed to estimate the runoff volume from urban land uses for relatively small storm events where the Rational and NRCS Methods prove less accurate. Water quality volume is calculated by the formula:

$$Vwq = ARv(1)(3630) \tag{4.13}$$

where:
V_{wq} = minimum required water quality volume (cubic feet).
A = area (acres); the developed portion of the site, both impervious and pervious, not receiving treatment with a non-structural BMP.
R_v = area-weighted volumetric runoff coefficient (from ***Table 10***).
1 = 90% non-exceedance storm rainfall amount (inches).
3630 = factor to convert acre-inches to cubic feet.

The Volumetric Runoff Coefficients (Rv) provided in ***Table 10*** are similar to the Rational runoff coefficient, but are exclusive to the rainfall amount (1-inch).

Table 10 - Runoff Coefficients for Small Storm Hydrology Method

Rainfall Amount (inches)	Volumetric Runoff Coefficient, R_v					
	Directly Connected Impervious Area			Disturbed Pervious Area		
	Flat Roofs /Unpaved	Pitched Roofs	Paved	Sandy Soils (HSG A)	Silty Soils (HSG B)	Clayey Soils (HSG C&D)
1.0	**0.815**	**0.965**	**0.980**	**0.035**	**0.120**	**0.205**

Source: Adapted from SEMCOG (2008). *Low Impact Development Manual for Michigan,* Table 9.3. (R. Pitt (2003). *The Source Loading and Management Model (WinSLAMM): Introduction and Basic Uses*).

B. Rainfall

The rainfall duration-frequency table provided in ***Table 11*** shall be used with the Rational Method to determine rainfall intensity for rainfall duration equal to the time-of-concentration.

The 24-hour rainfall amounts provided in ***Table 11*** shall be used with the Runoff Curve Number Method.

An MSE4 rainfall distribution shall be used when a unit hydrograph approach is used (e.g. WinTR-20 computer program).

Table 11 - Rainfall Amounts (inches)

Duration	1-year	2-year	5-year	10-year	25-year	50-year	100-year
24-hr	2.26	2.59	3.25	3.91	4.98	5.93	7.00
12-hr	1.92	2.21	2.79	3.37	4.30	5.14	6.07
6-hr	1.60	1.87	2.37	2.86	3.65	4.34	5.10
3-hr	1.33	1.56	1.99	2.39	3.03	3.57	4.17
2-hr	1.18	1.39	1.78	2.13	2.68	3.15	3.66
1-hr	0.96	1.14	1.45	1.74	2.18	2.55	2.94
30-min	0.75	0.89	1.13	1.35	1.67	1.94	2.22
15-min	0.55	0.65	0.82	0.98	1.21	1.40	1.60
10-min	0.45	0.53	0.67	0.80	0.99	1.15	1.31
5-min	0.31	0.36	0.46	0.55	0.68	0.78	0.90

Source: NOAA (2013). *Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0*. Station Name: MUSKEGON CO AP. Station ID 20-5712.

C. Calculating Storage Volumes and Release Rates

1. Water Quality

Treatment of the runoff generated from 1 inch of rain (the 90% annual nonexceedance storm) over the developed portion of the site is required. Water quality volume is calculated using the Small Storm Hydrology Method.

Treatment can be provided by settling (permanent pool or extended detention), filtration or infiltration, absorption, or chemical/mechanical treatment using BMPs from ***Table 4*** to meet the 80% TSS removal efficiency standard.

If a vegetated filter strip or vegetated swale is used, the filtering area must meet minimum standards for slope, length, and vegetative cover for a maximum allowable drainage area to filter strip ratio of 6:1.

2. Pretreatment

a. Sediment forebay:

$$Vpt = 0.15(Vwq) \tag{4.14}$$

where:
V_{pt} = minimum required pretreatment volume (cubic feet).
V_{wq} = water quality volume (cubic feet).

b. Vegetated filter strip: Provide a 5-foot minimum sheet-flow length at a maximum slope of 2% with an upstream impervious length no greater than 6 times the filter strip length.

c. Vegetated swale: Provide a 20-foot minimum length at a maximum slope of 2% with a 1-foot high check dam at the downstream end. No more than 0.33-acre upstream drainage area per 2-foot of bottom width.

d. Water quality device: Configured to trap floatables and sediment. Follow manufacturer's guidelines.

Pretreatment volume may be included in the total water quality volume. However, the pretreatment volume may need to be provided in a separate BMP to protect the integrity of the BMP providing treatment.

3. Channel Protection

a. Retention

Channel protection consists of retaining onsite the net increase in runoff volume between pre-development and post-development conditions for a 2-year, 24-hour storm using the Runoff Curve Number Method. Channel protection volume is calculated with the following equation:

$$Vcp = Vt_{post} - Vt_{pre} \quad (4.15)$$

where:
Vcp = minimum required channel protection volume (cubic feet).
Vt_{post}= runoff volume of the 2-year, 24 hour storm for post-development conditions.
Vt_{pre}= runoff volume of the 2-year, 24-hour storm for pre-development conditions.

Pre-developed (baseline) conditions for calculating channel protection volume shall consist of a "Meadow" cover type for all existing land covers other than woods and impervious surfaces. For existing woods, use the "Woods" cover type in "good" hydrologic condition. For existing impervious surfaces, use the "Open Spaces" cover type in "fair" hydrologic condition.

The "Open Spaces" cover type in "fair" hydrologic condition shall be used for post-development pervious areas that are <u>not</u> receiving non-structural BMP credits.

b. Extended Detention

If retention of the total channel protection volume is not possible due to site constraints, an alternative approach using extended detention may be allowed. The storage volume of an extended detention basin shall be sized for that part of the 2-year volume difference not met by retention, with a maximum release rate that results in a 24-hour detention time. The peak discharge for a 24-hour detention time may be calculated assuming triangular inflow and outflow hydrographs with a lag between the peaks of 24 hours. If the inflow peak occurs 12 hours into the 24 hour inflow hydrograph, then the outflow peak should occur 36 hours into a 72 hour outflow hydrograph. The extended detention peak discharge can then be computed with the following equation:

$$Qp_{ED} = (Vcp - Vret)/(36 * 3600) \quad (4.16)$$

where:
Qp_{ED} = peak extended detention release rate (cubic feet per second).
Vcp = total channel protection volume required (cubic feet).
Vret = channel protection volume met by retention (cubic feet).
*36*3600* = half of the base time of outflow hydrograph (seconds).

The 2-year peak discharge after extended detention (Qp_{ED}) must be equal to or less than the existing 2-year peak discharge. (Exceptions may be made for HSG A, where extended detention has been approved due to site constraints, but existing runoff is zero.) Reduce the required treatment volume and recalculate until this requirement is met. Simply selecting the lower existing release rate will violate the 72-hour drawdown time.

4. Flood Control

a. Detention

Detention of the 25-year rainfall event with a maximum allowable release rate of 0.13 cfs per acre is required.

If the volume of runoff released from the developed site is less than or equal to the volume of runoff from the existing site for the 25-year design storm, a maximum release rate no greater than the pre-development 25-year peak runoff rate may be used.

(1) Rational Method

If the Rational Method is used, the minimum required storage volume shall be calculated by the "Modified Chicago" Method. A Microsoft Excel spreadsheet application (Rational Method spreadsheet) is provided on the Drain Commissioner's website.

Runoff Coefficients for use in detention storage calculations shall be selected from ***Table 12*** to account for rainfalls exceeding a 10-year frequency. Frequency adjustment of factors of 1.1 and 1.25 have been applied for the 25- and 100-year frequencies respectively, with a maximum value of 1.00.

Table 12- Rational Method Runoff Coefficients (10- to 100-year rainfall frequencies)

Character of Surface	Runoff Coefficients		
	10-year	25-year	100-year
Asphalt and Concrete Pavement	0.95	1.00	1.00
Gravel Surface	0.75	0.82	0.94
Roofs	0.95	1.00	1.00
Lawns and Open (HSG A)	0.10	0.11	0.12
Lawns and Open (HSG B)	0.32	0.35	0.40
Lawns and Open (HSG C)	0.48	0.53	0.60
Lawns and Open (HSG D)	0.57	0.63	0.71
Sources: 10-year frequency runoff coefficients from Table 6 with coefficients for "Lawns and Open" calculated to match runoff volumes from CN method for "Open Spaces, Fair Condition" by HSG. Adjustment factors from Mays (2001). *Storm Water Collection Systems Design Handbook.*			

An additional adjustment factor of 1.25 shall be applied to the calculated storage volume since this method tends to underestimate the storage volume when compared to pond routing, particularly for short times-of-concentrations (15 to 30 minutes)[1].

(2) Runoff Curve Number Method

If the Runoff Curve Number Method is used, the minimum required storage volume shall be determined through routing, or may be calculated by the formula:

$$V_{fc} = \frac{(Qp - Qout)}{Qp} Vt - Vbmp \quad (4.17)$$

where:
V_{fc} = minimum required storage volume for flood control (cubic feet).
Q_p = peak runoff rate (cubic feet per second).
Q_{out} = maximum allowable peak discharge (cubic feet per second).
V_t = post-development runoff volume for the 25-year, 24-hour storm (cubic feet).
V_{bmp} = total volume (storage + infiltration) provided by BMPs used to meet water quality and/or channel protection volume standards.

Note: This formula provides a conservative approximation of the required storage volume. Therefore, the volume of any upstream BMPs can be subtracted from the storage volume versus the total runoff volume.

Retention

Retention basins and other infiltration practices shall be sized for the 25-year, 24-hour rainfall event.

(1) Rational Method

If the Rational Method is used, the minimum required storage volume shall be calculated by the formula:

$$V_{fc} = 0.85(3630CAP - Vbmp) \quad (4.18)$$

where:
V_{fc}= minimum required storage volume for flood control (cubic feet).
0.85 = ratio of storage volume to total runoff volume.
C = runoff coefficient for post-development conditions from ***Table 12***.
A = area (acres).
P = 25-year, 24-hour rainfall amount from ***Table 11*** (4.98 inches).
3630 = factor to convert acre-inches to cubic feet.
V_{bmp} = total volume (storage + infiltration) provided by BMPs used to meet water quality and/or channel protection volume standards.

Note: This simplified formula approximates the storage volume that results from inflow-outflow calculations for multiple spreadsheet runs with varying percent impervious and times-of-concentration, assuming a conservative infiltration rate of 0.5 inches per hour and adjusting the basin bottom area to achieve a 72-hour drain time. A conservative value for infiltration is used regardless of soil type based on the observation that retention basins fail most often due to the infiltration capacity of the *insitu* soil being compromised by sedimentation (even with properly sized sediment forebays) and/or overcompaction.

(2) Runoff Curve Number Method

If the Runoff Curve Number Method is used, the minimum required storage volume shall be calculated by the formula:

$$V_{fc} = 0.85(Vt - Vbmp) \quad (4.19)$$

where:
V_{fc} = minimum required storage volume for flood control (cubic feet).
V_t = runoff volume of the 25-year, 24-hour storm for post-development (cubic feet).
V_{bmp} = total volume (storage + infiltration) provided by BMPs used to meet water quality and/or channel protection volume standards.

(3) SEMCOG Method

This method may be used for LID and small site BMPs that provide infiltration.

Subtract the volume infiltrated by the BMP during the infiltration period (Vi) from the total runoff volume (Vt) to determine the required storage volume of the BMP (Vs).

$$Vs = Vt - Vi \quad (4.20)$$

The infiltration volume is calculated as:

$$Vi = \frac{6iA}{12} \quad (4.21)$$

where:
Vi = volume infiltrated (cubic feet).
6 = infiltration period (hours); time when the bed is receiving runoff and is capable of infiltrating at the design rate, conservatively estimated as 6 hours (SEMCOG, 2008).
i = design infiltration rate of underlying soil from ***Table 6*** (inches per hour).
A = infiltration area (square feet).
12 = factor to convert inches to feet.

Note: This method is more conservative than the above methods for infiltration rates between 0.5 and 2 inches per hour. However, it allows for practical sizing of small site BMPs in highly permeable soils (sands and gravels) based on the observation that the BMPs in this category are typically more effective at protecting the infiltration capacity of *insitu* soils (versus a retention basin), due to the use of stone and filter fabric in the design.

[1]Stahre, Peter and Urbonas, Ben (1990). *Storm water Detention For Drainage, Water Quality and CSO Management*, pp. 268-274.

County Storm Water Calculator.

The Storm water Calculator is a Microsoft Excel spreadsheet application that uses the Runoff Curve Number Method with a Michigan Unit Hydrograph and the Modified Puls Method for reservoir routing (see MDOT Drainage Manual, Section 8.4.8). Time-of-concentration formulas from NRCS TR-55 are also incorporated into the spreadsheet to calculate peak discharges.

Atlas 14 rainfall amounts are used with an MSE4 rainfall distribution.

The County Storm Water Calculator can be used to calculate required water quality and channel protection volumes, and detention release rates and storage volumes for a single discharge point from the site. A site with multiple discharge points requires one spreadsheet for each outlet.

The spreadsheet allows the user to select non-structural and structural BMPs to meet required runoff rates and volumes and accounts for protected areas on the site.

Output is graphed as hydrographs and summarized in tabular form for a range of rainfall frequencies. A copy is available on line.

Speed up the Review Process.

Design calculations submitted using the County Storm Water Calculator will help to expedite the review process because reviewing engineers are familiar with the spreadsheet and can more quickly check that sizing requirements are being met.

III. NON-STRUCTURAL BEST MANAGEMENT PRACTICES

Non-structural BMPs consist of protection measures that reduce the volume of storm water runoff from the site. This differs from the goal of many structural BMPs which is to help mitigate the impact of storm water runoff.

The Drain Commissioner has adopted standards for the following non-structural BMPs:

A. Minimize Soil Compaction and Total Disturbed Area

B. Protect Natural Flow Pathways (including Riparian Buffers)

C. Protect Sensitive Areas

D. Native Revegetation

E. Storm Water Disconnection

Further information and examples are provided in the BMP Fact Sheets in Chapter 6 of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008), which is provided on the Drain Commissioner's website.

All of the following criteria must be met to receive credit for each non-structural BMP selected for use.

A. Minimize Soil Compaction and Total Disturbed Area

1. Summary

Pretreatment Required:	No.
Maintenance Plan:	Yes, for trees receiving a credit.
Calculation Credits:	
Volume Reduction:	Assign a CN reflecting open space in "good" condition, or woods in "good" condition, instead of open space in "fair" condition as required for disturbed pervious areas. For small sites, individual trees can receive a credit of 800 square feet per tree, counted as woods in "good" condition.[1]
Rate Reduction:	By virtue of lower CN.
Water Quality:	Exempt from water quality criteria.

[1]Source: *Low Impact Development Manual for Michigan* (SEMCOG, 2008).

Note: Trees in minimal disturbance areas receive a larger area credit than trees planted under "Native Revegetation" due to the assumption that the existing trees will typically be larger and more mature than planted trees at the time of site plan submittal and during ensuing years.

2. Criteria

This BMP applies to those portions of buildable lots located outside of lot building zones, construction traffic areas, and staging areas that can be maintained as "minimal disturbance areas" during construction (i.e. wooded back portions of residential lots, green space required by ordinance).

Minimal disturbance area - Construction disturbance is limited to clearing of brush and minor grading. No clear-cutting, excavation, filling, stockpiling of material, or construction traffic is allowed. Area is vegetated after disturbance (if any).

a. Identify "minimal disturbance areas" on site plan and construction drawings.

b. Minimal disturbance areas must be protected by having the limits delineated/flagged/fenced in the field. Notes to this effect must be included on construction drawings.

c. Minimal disturbance areas must not be subject to excessive equipment movement. Vehicle traffic and storage of equipment and/or materials is not permitted.

d. Pruning or other required maintenance of vegetation is permitted. Additional planting with site-appropriate plants including turf grass is permitted.

e. Areas receiving credit must be located on the development project.

B. Protect Natural Flow Pathways

1. Summary

Pretreatment Required:	No. This BMP can provide pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	Due to longer time-of-concentration for natural flow pathway.
Water Quality:	Exempt from water quality criteria.

2. Criteria

a. Identify all existing natural flow pathways on site plan.

b. Identify natural flow pathways to be protected on site plan and construction drawings.

c. Protected natural flow pathways on private property must have an easement or deed restriction to prevent future disturbance or neglect.

d. Natural flow pathways to be protected must have the limits delineated/flagged/ fenced in the field. Notes to this effect must be included on construction drawings.

e. Identify flow pathways designed as part of the storm water management system including strategies such as:

   (1) Increased length.

   (2) Increased roughness.

   (3) Decreased slope.

f. Ensure adequacy of flow pathway for post-development flows.

C. Protect Sensitive Areas (including Riparian Buffers)

1. Summary

Pretreatment Required:	No.
Maintenance Plan:	No.
Calculation Credits:	Remove protected sensitive areas from storm water management calculations. (The area must still be included in storm water runoff calculations if it is necessary to determine the total downstream discharge from the site for sizing conveyance systems.)
Volume Reduction:	Exempt from channel protection criteria.
Rate Reduction:	Exempt from flood control criteria.
Water Quality:	Exempt from water quality criteria.

2. Criteria

This BMP includes protected areas on the development property located on separate out lots or set-asides with language in the master deed or bylaws that requires protection and preservation, and that restricts land uses to those that do not increase runoff. For developments involving county drains, a recordable conservation easement must also be provided to the Drain Commissioner.

a. Identify all sensitive areas on site plan.

b. Identify all sensitive areas to be protected on the site plan and construction drawings.

c. Sensitive areas to be protected must have the limits delineated/flagged/ fenced in the field during construction and visible permanent boundary markers set to minimize encroachment (as appropriate). Notes and details to this effect must be included on construction drawings.

d. Identify municipal/township ordinance requirements, if any, and incorporate sensitive area standards for development site. In the absence of a local ordinance, Drain Commissioner standards for riparian buffers shall consist of:

   (1) Variable width depending on topography, minimum 25-foot width (Zone 1).

   (2) Naturally vegetated.

e. Minimal clearing is allowed for lot access and fire protection.

f. For activities proposed within floodplains the Developer shall demonstrate any activity proposed within a 100-year floodplain will not diminish the flood storage capacity. Compensatory storage will be required at a minimum ratio of one-to-one (1:1) for all lost floodplain storage.

   (1) The compensating cut must be available during a flood event.

   (2) Water must be able to move freely from stream to storage.

   (3) Excavation must be adjacent to the floodplain.

   (4) Flood storage must be between the 2-year flood elevation and the 100-year flood elevation.

   (5) Compensating storage shall NOT be provided through channel widening.

D. Native Revegetation

1. Summary

Pretreatment Required:	No. This BMP can provide pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	Assign a CN reflecting a meadow instead of open space in "fair" condition as required for other disturbed pervious areas. For small sites, individual trees can receive a credit of 200 square feet per tree, counted as woods in "good" condition.[1]
Volume Reduction:	None.
Rate Reduction:	By virtue of lower CN.
Water Quality:	Exempt from water quality treatment criteria.

[1]Source: SEMCOG (2008). *Low Impact Development Manual for Michigan*.
Note: Trees in minimal disturbance areas receive a larger area credit than trees planted under "Native Revegetation" due to the assumption that the existing trees will typically be larger and more mature than planted trees at the time of site plan submittal and during ensuing years.

2. Criteria

a. Identify native revegetation areas on site plan and construction drawings.

b. Native revegetation areas must be protected by having the limits delineated/flagged/fenced in the field. Notes to this effect must be included on construction drawings.

c. Standards shall consist of:

   (1) Variable width depending on topography, minimum 25-foot width (Zone 1).

   (2) Native revegetation selected from the *Low Impact Development Manual for Michigan (SEMCOG, 2008)*, Appendix C.

d. Areas receiving credit must be located on the development project.

E. Storm Water Disconnection

1. Summary

Pretreatment Required:	No.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Weight impervious runoff coefficient with pervious area runoff coefficient.
Rate Reduction:	By virtue of weighted runoff coefficient.
Water Quality:	Exempt from water quality criteria.

2. Criteria

a. Storm water from rooftops and other impervious areas is considered disconnected if it is routed to a stabilized vegetated area including onsite swales and bioretention areas, or an onsite depression storage area that meets the following criteria:

(1) Impervious area must be limited to 1,000 square feet per discharge point.

(2) Roof downspouts and curb cuts must be at least 10 feet away from the nearest connected impervious surface to discourage “re-connections.”

(3) Disconnection in less permeable soils (HSGs C and D) may require the use of dry wells, french drains, or other temporary storage device to compensate for poor infiltration capability if ponding of water for extended period of time becomes problematic.

(4) For disconnects to stabilized vegetated areas:

(a.) Size of disconnect area shall be twice the size of the contributing impervious area.

(b.) Length of disconnect area must be at least the length of the flow path of the contributing impervious area (maximum 75 feet).

(c.) Slope of disconnect area must be no greater than 5%.

(d.) Disconnect area may be a “minimal disturbance” area.

(5) Disconnection must ensure no basement seepage.

b. Identify disconnect areas on site plan and construction drawings.

IV. Structural Best Management Practices

Structural Best Management Practices (BMPs) are constructed measures that convey, store and treat storm water in a site-specific location and help mitigate the impact of storm water runoff.

The Drain Commissioner has adopted standards for the following structural BMPs:

Conveyance and Storage

A. Storm Sewer
B. Culvert or Bridge
C. Open Channel
D. Detention Basins
E. Retention Basins

Low Impact Design (LID) and Small Site

F. Infiltration Practices
G. Bioretention/Rain Garden
H. Constructed Filter
I. Planter Box
J. Pervious Pavement
K. Capture Reuse
L. Vegetated Roof
M. Water Quality Device
N. Sediment Forebay
O. Spill Containment Cell
P. Water Quality Swale
Q. Vegetated Swale
R. Vegetated Filter Strip
S. Level Spreader

BMPs shall be designed in accordance with these standards.

Further information and examples for LID and Small Site BMPs are provided in the BMP Fact Sheets in Chapter 7 the *Low Impact Development Manual for Michigan* (SEMCOG, 2008).

Note: Design criteria for BMPs used primarily for SESC and channel stabilization (i.e. riprap, in-stream structures, natural channel design), and technical specifications for construction are beyond the scope of this manual.

A. Storm Sewer

1. Summary

Description:	Provides storm water conveyance in an enclosed system.
Types:	Pipe (solid wall, perforated).
Pretreatment Required:	No. This BMP can provide spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Solid wall pipe: None. Perforated pipe (with slope): None. Perforated pipe or leaching basin: Count storage volume below outlet pipe invert.
Rate Reduction:	None.
Water Quality:	None.

2. Design Requirements

a. Sizing and Configuration

(1) The storm sewer shall be designed to convey runoff from a 10-year frequency rainfall event.

(2) Storm sewer design velocities, capacities, and friction losses shall be based on Manning's equation:

$$Q = \frac{1.49 A R^{\frac{2}{3}} S^{\frac{1}{2}}}{n} \quad (4.22)$$

where:
Q = discharge (cubic feet per second)
A = wetted area (square feet)
R = hydraulic radius (feet)
S = slope (feet per foot)
n = Manning's Roughness Coefficient

(3) Manning's coefficients for closed conduit are included in ***Table 13.***

(4) Acceptable slopes for circular pipe ("n" = 0.013) are included in ***Table 14.*** Minimum and maximum grade for other Manning's n values must be calculated based on allowable minimum and maximum velocities (V).

(5) As a general rule, surcharging the pipe will be allowed to 1 foot below the top of casting. However, minor losses must be considered in hydraulic grade line calculations.

(6) Storm sewer pipe shall have a minimum diameter of 12 inches. Smaller pipe may be approved for private systems.

(7) The minimum depth of cover shall be 24 inches from grade to the top of pipe.

Storm Sewer (continued)

b. End Treatment

(1) Outlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 8 feet per second.

Table 13 - Manning's Roughness Coefficients

Conduit	Coefficients
Closed Conduits	
Asbestos-Cement Pipe	0.011 to 0.015
Brick	0.013 to 0.017
Cast Iron Pipe (Cement-lined and seal-coated)	0.011 to 0.015
Concrete (Monolithic)	
Smooth forms	0.012 to 0.014
Rough forms	0.015 to 0.017
Concrete Pipe	0.011 to 0.015
Corrugated-Metal Pipe (1/2-inch corrugated)	0.022 to 0.026
Paved invert	0.018 to 0.022
Spun asphalt-lined	0.011 to 0.015
Plastic Pipe (Smooth)	0.011 to 0.015
Vitrified Clay Pipes	0.011 to 0.015
Liner channels	0.013 to 0.017
Open Channels	
Lined Channels	
Asphalt	0.013 to 0.017
Brick	0.012 to 0.018
Concrete	0.011 to 0.020
Rubble or riprap	0.020 to 0.035
Vegetal	0.030 to 0.040
Excavated or Dredged	
Earth, straight and uniform	0.020 to 0.030
Earth, winding, fairly uniform	0.025 to 0.040
Rock	0.030 to 0.045
Unmaintained	0.050 to 0.140
Natural Channels (streams, top width at flood state <100 feet)	
Fairly regular section	0.030 to 0.070
Irregular section with pools	0.040 to 0.100
Source: American Society of Civil Engineers and the Water Pollution Control Federation (1969). *Design and Construction of Sanitary and Storm Sewers*.	

Table 14 - Minimum and Maximum Slopes for Storm Sewers

Pipe Size (Inches)	Minimum % of Grade (V = 2.5 feet/second)	Maximum % of Grade (V = 10 feet/second)
12	0.32	4.88
15	0.24	3.62
18	0.20	2.84
21	0.16	2.30
24	0.14	1.94
27	0.12	1.66
30	0.10	1.44
36	0.08	1.12
42	0.06	0.92
48	0.06	0.76
54	0.04	0.60
60	0.04	0.54
66	0.04	0.48
Manning's "n" = 0.013		

c. Manholes and Catch Basins

(1) Manhole spacing shall not exceed 400 feet for sewers less than 42 inches in diameter and 600 feet for larger sewers.

(2) Manholes shall be placed at all changes in pipe direction, pipe size, all inlet connection locations, and at the end of the storm sewer.

(3) Where possible, pipe inverts at junctions shall be designed to minimize junction losses (match 0.8 points of pipe diameters).

(4) Minimum in side diameter of all manholes, catch basins, and inlet structures shall be 48 inches, except that a 24-inch diameter structure may be allowed for structures with a single 12-inch outlet pipe.

(5) All structures receiving direct surface water runoff shall have a sump not less than 24-inches deep.

(6) Catch basins shall be placed at low points of streets and yards. Spacing and/or number of inlet structures required to accommodate the design flows in streets, private drives, and parking areas shall be provided based on inlet capacity with no ponding occurring during a 10-year storm, and the following additional stipulations:

(a.) No more than 300 feet of pavement surface drainage will be allowed. No more than 200 feet of surface drainage will be allowed for grades exceeding 4%.

(b.) Consideration shall be given to pedestrian crossings when siting catch basins in intersections. Catch basins shall be placed upstream of pedestrian crossings when practical.

(c.) No more than 150 feet of street drainage will be allowed to flow around a corner.

(d.) No flow will be allowed across a public street intersection.

d. Materials

(1) Storm sewer pipe shall be reinforced concrete or smooth interior wall polyethylene in accordance with MDOT Standard Specifications. Other materials shall be subject to approval of the Drain Commissioner.

(2) Pipe joints shall be designed to prevent excessive infiltration or exfiltration.

(3) Manholes and catch basins shall be in accordance with MDOT Standard Specifications.

(4) Connections to manholes shall be made with a resilient connector for pipe diameters 24 inches or less. Concrete pipe connections shall be made by grouting the inside and outside wall of the structure.

B. Culvert or Bridge

1. Summary

Description:	Provides storm water conveyance through a crossing structure.
Types:	Pipe Culvert; Box Culvert; Bridge.
Pretreatment Required:	No.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	None.

2. Design Requirements

a. Sizing and Configuration

(1) Bridges shall be designed to provide a 4.3-foot minimum under clearance at normal flow for canoe traffic on navigable waterways, and a 2-foot minimum freeboard to the underside (low chord) of the bridge for a 100-year flood.

(2) Footings shall extend at least 4 feet below the bottom of the channel.

(3) Culverts serving a drainage area of less than 2 square miles shall be designed for the 25-year peak discharge in the developed watershed with a maximum outlet velocity of 8 feet per second. A maximum of 1 foot of inlet submergence may be permitted if this does not backup water out of the easement.

(4) The effect of the 100-year storm shall be reviewed to ensure no adverse increase in water elevation off of the development property or flooding of structures within the development.

(5) Sizing of culverts and bridges shall be performed using the Bernouli Equation and include consideration of inlet and outlet control, entrance and exit losses, and tailwater condition. Published culvert nomographs and other computer software may be used.

(6) Minimum diameter of a drive culvert shall be 12 inches.

(7) Minimum diameter of a road crossing culvert shall be 18 inches or equivalent pipe arch.

b. End Treatment

(1) Headwalls, wingwalls, and all other end treatments shall be designed to ensure the stability of the surrounding soil. MDOT, County Road Commission, or manufacturer's designs may be used.

(2) Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 8 feet per second.

c. Materials

Culverts may be reinforced concrete pipe, corrugated steel pipe, or pipe arch in accordance with MDOT Standard Specifications.

C. Open Channel

1. Summary

Description:	Storm water conveyance in an excavated channel.
Types:	Channel; Ditch.
Pretreatment Required:	No.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	None.

2. Design Requirements

a. Sizing and Configuration

(1) The open channel shall be designed to convey the 25-year peak discharge.

(2) Open channel design velocities, capacities, and friction losses shall be based on Manning's equation:

$$Q = \frac{1.49 A R^{\frac{2}{3}} S^{\frac{1}{2}}}{n} \quad (4.22)$$

where:
Q = discharge (cubic feet per second)
A = wetted area (square feet)
R = hydraulic radius (feet)
S = slope (feet per foot)
n = Manning's roughness coefficient

(3) Manning's Coefficients shall be determined from ***Table 13.*** A minimum Manning's Coefficient of 0.035 shall be used for open channels, unless special treatment is given to the bottom and sides (riprap, paving, mown sod, etc.).

(4) Minimum bottom width shall be 2 feet.

(5) Minimum longitudinal slope shall be 0.10%.

(6) Side slopes shall be no steeper than 2:1 (horizontal to vertical).

(7) The minimum velocity for open channels during the design event shall be 1.5 feet per second.

(8) The maximum velocity shall be 4 feet per second. Riprap protection or equivalent shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 8 feet per second.

b. Connections and Crossings

(1) Outlets into the open channel shall enter at an angle of 90 degrees or less with the direction of flow.

(2) A minimum clearance of 4 feet is required between open channel inverts and underground utilities unless special provisions are approved.

D. Detention Basins

1. Summary

Description:	Provides storm water storage with a surface outlet.
Types:	Dry Basin; Underground Vault; Extended Detention Basin; Wet Pond; Constructed Wetland.
Pretreatment Required:	Yes.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	Calculated release rate.
Water Quality:	Dry Basin: Count volume detained. Underground Vaults: Count volume detained. Extended Detention: Count volume detained 24 hours. Wet Pond: Count volume of permanent pool. Constructed Wetland: Count volume of permanent pool.

2. Sizing Calculations

a. Calculate the allowable release rate and the required storage volume for flood control as outlined in "Calculating Storage Volumes and Release Rates, Flood Control, Detention."

b. Extended detention volume provided for water quality treatment and/or channel protection may be included in the flood control volume. Where channel protection and water quality treatment are provided through upstream retention BMPs, these volumes may be subtracted from the total inflow volume.

c. Size forebay(s) for pretreatment using equation given in "Calculating Storage Volumes and Release Rates, Pretreatment."

d. Detention basins without an acceptable surface water overflow route shall be designed for 2 times the required flood control volume.

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 2 feet is required between the bottom of dry detention basins and the highest known groundwater elevation.

(b.) A minimum of 1 foot is required between the bottom of extended detention basins and the highest know groundwater elevation.

(c.) Wet ponds and constructed wetlands shall have a reliable supply of baseflow or groundwater to support a permanent pool.

(d.) A constructed wetland must have a minimum contributing drainage area of 10 acres (5 acres for a pocket wetland).

(e.) Wet ponds and constructed wetlands proposed in HSG A and HSG B soils above the groundwater table shall have a clay or synthetic liner to minimize infiltration.

(2) Setbacks shall be as follows:

(a.) Adjacent property line: 10 feet.

(b.) Building foundation: 30 feet.

(c.) Private well: 50 feet.
(d.) Public well: 200 feet from Type I or Type IIa wells, 75 feet from Type IIb or Type III wells (Safe Drinking Water Act, Act 399, PA 1976).
(e.) Septic system drainfield: 100 feet.

(3) Offsite Water

(a.) Surface water flows from offsite land shall be routed around the development's onsite storm water system unless otherwise approved by the Drain Commissioner.

b. Configuration

(1) General

(a.) Distances of flow paths between inlets and outlets shall be maximized. A minimum basin length-to-width ratio of 3 to 1 is required.

(b.) If site constraints preclude placing pipes at opposite ends of the basin or meeting the length-to-width ratio, baffles (berms) may be used to lengthen the flow path.

(c.) Where steeper side slopes than those specified are unavoidable, safety railing, fencing, or other access barriers may be approved.

(2) Dry Basin

(a.) The design high water depth should generally not exceed 10 feet above the bottom of the basin.

(b.) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.

(c.) The bottom of dry detention basins shall be graded to provide positive flow to the pipe outlet. A minimum flow line bottom slope of 1% should be provided. Cross slopes should be 2% minimum. If continuous flow is anticipated, a low-flow channel shall be provided, with necessary crossings, and sloped to eliminate standing water. If site grades prohibit achieving these minimum slopes, the Drain Commissioner may approve the use of an underdrain with flatter slopes.

(3) Wet Pond

(a.) At a minimum, the volume of the permanent pool for wet ponds shall be 2.5 times the water quality volume to account for reduced settling efficiency due to turbulence caused by wind.

(b.) Wet ponds shall generally be wedge-shaped with inflow at the narrow end to prevent short-circuiting and stagnation. However, other shapes meeting the design intent may be approved.

(c.) Permanent pools shall have a minimum depth of 3 feet across the deepest part of the basin to discourage aquatic plant infill and provide open water.

(d.) The design high water depth should generally not exceed 10 feet above the permanent pool elevation.

Detention Basins (continued)

(e.) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn to the water's edge, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.

(f.) Permanent pools deeper than 4 feet shall have two safety ledges each between 6 and 8 feet wide. One shall start at the normal water surface and extend up to the pond side slopes at a maximum slope of 15%. The other shall extend from the water surface into the pond to a depth of 12 inches at a slope of 15%.

(g.) Warning signs prohibiting swimming and skating shall be posted for wet ponds.

(4) Constructed Wetland

(a.) The emergent vegetation zone shall comprise 60 to 65% of the total surface area. Half shall be high marsh with a normal water depth of 6 inches or less, and half shall be low marsh with a normal water depth between 6 and 18 inches.

(b.) The open water zone shall comprise 35 to 40% of the total surface area with a normal water depth of between 18 inches and 6 feet.

(c.) At a minimum, the volume of the permanent pool for the open water zone shall be 2.5 times the water quality volume to account for reduced settling efficiency due to turbulence caused by wind.

(d.) The 25-year water surface elevation shall not exceed the normal water surface elevation by more than 4 feet.

(e.) Side slopes shall be 4:1 to 5:1 (H:V) wherever possible. Side slopes shall not be steeper than 3:1 (H:V).

(f.) Open water deeper than 4 feet shall have two safety ledges each between 4 and 6 feet wide. One shall be situated 12 to 18 inches above the normal water surface and the other 24 to 30 inches below the water surface.

(g.) A micro pool shall be located at the outlet of the storm water wetland to protect the low flow pipe from clogging and prevent sediment resuspension. The micro pool shall be 3 to 6 foot deep and have a minimum surface area equivalent to the forebay.

(h.) A pocket wetland shall consist of a forebay and micropool with safety ledges.

c. Inlet Design

(1) Inlet pipes shall not be fully submerged at normal pool elevations.

(2) Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second up to maximum allowable design velocity of 8 feet per second.

(3) Pretreatment is required for each inlet, unless the inlet supplies less than 10% of the total design flow to the detention basin.

(4) Pretreatment shall be provided in a sediment forebay or spill containment cell located within the detention basin. For small sites, a water quality device located

prior to the basin may be allowed. Pretreatment for overland sheet flow entering the basin can be provided through a vegetated filter strip.

(5) When spill containment is required and a spill containment cell is used, all pipes contributing runoff from the high risk area must enter this cell for pretreatment.

d. Outlet Design

(1) The outlet shall consist of a multi-stage outlet and include a low flow orifice or multiple orifice openings, a primary overflow (typically provided through the top of a grated riser pipe), and a secondary emergency overflow spillway.

(2) Low Flow Outlet

(a.) The low flow outlet may be designed using the orifice equation, rearranged to solve for area.

$$A = \frac{Q}{c\sqrt{2gH}} \tag{4.23}$$

where:
A = required area (square feet)
Q = required outflow (cubic feet per second)
c = orifice coefficient (approximately 0.6)
$2g$ = two times the gravitation constant (g = 32.2 feet per second)
H = height of design high water level above center of orifice outlet (feet)

(b.) Other types of outlet devices shall have full design calculations provided for review.

(c.) The outlet shall be designed to prevent clogging.

(d.) Pipes or orifice plates shall have a minimum diameter of 4 inches.

(e.) Orifices used to maintain a permanent pool shall be designed to withdraw water a minimum of 2 feet below the normal water surface.

(f.) Riser pipes with holes or slits less than 4 inches in diameter shall have a stone and gravel filter placed around the outside of the pipe.

(g.) A gravel filtration jacket consisting of 3-inch washed stone and 1-inch washed stone must be placed around all riser pipes. The orifice configuration must be wrapped with hard wire mesh with an appropriate opening size to prevent any stone from passing through the orifice. The 3-inch stone must be placed immediately adjacent to the riser pipe with the 1-inch stone covering the larger stone. The gravel jacket must extend sufficiently above all orifice patterns.

Detention Basins (continued)

(3) Primary Overflow

(a.) All detention basins must have a primary overflow at the design high water level.

(b.) The primary overflow shall be designed to convey the 10-year peak inflow at the maximum design high water level. The depth of water at the crest of the secondary emergency overflow is the maximum design high water level.

(c.) The downstream outlet pipe shall be designed to convey the 10-year peak inflow from the primary overflow and the discharge from the low flow orifice at the maximum design high water level.

(d.) Hoods and trash racks shall be placed on riser pipes. Grate openings shall be a maximum of 3 inches on center.

(e.) Riser pipes shall have a minimum diameter of 24 inches. Riser pipes greater than 4 feet in height shall be a minimum of 48 inches in diameter.

(f.) Riser pipes shall be constructed of reinforced concrete or corrugated metal and be set in a concrete base. Plastic is not acceptable as a riser material due to lack of durability.

(g.) The riser must be placed near or within the embankment to provide for ready maintenance access.

(h.) When possible, a drain for completely dewatering the detention basin shall be installed for maintenance purposes.

(i.) Pipes placed through embankments shall have anti-seep collars.

(j.) Outlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second up to maximum allowable design velocity of 8 feet per second.

(4) Secondary Emergency Overflow

(a.) All detention basins must have a provision for emergency overflow (i.e. a spillway).

(b.) The spillway shall be designed for the 10-year peak inflow with a maximum flow depth of 1 foot. The spillway shall be sized using the weir equation:

$$Q = 2.6LH^{\frac{3}{2}} \qquad (4.24)$$

where:
Q = discharge (cubic feet per second)
2.6 = coefficient of discharge
L = length of spillway crest (feet)
H = total head measured above spillway crest (feet)

(c.) Freeboard: The top of berm elevation shall be a minimum of 0.5 foot above the design flow depth over the spillway. In no case shall the spillway depth (distance between spillway crest and top of berm) be less than 1 foot.

(d.) Overflow spillways shall be protected with concrete, riprap or a permanent erosion control blanket (preferred) to prevent erosion of the structure. Protection shall extend across the entire spillway up to the top of berm, start on the basin side a minimum of 3-feet below the spillway crest and extend down the spillway to an apron a minimum of 6-feet beyond the toe of the spillway.

e. Access

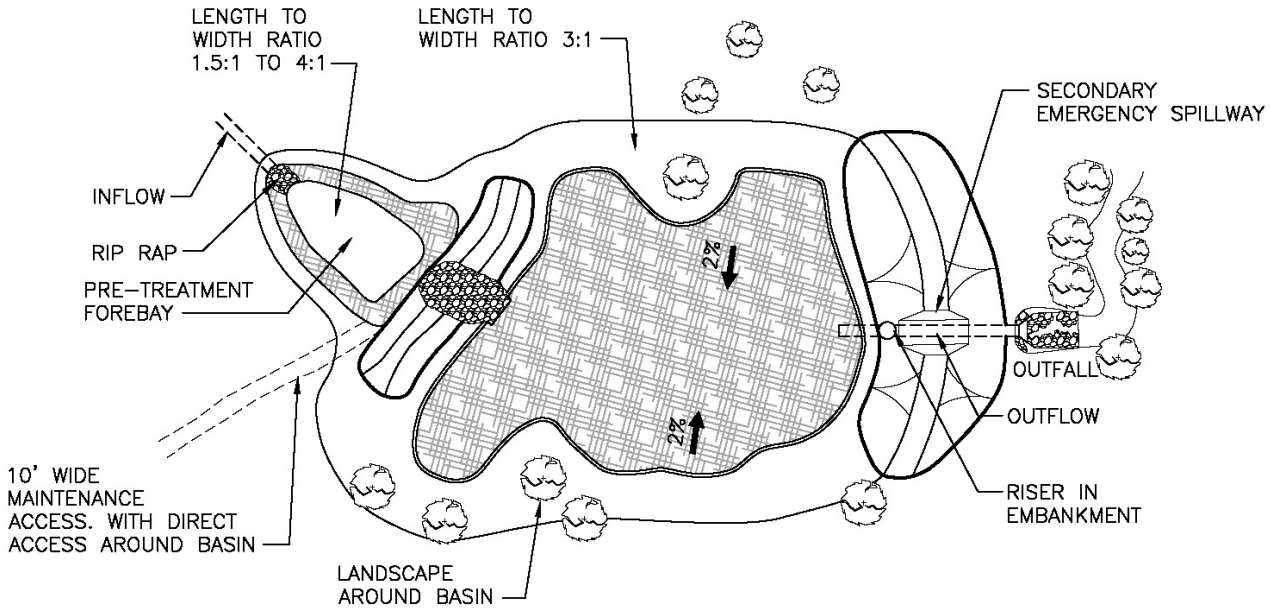
(1) Outlet control structures shall be placed near or within the embankment to facilitate maintenance access.

(2) Berm top width shall be a minimum of 12 feet.

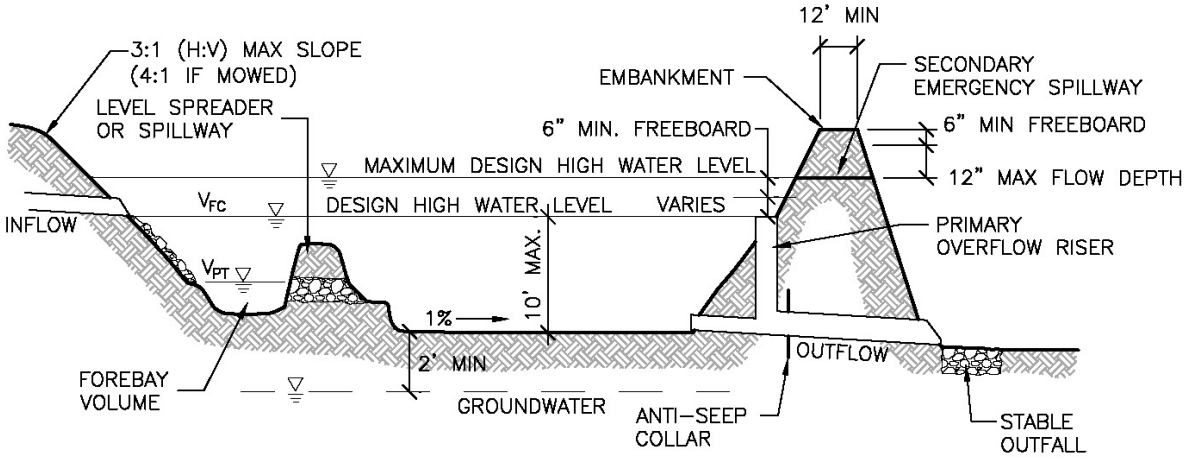
(3) A minimum 10-foot wide maintenance access route from a public or private right-of-way shall be provided to the basin. The access way shall have a vertical grade of no greater than 20% (5:1 H:V slope) and shall be stabilized to withstand the passage of heavy equipment. Direct access to the forebay, control structures and the outlet shall be provided.

4. Design Schematics

DRY DETENTION BASIN



PLAN VIEW

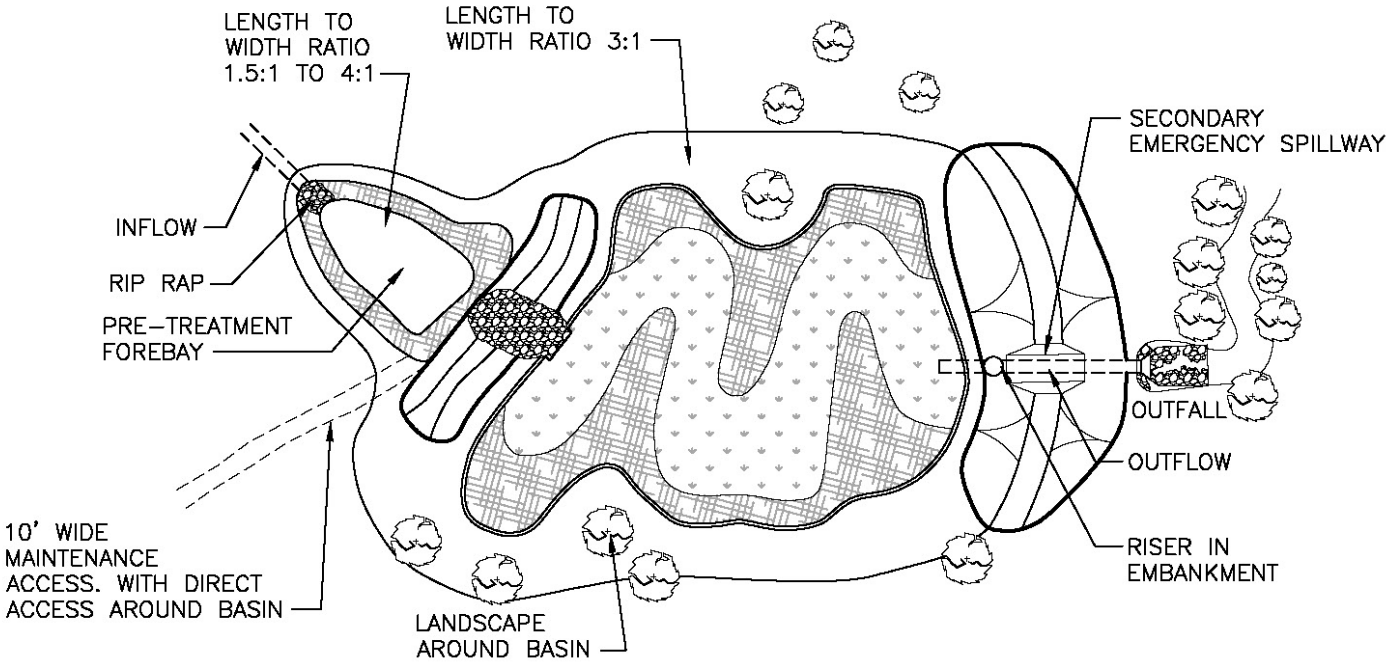


PROFILE

DRY DETENTION BASIN MUST BE COMBINED WITH OTHER BMP'S TO MEET WATER QUALITY TREATMENT CRITERIA.

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

EXTENDED DRY DETENTION BASIN



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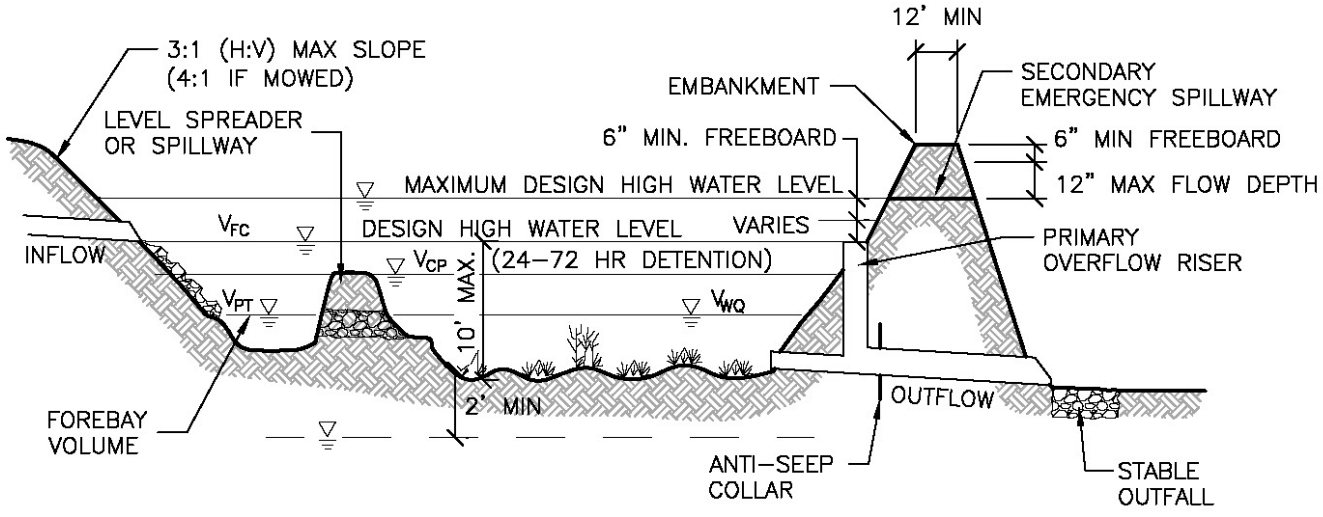
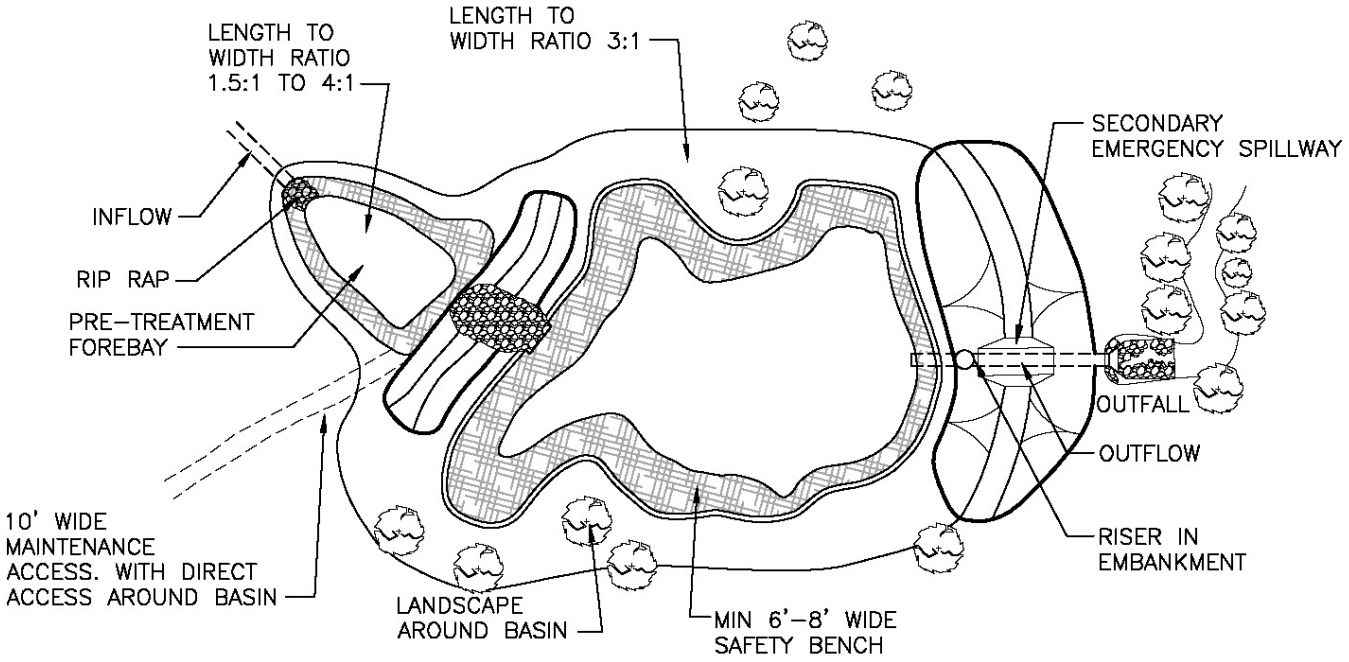


PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

WET DETENTION BASIN (WET POND)



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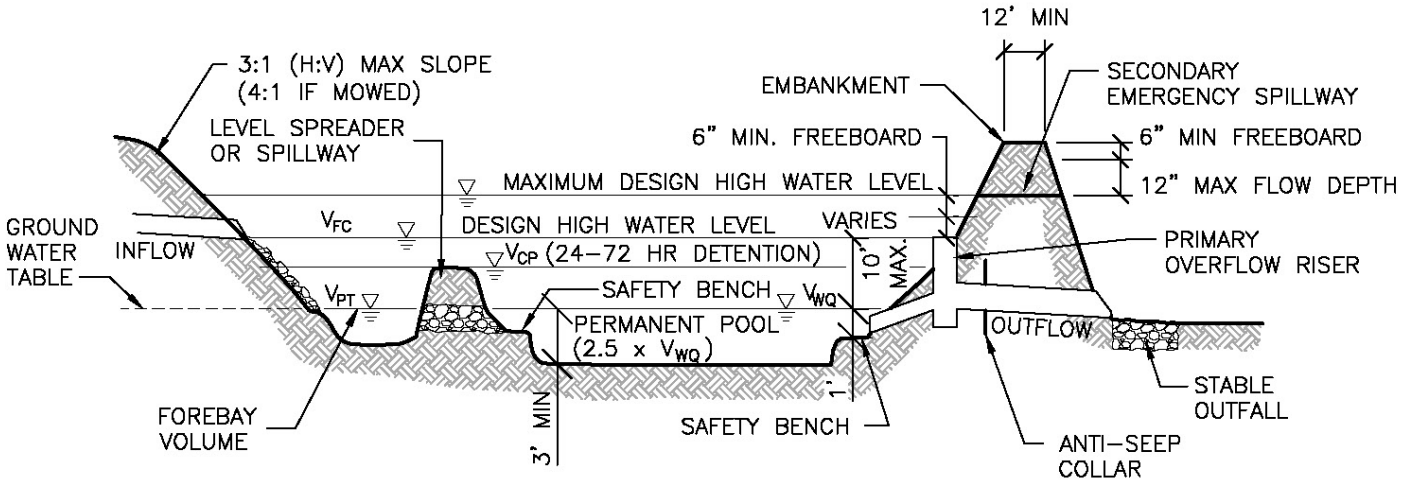
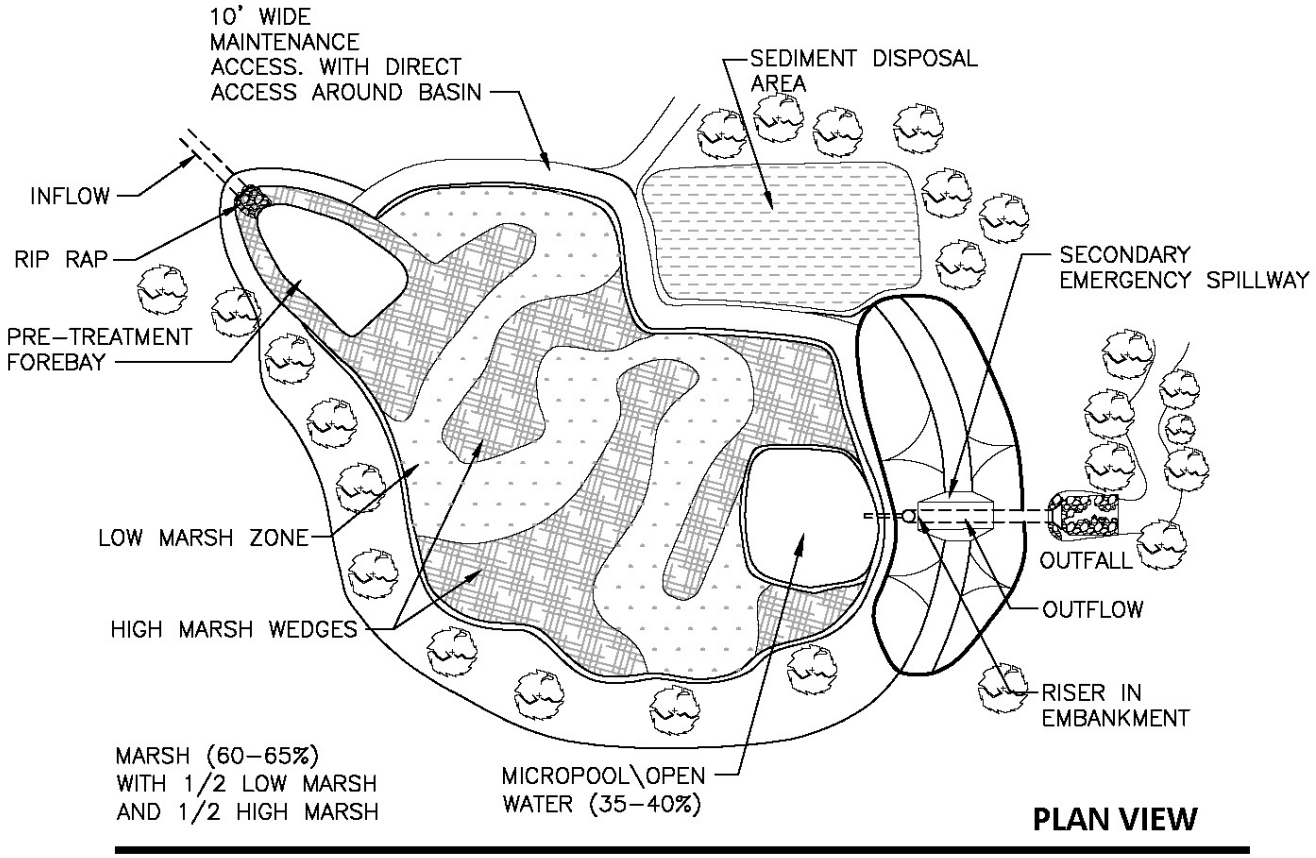
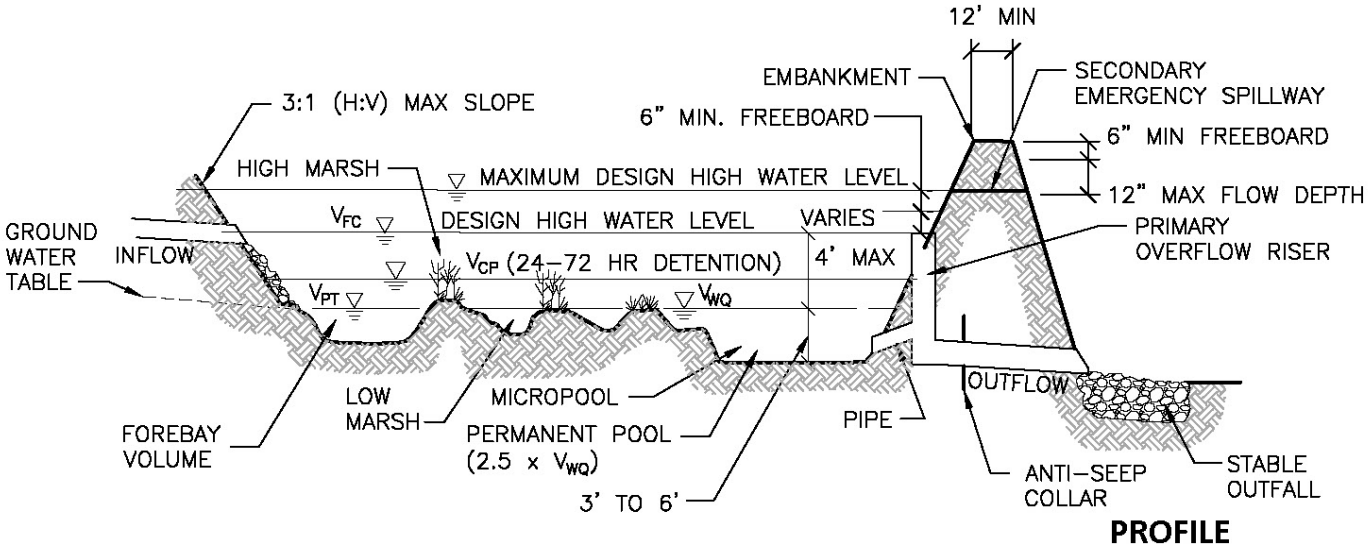


PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

CONSTRUCTED WETLAND





FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

E. Retention Basins

1. Summary

Description:	Provides storm water storage without a surface outlet.
Types:	Dry Basin; Wet Pond.
Pretreatment Required:	Yes.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count volume stored and infiltrated.
Rate Reduction:	Designed for flood control: 100%.
Water Quality:	Count volume stored and infiltrated.

2. Sizing Calculations

a. Calculate the required storage volume for flood control as outlined in "Calculating Storage Volumes and Release Rates, Flood Control, Retention."

b. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil from field permeability tests or ***Table 6***.

$$A = \frac{12Vs}{i(t_d)} \tag{4.25}$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour)
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

c. Drawdown time shall be no more than 72 hours.

d. The infiltration area shall be defined as the bottom of the basin, or the horizontal projection of the side slopes up to half of the design water depth above a permanent pool.

e. Where channel protection and water quality treatment are provided through upstream retention BMPs, these volumes may be subtracted from the total inflow volume. If provided in the same retention basin, channel protection and water quality volumes are included in the flood control volume.

f. Size forebay(s) for pretreatment using equation given in "Calculating Storage Volumes and Release Rates, Pretreatment."

g. Retention basins without an acceptable surface water overflow route shall be designed for 2 times the required flood control volume.

Retention Basins (continued)

3. Design Requirements

a. Siting
   (1) Soil borings are required as outlined in "Soils Investigation."
      (a.) A minimum of 3 feet is required between the bottom of dry retention basins and the highest known groundwater elevation.
   (2) Setbacks shall be as follows:
      (a.) Adjacent property line: 10 feet
      (b.) Building foundation: 30 feet
      (c.) Private well: 50 feet
      (d.) Public well: 200 feet from Type I or Type IIa wells, 75 feet from Type IIb or Type III wells (Safe Drinking Water Act, Act 399, PA 1976)
      (e.) Septic system drainfield: 100 feet

b. Configuration
   (1) General
      (a.) Where steeper side slopes than those specified are unavoidable, safety railing, fencing or other access barriers may be approved.
   (2) Dry Basin
      (a.) The design high water depth should generally not exceed 7 feet above the bottom of the basin.
      (b.) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.
      (c.) The bottom of dry retention basins shall be flat to encourage uniform ponding and infiltration.
      (d.) The bottom of dry retention basins shall be scarified to a depth of 4 to 6 inches after final grading has been established.
      (e.) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.
   (3) Wet Pond (no surface water outlet)
      (a.) The design high water depth should generally not exceed 7 feet above the permanent pool elevation.
      (b.) Where excavation and reshaping of the retention area is necessary, side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn to the water's edge, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.
      (c.) Where excavation and reshaping of the retention area is necessary, permanent pools deeper than 4 feet shall have two safety ledges each between 6 and 8 feet wide. One shall start at the normal water surface and extend up to the pond side slopes at a maximum slope of 15%. The other shall extend from the water surface into the pond to a depth of 12 inches at a slope of 15%.
      (d.) Warning signs prohibiting swimming and skating shall be posted for wet ponds.

Retention Basins (continued)

c. Inlet Design

(1) Inlet pipes shall not be fully submerged at normal pool elevations.

(2) Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 8 feet per second.

(3) Pretreatment is required for each inlet and shall be provided in a sediment forebay or spill containment cell located within the retention basin. For small sites, a water quality device may be allowed prior to the basin. Pretreatment for overland sheet flow entering the basin can be provided through a vegetated filter strip.

(4) When spill containment is required and a spill containment cell is used, all pipes contributing runoff from the high risk area must enter this cell for pretreatment.

d. Overflow

(1) Primary Overflow

(a.) When possible, retention basins must have a primary overflow at the design high water level.

(b.) The primary overflow and downstream pipe shall be designed to convey the 10-year peak inflow at the maximum design high water level. The depth of water at the crest of the secondary emergency overflow is the maximum design high water level.

(c.) Hoods and trash racks shall be placed on riser pipes. Grate openings shall be a maximum of 3 inches on center.

(d.) Riser pipes shall have a minimum diameter of 24 inches. Riser pipes greater than 4 feet in height shall be a minimum of 48 inches in diameter.

(e.) Riser pipes shall be constructed of reinforced concrete or corrugated metal and be set in a concrete base. Plastic is not acceptable as a riser material due to lack of durability.

(f.) When possible, a drain for completely dewatering the retention basin shall be installed for maintenance purposes.

(g.) Pipes placed through embankments shall have anti-seep collars.

(h.) Outlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second up to maximum allowable design velocity of 8 feet per second.

(2) Secondary Emergency Overflow

(a.) All retention basins must have a provision for emergency overflow (i.e. a spillway).

(b.) The spillway shall be designed for the 10-year inflow with a maximum flow depth of 1 foot. The spillway shall be sized using the weir equation.

$$Q = 2.6LH^{\frac{3}{2}} \quad (4.24)$$

where:
Q = discharge (cubic feet per second)
2.6 = coefficient of discharge
L = length of spillway crest (feet)
H = total head measured above spillway crest (feet)

(c.) Freeboard: The top of berm elevation shall be a minimum of 0.5 foot above the design flow depth over the spillway. In no case shall the spillway depth (distance between spillway crest and top of berm) be less than 1 foot.

(d.) Overflow spillways shall be protected with concrete, riprap or a permanent erosion control blanket (preferred) to prevent erosion of the structure. Protection shall extend across the entire spillway up to the top of berm, start on the basin side a minimum of 3-feet below the spillway crest and extend down the spillway to an apron a minimum of 6-feet beyond the toe of the spillway.

e. Access

(1) Berm top width shall be a minimum of 12 feet.

(2) A minimum 10-foot wide maintenance access route from a public or private right-of-way shall be provided to the basin. The access way shall have a vertical grade of no greater than 20% (5:1 H:V slope) and shall be stabilized to withstand the passage of heavy equipment. Direct access to the forebay, control structures and the outlet shall be provided.

f. Supplemental Measures

(1) Supplemental measures may be required to ensure that a retention basin drains sufficiently as the soil becomes less permeable with use. The need for supplemental measures may be based on a number of indicators including:

(a.) Soils with a design infiltration rate between 0.50 and 1.63 inches per hour (Sandy Loam).

(b.) High probability for sedimentation (particularly fines).

(c.) Larger regional basin where there is less control over contributing area runoff.

(d.) Probability of groundwater rising higher than minimum isolation distance.

(2) Supplemental measures may include:

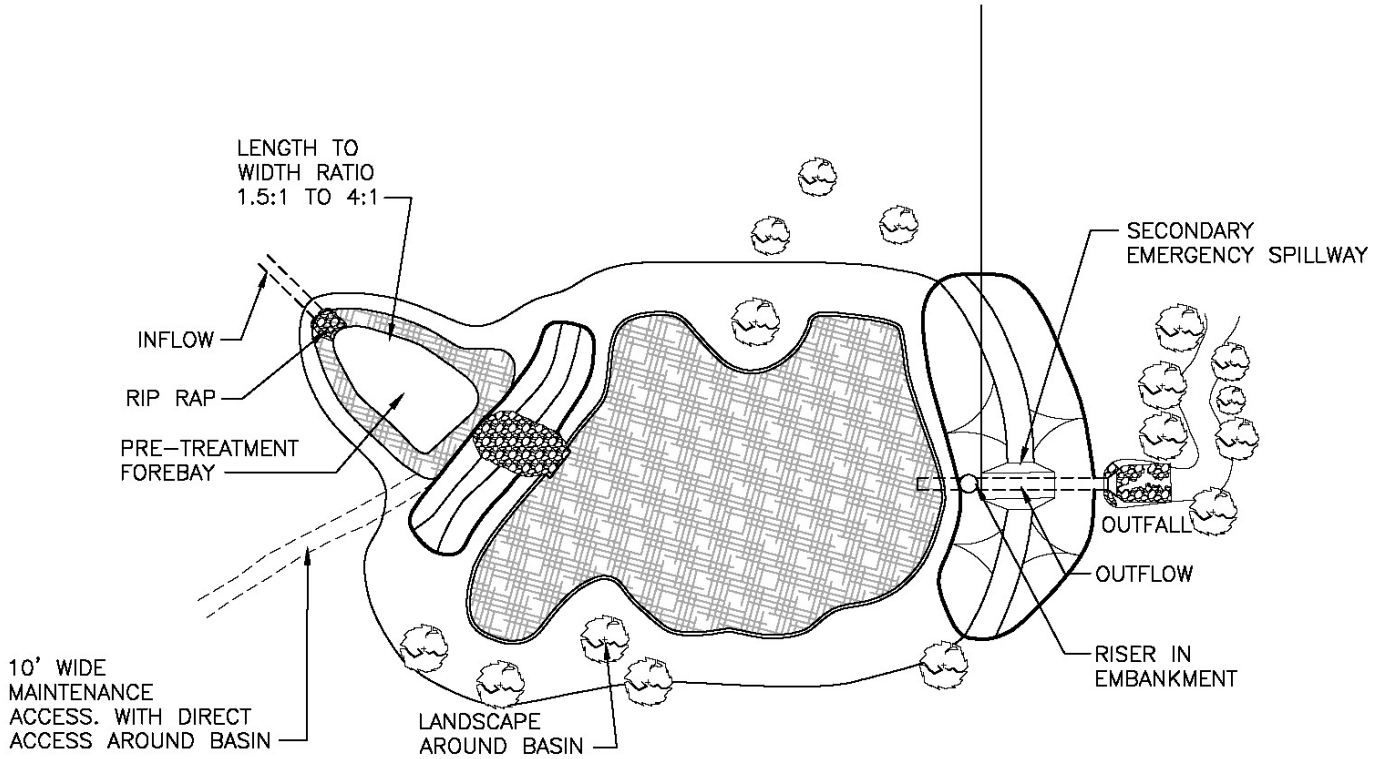
(a.) Leaching basins or infiltration trench placed in the bottom of the basin.

(b.) Valved outlet to drain basin.

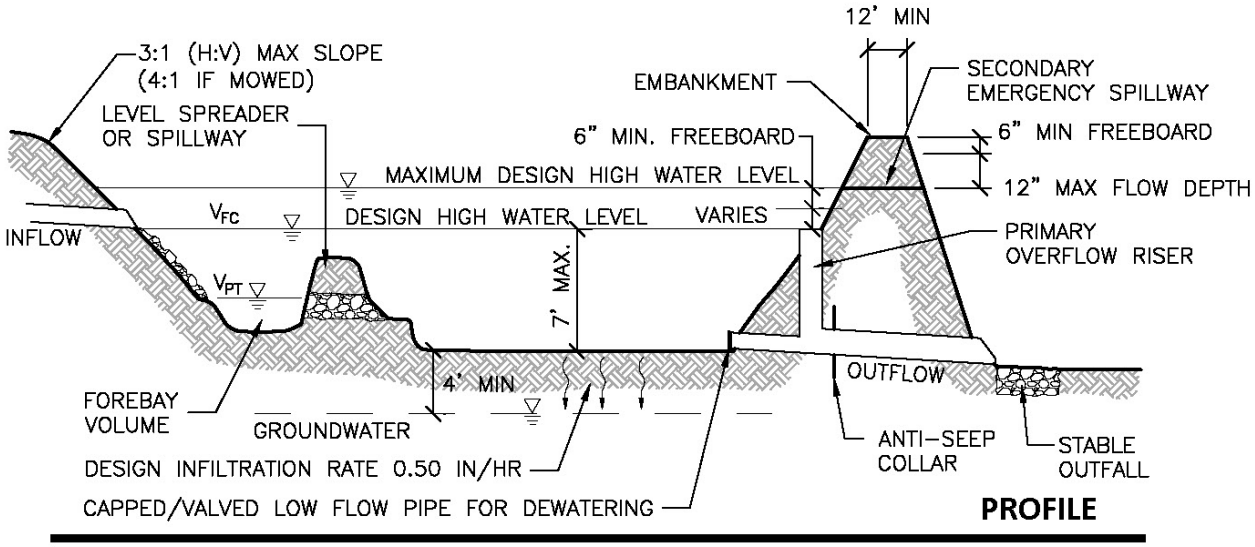
(c.) Conversion to a wet basin with sufficient storage volume provided above the permanent pool for reduced infiltration area.

4. Design Schematics

DRY RETENTION BASIN



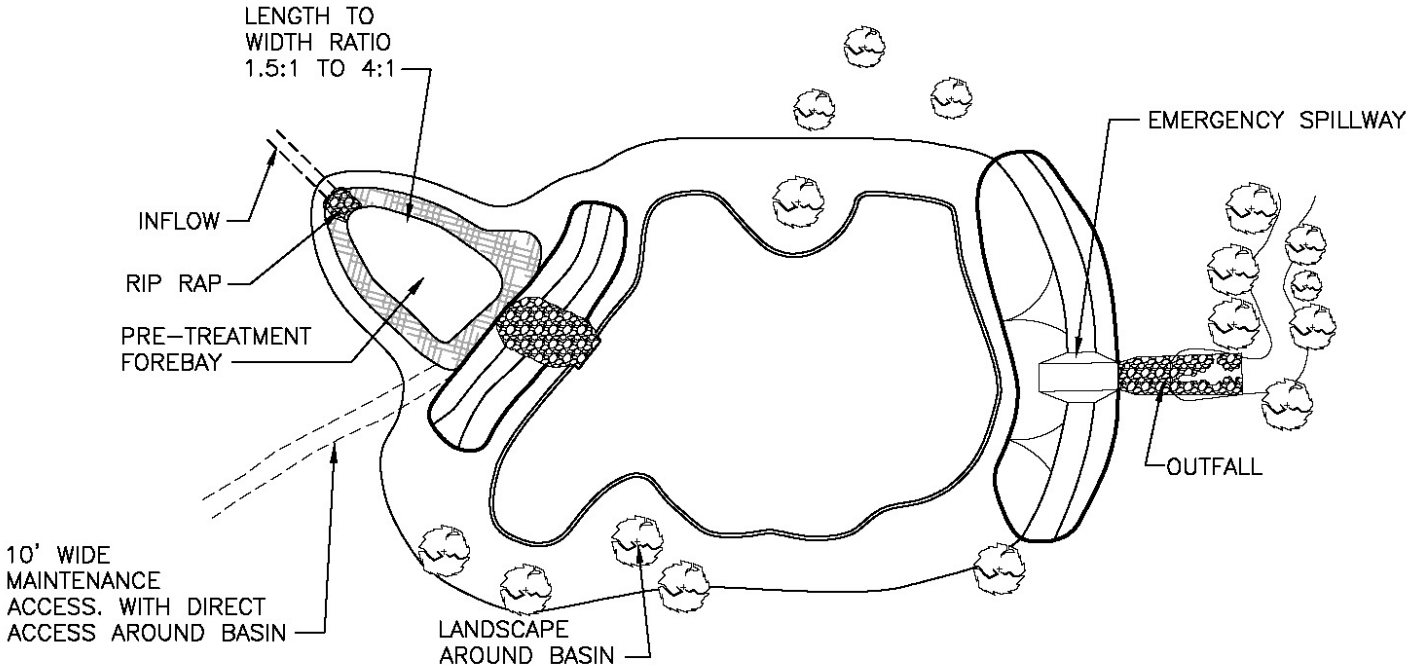
PLAN VIEW



PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

WET RETENTION BASIN



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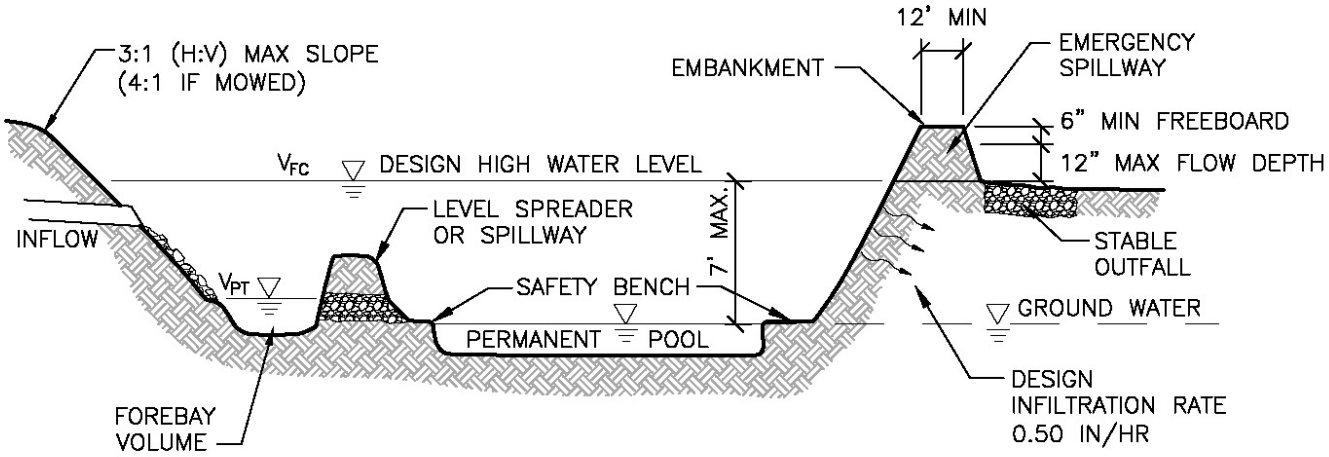


PROFILE

F. Infiltration Practices

1. Summary

Description:	Storm water treatment and storage without a surface outlet.
Types:	Dry Well; Leaching Basin; Infiltration Trench; Infiltration Bed; Infiltration Berm.
Pretreatment Required:	Yes.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count volume stored and infiltrated.
Rate Reduction:	Designed for flood control: 100%. Designed for channel protection and/or water quality: Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate.
Water Quality:	Count volume stored and infiltrated.

2. Sizing Calculations

a. Infiltration practices may be sized for channel protection or water quality treatment. Use the methods outlined in "Calculating Storage Volumes and Release Rates" to calculate the required volumes. Use the SEMCOG Method to calculate the required storage volume of the BMP.

b. Infiltration practices may be able to provide flood control for small drainage areas.

c. Channel protection and water quality volumes may be included in the flood control volume.

d. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil from field permeability tests or ***Table 6.***

$$A = \frac{12Vs}{i(t_d)} \tag{4.25}$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour)
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

e. Total drawdown time shall be no more than 72 hours. Depth of surface ponding shall be no more than 2 feet and drain within 24 hours.

f. Infiltration area shall be defined as:

(1) Dry Well/Leaching Basin: Bottom and sides (lateral)
(2) Infiltration Trench: Bottom of trench (length x width) and 1/2 the height of each side
(3) Infiltration Bed: Bottom area of the bed
(4) Infiltration Berm: Ponding area (length of berm x average width of ponding behind berm)

Infiltration Practices (continued)

g. Calculate the storage volume of the BMP:

(1) Dry wells, infiltration trenches, infiltration beds:

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

Where perforated pipe is used, the formula is modified:

Subsurface Storage Volume (cubic feet) = Volume of Pipe (cubic feet) + [Length (feet) x Width (feet) x Depth (feet) – Volume of Pipe (cubic feet)] x Void Ratio of Material

(2) Leaching basins:

Storage Volume (cubic feet) = πr^2 (square feet) x Depth (feet)
where:
r = radius of leaching basin (feet)
π = *pi* (approximately 3.14)

Volume of storage in stone envelope around leaching basin may also be counted.

(3) Infiltration berm:

Surface Storage Volume (cubic feet) = Average Ponding Area (square feet) x Design High Water Depth (feet)

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 3 feet is required between the bottom of infiltration practices and the highest known groundwater elevation.

(b.) Void ratio for the imported material shall be based on the USDA soil textural class and effective water capacity in ***Table 6.*** A maximum design value of 0.40 shall be used for the void ratio of stone.

(2) Setbacks shall be as follows:

(a.) Adjacent property line: 10 feet
(b.) Building foundation: 10 feet
(c.) Private well: 50 feet
(d.) Public well: 200 feet from Type I or Type IIa wells, 75 feet from Type IIb or Type III wells (Safe Drinking Water Act, Act 399, PA 1976)
(e.) Septic system drainfield: 50 feet

(3) Infiltration practices shall be located outside of the drip line of adjacent trees to avoid root intrusion.

b. Configuration

(1) General

(a.) A combination of surface and subsurface storage may be used to provide the required storage volume.

(2) Dry wells, infiltration trenches and infiltration beds

(a.) Infiltration trench width shall generally be as follows: 3-foot minimum to 6-foot maximum.

(b.) Course aggregates shall be uniformly graded, washed and wrapped in a non-woven geotextile to provide separation between the aggregate and the surrounding soil and prevent fines from clogging the infiltration surface.

(c.) An observation well shall be provided for each dry well, at each end of an infiltration trench, and at each corner of an infiltration bed with intermediate center wells added so as not to exceed maximum distance of 50 feet between wells.

(d.) Perforated pipes laid flat may be used to distribute runoff over the bottom of infiltration trenches and infiltration beds.

(e.) Cleanouts shall be provided at pipe ends.

(f.) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

(3) Leaching Basins

(a.) Leaching basins shall have a minimum diameter of 4 feet, and meet the layout requirements for catch basins (refer to Part 4 section “Storm Sewer”).

(b.) Leaching basins shall have an open bottom and perforations around the circumference of the structure at no greater than 12-inch intervals horizontally and vertically the entire depth of the sump.

(c.) Bedding and backfill shall consist of clean stone with nonwoven geotextile fabric placed along the walls of the trench and wrapped around the stone and the basin.

(4) Infiltration Berms

(a.) Infiltration berms shall be constructed along (parallel to) contours at a constant level elevation.

(b.) Maximum berm height shall be 2 feet to prevent excessive ponding behind berm.

(c.) Berm top width shall be a minimum of 16 feet.

(d.) Side slopes shall not be steeper than 4:1 (H:V) to facilitate mowing and ensure stable side slopes.

(e.) Well compacted cohesive soil shall be used to construct the berm.

(f.) The berm shall be well vegetated to prevent erosion if overtopped.

(5) Inlet Design

Pretreatment is required for each inlet and for overland flow entering the infiltration practice. Exceptions may be allowed for small paved drainage areas contributing directly to a leaching basin.

(6) Emergency Overflow

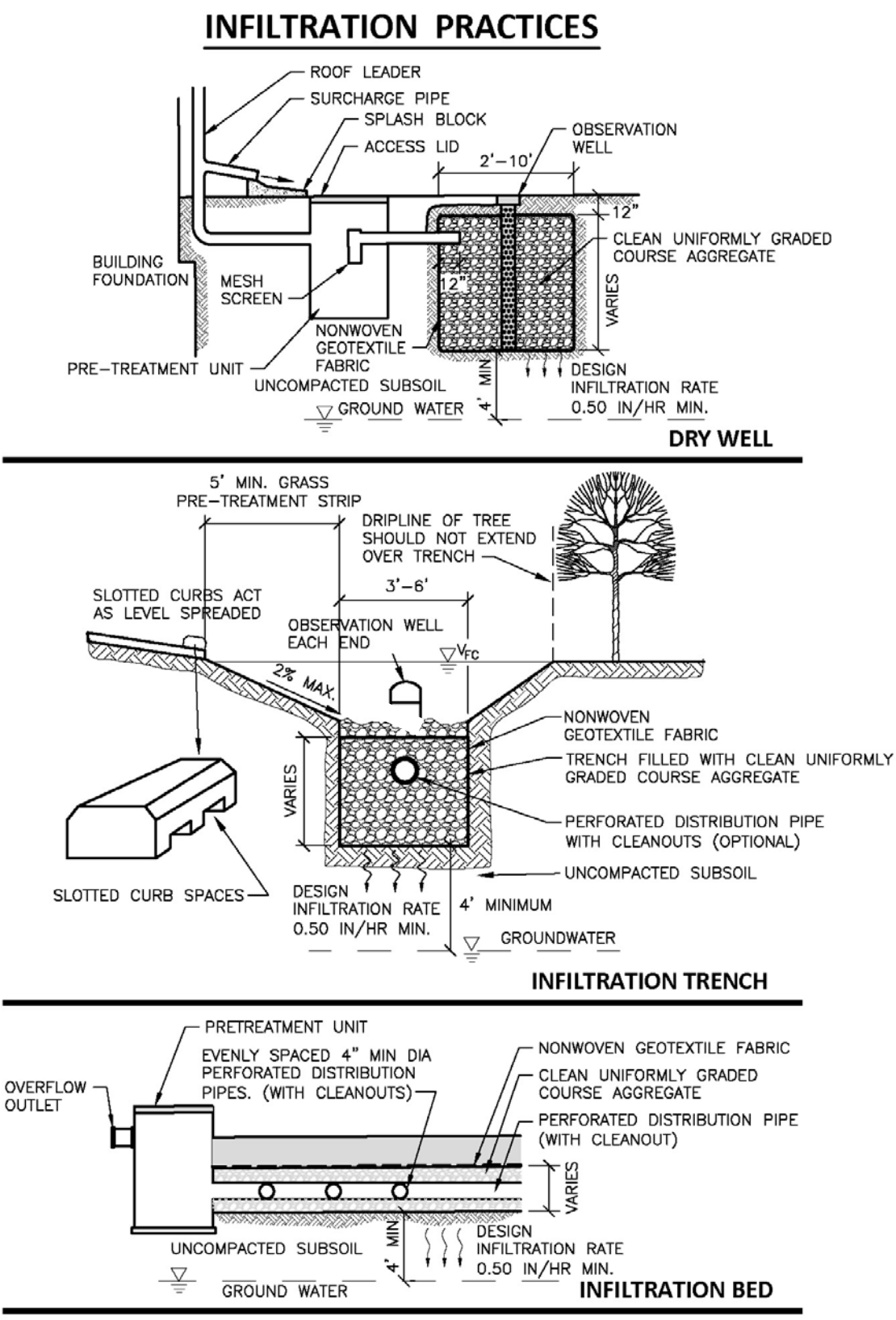
(a.) All infiltration practices must have a provision for overflow at the high water level.

(b.) Infiltration practices without an acceptable surface water overflow route shall be designed for 2 times the required flood control volume.

(7) Access

Inspection and maintenance access to the infiltration practice shall be provided.

4. Design Schematics



G. Bioretention/Rain Garden

1. Summary

Description:	Provides storm water treatment, storage and uptake with or without a surface outlet; Underdrained BMP may be allowed on small sites in lieu of extended detention.
Types:	Bioretention: Natural-looking herbaceous. Rain garden: Landscaped and manicured Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; Lined.
Pretreatment Required:	Yes.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Infiltration: Count volume stored and infiltrated. Underdrained: Count volume stored and volume infiltrated between bottom of BMP and invert of underdrain.
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate.
Water Quality:	Count total volume stored and infiltrated/filtered.

2. Sizing Calculations

a. For underdrained BMP, follow criteria for "Constructed Filter."

b. Bioretention/rain gardens may be sized for channel protection or water quality treatment. Use the methods outlined in "Calculating Storage Volumes and Release Rates" to calculate the required volumes. Use the SEMCOG Method to calculate the required storage volume of the BMP.

c. Bioretention/rain gardens may be able to provide flood control for small drainage areas.

d. Channel protection and water quality volumes may be included in the flood control volume.

e. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil from field permeability tests or ***Table 6*****.**

$$A = \frac{12Vs}{i(t_d)} \qquad (4.25)$$

where: A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour)
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

f. Total drawdown time shall be no more than 72 hours. Depth of surface ponding shall be no more than 9 inches and drain within 24 hours.

Bioretention/Rain Garden (continued)

g. Surface ponding depth may be increased up to 18 inches for bioretention areas.

h. The bottom area of the BMP shall be used as the infiltration area.

i. Calculate the storage volume of the BMP:

Average Bed Area (square feet) = [Area at Design High Water Depth (square feet) + Bottom Area (square feet)] / 2

Surface Storage Volume (cubic feet) = Average Bed Area (square feet) x Design High Water Depth (feet)

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

Total Storage Volume (cubic feet) = Surface Storage Volume (cubic feet) + Subsurface Storage Volume (cubic feet)

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 3 feet is required between the bottom of bioretention/rain gardens capable of infiltration and the highest known groundwater elevation.

(b.) A minimum of 1 foot is required between the bottom of lined or underdrained bioretention/rain gardens and the highest known groundwater elevation.

(c.) An underdrain shall be provided for design infiltration rates of the underlying native soil less than 0.50 inches per hour, or if bioretention/rain garden will be lined.

(d.) Void ratio for the amended soil material shall be based on the USDA soil textural class and effective water capacity in ***Table 6*****.** A maximum design value of 0.30 shall be used for the void ratio of the amended soil material. A maximum design value of 0.40 shall be used for the void ratio of stone.

(2) Setbacks shall be as follows:

(a.) Adjacent property line: 10 feet
(b.) Building foundation: 10 feet
(c.) Private well: 50 feet
(d.) Public well: 200 feet from Type I or Type IIa wells, 75 feet from Type IIb or Type III wells (Safe Drinking Water Act, Act 399, PA 1976)
(e.) Septic system drain field: 50 feet

b. Sizing and Configuration

(1) General

(a.) The bottom shall be flat to encourage uniform ponding and infiltration.
(b.) Minimum bottom width shall be 3 feet.
(c.) Bioretention/rain gardens located in areas with steep slopes shall be terraced to minimize earth disturbance and maximize infiltration area.
(d.) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

(e.) Bioretention/rain gardens located in areas of existing soil contamination shall be lined to prevent infiltration.
(f.) Underdrains shall have a 4-inch minimum pipe diameter.
(g.) All underground pipes shall have clean-outs accessible from the surface.
(h.) Pipe slopes shall have a minimum slope of 1%.
(i.) Side slopes shall not be steeper than 3:1 (H:V), unless landscape retaining walls are used.
(j.) An observation well shall be provided for each bioretention/rain garden.

(2) Rain gardens

(a.) A landscape plan shall be provided.

c. Inlet Design

(1) Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second up to a maximum allowable design velocity of 8 feet per second.

(2) Pretreatment is required for each inlet and for overland flow entering the bioretention/rain garden.

d. Emergency Overflow

(1) All bioretention/rain gardens must have an overflow at the high water level.

e. Materials

(1) Amended soil material shall consist of 18 to 48 inches of the following materials, evenly mixed: Compost: 30-50%; Sand: 20-40%; Topsoil: 20-30% (maximum clay content of topsoil shall be 20%.)

(a.) Alternative mix designs with ratios outside of the limits provided will be considered with justification.
(b.) The soil mix shall have a pH between 5.5 and 7.5.

(2) Stone shall consist of clean, uniformly graded course aggregate.

(3) A nonwoven geotextile fabric shall be placed between the amended soil and the stone, when a stone layer is used.

(4) When used, impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

(5) Plant selection shall consider exposure and tolerance to salt, sediment and pollutants, and the design depth of surface storage. Native species are encouraged.

(a.) Bioretention: Plugs and seed.
(b.) Rain gardens: Container stock.

(6) Mulch shall be applied after planting.

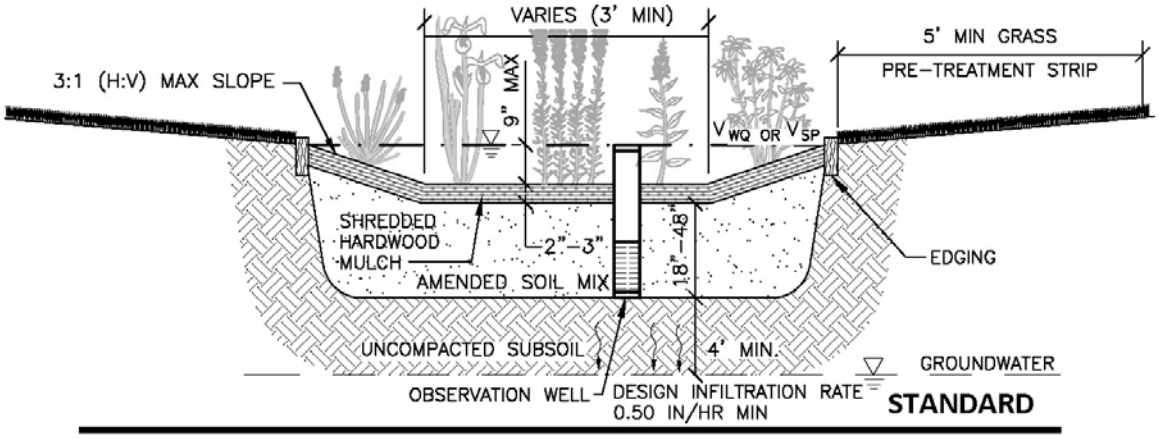
(a.) Bioretention: Straw mulch or mulch blanket shall be uniformly applied and tacked.
(b.) Rain gardens: Shredded hardwood mulch shall be uniformly applied to a depth of 2 to 3 inches.

f. Access

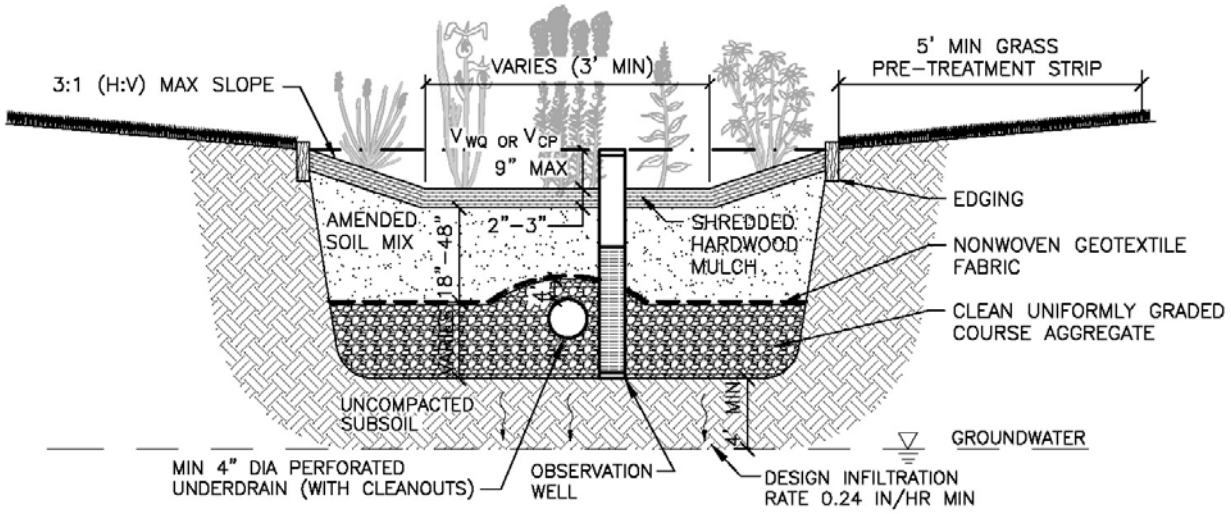
Inspection and maintenance access to the bioretention/rain garden shall be provided.

4. Design Schematics

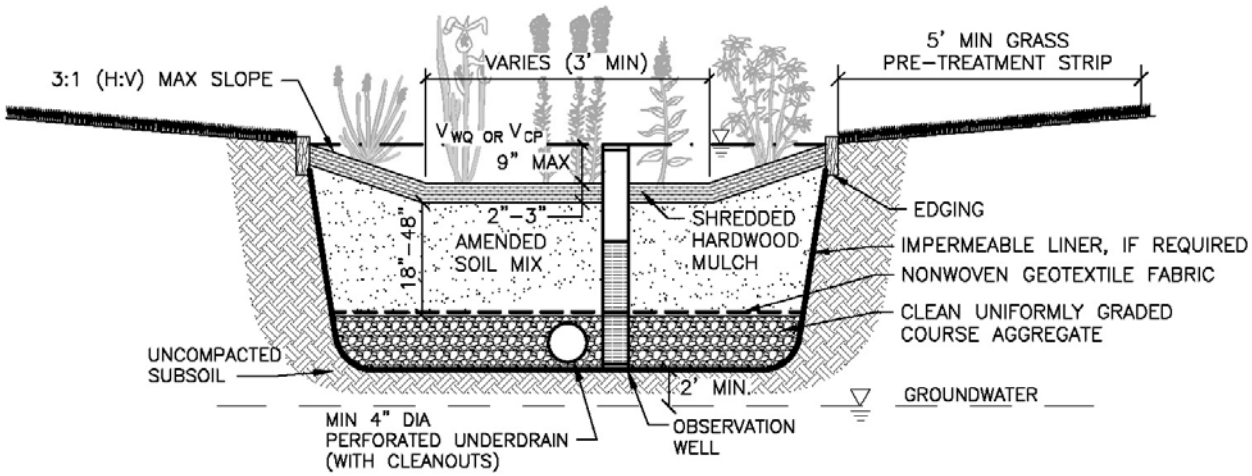
BIORETENTION/RAIN GARDEN



STANDARD



BIORETENTION/RAIN GARDEN WITH STONE STORAGE LAYER



BIORETENTION/RAIN GARDEN WITH BOTTOM DRAIN

H. Constructed Filter

1. Summary

Description:	Provides storm water treatment and storage with a surface outlet (underdrain); May be used on small sites in lieu of extended detention.
Types:	Sand; Gravel; Sand/compost mix; Other media.
Pretreatment Required:	Yes. This BMP can provide spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count storage volume of BMP.
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate.
Water Quality:	Count total volume stored and filtered.

2. Sizing Calculations

a. Use the methods outlined in "Calculating Storage Volumes and Release Rates" to calculate the required volumes for channel protection, water quality and/or pretreatment.

b. Calculate filter surface area required to drain the design volume in the specified drawdown time using hydraulic conductivity of filter media:

$$A = \frac{V(d_f)}{K(t_d)(h_f + d_f)} \quad (4.26)$$

where:
A = minimum surface area of filter (square feet)
V = design runoff volume (cubic feet)
d_f = depth of filter media (1.5-foot minimum to 3-foot maximum)
K = hydraulic conductivity (feet per day)
t_d = maximum allowable drawdown time (days)
h_f = average head; typically ½ of the maximum head on filter media (feet)

c. Total drawdown time shall be no more than 72 hours.

d. Check whether soil conductivity or hydraulics of underdrain governs.

e. Underdrained BMPs used for channel protection must be sized to store the entire channel protection volume.

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 1 foot is required between the bottom of the constructed filter and the highest known groundwater elevation.

(b.) Design values for hydraulic conductivity of the filter media shall be as specified in ***Table 15***, or documented by field tests in accordance with "Soils Investigation," or by other sources for other filter media.

Constructed Filter (continued)

Table 15 - Minimum Hydraulic Conductivities for Filter Media

Filter Media	Hydraulic Conductivity (feet per day)
Gravel	20
Course Sand	7.2
Compost (loose)	8.7[1]
Rain Garden Mix (compost, sand, topsoil)	1.5[2]
Peat	1[3]

Source: From design infiltration rates in ***Table 6.***

[1] SEMCOG (2008). *Low Impact Development Manual for Michigan.*

[2]Adapted from D. Carpenter and L. Hallam (2007). An *Investigation of Rain Garden Planting Mixtures and the Implications for Design.*

[3] J. Bear (1972). *Dynamics of Fluids in Porous Media,* p. 136.

b. Configuration

(1) Filter media shall have a minimum depth of 18-inches and a maximum depth of 36 inches.

(2) Pipe bedding shall consist of at least 3 inches of gravel under the pipe and 6 inches above the pipe.

(3) A 4-inch minimum diameter underdrain shall be provided in the gravel layer with lateral spacing no more than 10 feet.

(4) All underground pipes shall have clean-outs accessible from the surface.

(5) Pipe slopes shall have a minimum slope of 1%.

(6) Constructed filters located in areas of existing soil contamination shall be lined to prevent infiltration.

c. Inlet Design

(1) A level spreader, distribution pipes or other flow dispersion measure shall be used for energy dissipation and to uniformly distribute the flow.

(2) Pretreatment is required for each inlet and for overland flow entering the constructed filter.

d. Emergency Overflow

(1) All constructed filters must be designed so that larger storms may safely overflow or bypass the filter. Flow splitters, multi-stage chambers or other devices may be used.

(2) Sufficient space must be provided between the top of the filtering bed and the overflow to allow the maximum design head to be stored for filtration.

e. Materials

(1) Gravel shall consist of clean, uniformly graded course aggregate (MDOT course or open-graded aggregate).

(2) A nonwoven geotextile fabric shall be placed between the filter media layer(s) and the gravel layer.

(3) When used, impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

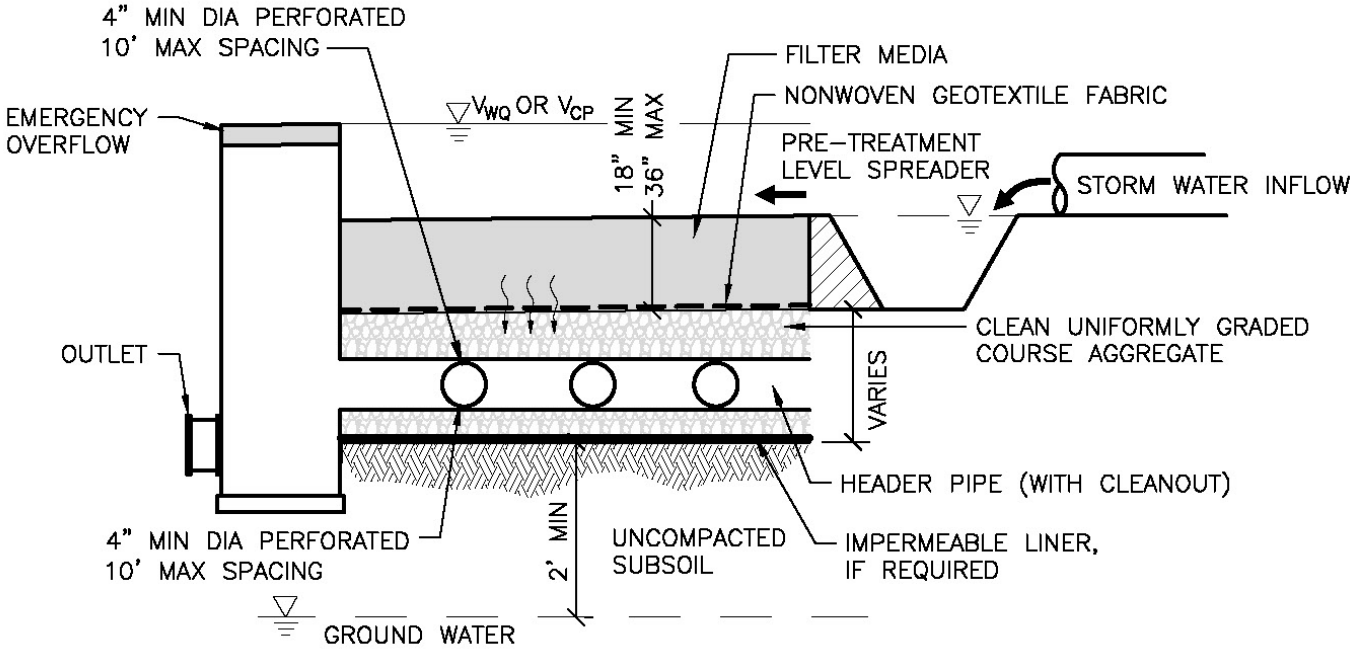
f. Access

(1) Inspection and maintenance access to the constructed filter shall be provided.

(2) For underground vault heights greater than 4 feet, ladder access shall be provided.

4. Design Schematics

CONSTRUCTED FILTER



I. Planter Box

1. Summary

Description:	A type of rain garden applicable for small sites or highly urban areas; Underdrained BMP may be allowed on small sites in lieu of extended detention.
Types:	Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; Lined.
Pretreatment Required:	No.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Infiltration: Count volume stored and infiltrated. Underdrained: Count volume stored and volume infiltrated between bottom of BMP and invert of underdrain.
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate.
Water Quality:	Count total volume stored and infiltrated/filtered.

2. Sizing Calculations

a. For underdrained BMP, follow criteria for "Constructed Filter."

b. Planter boxes may be sized for channel protection or water quality treatment. Use the methods outlined in "Calculating Storage Volumes and Release Rates" to calculate the required volumes. Use the SEMCOG Method to calculate the required storage volume of the BMP.

c. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil from field permeability testing or ***Table 6.***

$$A = \frac{12Vs}{i(t_d)} \tag{4.25}$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour)
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

d. Total drawdown time shall be no more than 12 hours. Depth of surface ponding shall be no more than 1 foot and drain within 4 hours.

e. The bottom area of the BMP shall be used as the infiltration area.

Planter Box (continued)

f. Calculate the storage volume of the BMP:

Surface Storage Volume (cubic feet) = Bed Area (square feet) x Design High Water Depth (feet)

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

Total Storage Volume (cubic feet) = Surface Storage Volume (cubic feet) + Subsurface Storage Volume (cubic feet)

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 3 feet is required between the bottom of the planter box and the highest known groundwater elevation.

(b.) A minimum of 1 foot is required between the bottom of a lined or underdrained planter box and the highest known groundwater elevation.

(c.) An underdrain shall be provided for design infiltration rates less than 0.50 inches per hour, or if planter box will be lined.

(d.) Void ratio for the amended soil material shall be based on the USDA soil textural class and effective water capacity in ***Table 6***. A maximum design value of 0.30 shall be used for the void ratio of the amended soil material. A maximum design value of 0.40 shall be used for the void ratio of stone.

(e.) No more than 15,000 square feet of impervious area shall be directed to a planter box.

b. Configuration

(1) A combination of surface and subsurface storage may be used to provide the required storage volume.

(2) Minimum width of planter boxes shall be 30 inches.

(3) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

(4) Planter boxes located in areas of existing soil contamination shall be lined to prevent infiltration.

(5) Underdrains shall have a 4-inch minimum pipe diameter.

(6) All underground pipes shall have clean-outs accessible from the surface.

(7) Pipe slopes shall have a minimum slope of 1%.

(8) A planting plan shall be provided.

Planter Box (continued)

c. Inlet Design

(1) Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to a maximum allowable design velocity of 8 feet per second.

d. Emergency Overflow

(1) All planter boxes must have a provision for overflow at the high water level.

e. Materials

(1) Suggested structural elements of planter boxes are stone, concrete, brick or pressure-treated wood.

(2) Amended soil material shall consist of 12 to 36 inches of the following materials, evenly mixed: Compost: 20-40%; Sand: 30-50%; Topsoil: 20-30% (with a clay content of 0-10%).

(a.) Alternative mix designs with ratios outside of the limits provided will be considered with justification.

(b.) The soil mix shall have a pH between 5.5 and 6.5.

(3) Stone bedding shall consist of clean, uniformly graded course aggregate.

(4) A nonwoven geotextile fabric shall be placed between the amended soil and the stone.

(5) Impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

(6) Plant selection shall consider exposure and tolerance to salt, sediment and pollutants, and the design depth of surface storage. Native species are encouraged.

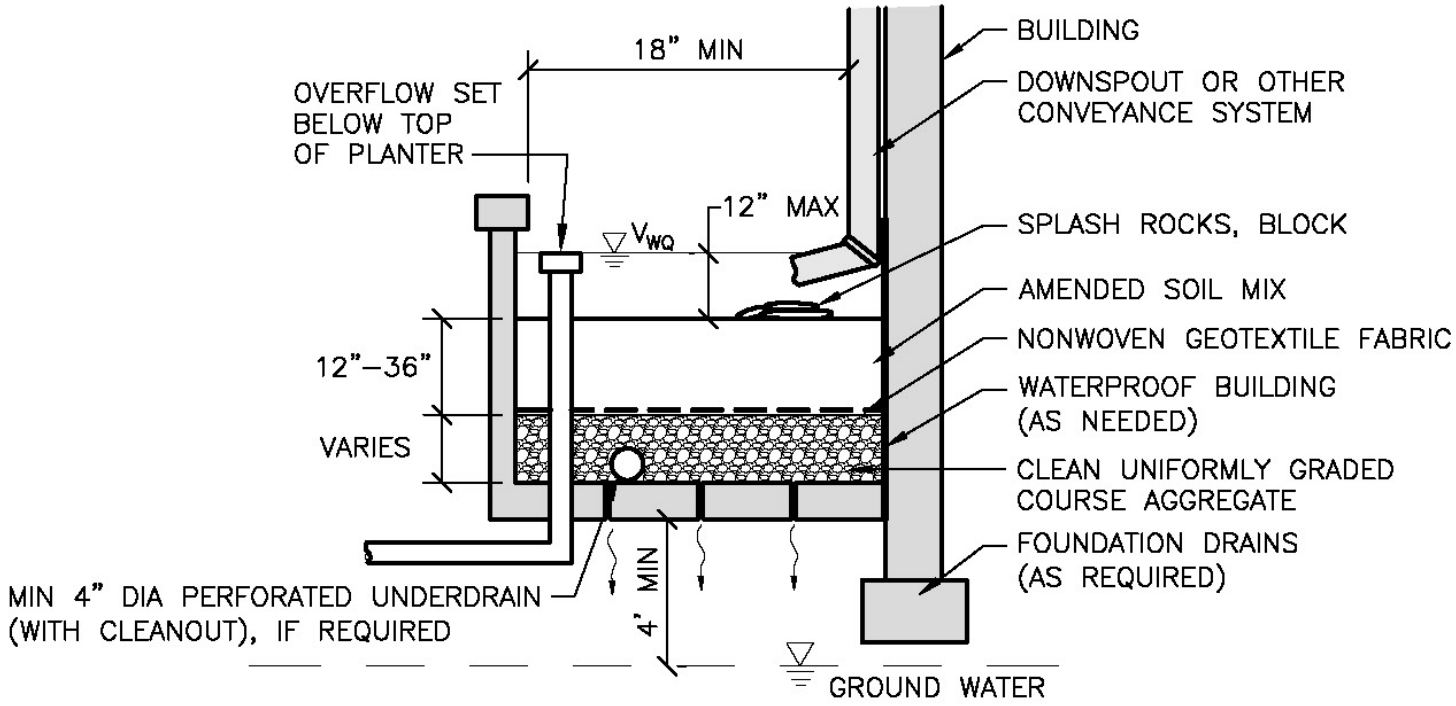
(7) Plants shall be container stock.

f. Access

(1) Inspection and maintenance access to the planter box shall be provided.

4. Design Schematic

PLANTER BOX



PLANTER MAY HAVE AN OPEN BOTTOM OR BE LINED

SECTION

PLANTER BOX MUST BE COMBINED WITH OTHER BMP'S TO MEET WATER QUALITY TREATMENT CRITERIA.

J. Pervious Pavement

1. Summary

Description:	Provides storm water treatment and storage with or without a surface outlet.
Types:	Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; lined.
Pretreatment Required:	No.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Infiltration: Count volume stored and infiltrated (limited by design rainfall on pavement and roof). Underdrained: Count volume stored and volume infiltrated between bottom of BMP and invert of underdrain (limited by design rainfall on pavement and roof).
Rate Reduction:	Infiltration: 100%. Underdrained: Calculated allowable release rate.
Water Quality:	Count total volume stored and infiltrated/filtered (limited by design rainfall on pavement and roof).

2. Sizing Calculations

a. Use the methods outlined in "*Calculating Storage Volumes and Release Rates*" to calculate the required volumes for water quality and channel protection.

b. The required storage volume shall be equal to the volume from a 25-year, 24-hour rainfall event from the contributing surface area (porous pavement, roof).

c. The bottom area of the BMP shall be used as the infiltration area.

d. Maximum allowable drawdown time shall be 72 hours.

e. Calculate the subsurface storage volume of the BMP:

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

f. For underdrained BMP, follow criteria for "Constructed Filter."

3. Design Requirements

a. Siting

(1) Soil borings are required as outlined in "Soils Investigation."

(a.) A minimum of 3 feet is required between the bottom of pervious pavement capable of infiltration and the highest known groundwater elevation.

(b.) A minimum of 1 foot is required between the bottom of lined or underdrained pervious pavement and the highest known groundwater elevation.

(c.) An underdrain shall be provided for design infiltration rates less than 0.50 inches per hour, or if stone bed will be lined.

Pervious Pavement (continued)

(d.) A maximum design value of 0.40 shall be used for the void ratio of stone.

(2) Runoff from offsite areas shall not be directed onto pervious pavement surface.

b. Configuration

(1) The stone bed shall be flat to encourage uniform ponding and infiltration.

(2) For pervious pavements located in areas with steep slopes, stone beds shall be terraced to maximize infiltration area.

(3) Pervious pavements located in areas of existing soil contamination shall be lined to prevent infiltration.

(4) Underdrains shall have a 4-inch minimum pipe diameter with lateral spacing no more than 10 feet.

(5) All underground pipes shall have clean-outs accessible from the surface.

(6) Pipe slopes shall have a minimum slope of 1%.

c. Inlet Design

(1) Pervious pavements shall have a backup method for water to enter the storage bed. Backup drainage may consist of an unpaved 1- to 2-foot wide stone edge or inlets with sediment traps.

d. Emergency Overflow

(1) Stone beds must have a provision for overflow below the level of the pavement surface when an underdrain is not already provided.

e. Materials

(1) Stone bed shall consist of 8 to 36 inches of clean, uniformly graded course aggregate.

(2) A woven geotextile fabric may be placed between the pervious pavement and stone bed. (If a woven geotextile fabric is used, the pervious pavement is considered “lined” for the purpose of meeting water quality treatment standards.)

(3) A nonwoven geotextile fabric shall be placed between the stone bed and the subsoil.

(4) Impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

K. Capture Reuse

1. Summary

Description:	Storm water capture, storage and removal from storm flow by reuse for irrigation or as greywater.
Types:	Rain barrels; Cisterns (both above ground and underground); Tanks; Ponds.
Pretreatment Required:	Yes. This BMP can provide spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count storage volume provided.
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak inflow rate.
Water Quality:	Count total volume stored.

2. Sizing Calculations

a. Determine water use (gallons per day) and add up for each month of the year.

b. Obtain average monthly precipitation (inches) and evapotranspiration (ET) in inches. www.enviroweather.msu.edu

c. Multiply average monthly precipitation by contributing area and area-weighted Small Storm Hydrology Method runoff coefficient (assuming 90% of the storms produce 1 inch of rain or less) to obtain volume of recharge. The Small Storm Hydrology Method is given below:

$$V = PR_v A(3630) \tag{4.27}$$

where:
V = recharge volume (cubic feet)
P = rainfall (inches)
R_v = area-weighted volumetric runoff coefficient (individual runoff coefficients are given in ***Table 10***.)
A = contributing area (acres)
3630 = factor to convert acre-inches to cubic feet

d. Multiply recharge volume by 7.48 gallons per cubic foot to convert to gallons.

e. Calculate ET for open water surfaces. Multiply average monthly ET (inches) by surface area of pond (square feet) and divide by 12 to calculate the volume of water evaporated in cubic feet. Multiply by 7.48 gallons per cubic foot to convert to gallons.

f. Select trial size container or pond volume.

Capture Reuse (continued)

g. Calculate the water balance. A tabular method may be used similar to that illustrated below:

Volume of Water in Storage at End of Month = Storage Volume at Start of Month + Recharge from Monthly Precipitation - ET - Monthly Water Use

Month	Vstart	+Recharge	- ET	- Use	= Vend*	Lost
1						
2	=Vend1					
Total	--				--	

* Limited by total volume of the selected container or pond. If value is greater than container volume, surplus is lost to overflow. If value is negative, it means that amount must be supplemented.

h. Adjust size of container or pond to balance reuse efficiency and cost.

3. Design Requirements

a. Siting

(1) Storage units shall be positioned to receive rooftop runoff.

(2) Protect storage units from direct sunlight to minimize algae growth.

(3) Discharge points and storage units shall be clearly marked “Caution: Untreated Rainwater. Do Not Drink.”

b. Configuration

(1) If storage units are used to supplement greywater needs, a parallel conveyance system must be installed to separate greywater from other potable water piping systems.

(2) Storage units shall be watertight with a smooth interior surface.

(3) Covers and lids shall have a tight fit to keep out surface water, insects, animals, dust and light.

(4) Observation risers shall be provided for buried storage units.

(5) Pumps and pressure tanks may be used to add pressure (most irrigation systems require at least 15 pounds per square inch).

c. Inlet Design

(1) Screens shall be used to filter debris from runoff flowing into the storage unit.

d. Emergency Overflow

(1) A positive outlet for overflow shall be provided a few inches from the top of the storage unit and sized to safely discharge the peak flow from the 10-year design storm when the storage unit is full.

(2) Above-ground storage units shall have a release mechanism to drain and empty the unit between storm events.

L. Vegetated Roof

1. Summary

Description:	Provides storm water treatment and storage with a surface overflow.
Types:	Intensive (> 4 inches, wide variety of plants, public use); Extensive (≤ 4 inches, plants are herbs, mosses, succulents and grasses).
Pretreatment Required:	No. This BMP can provide pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count subsurface storage volume below the overflow (limited by design rainfall on roof).
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak inflow rate.
Water Quality:	Count subsurface storage volume (limited by design rainfall on roof).

2. Sizing Calculations

a. For water quality, the minimum subsurface storage volume shall be equal to the volume from 1-inch of rain falling on the roof area.
b. For channel protection, the subsurface storage volume below the overflow may be counted as retention.
c. Calculate the subsurface storage volume of the BMP:

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material.

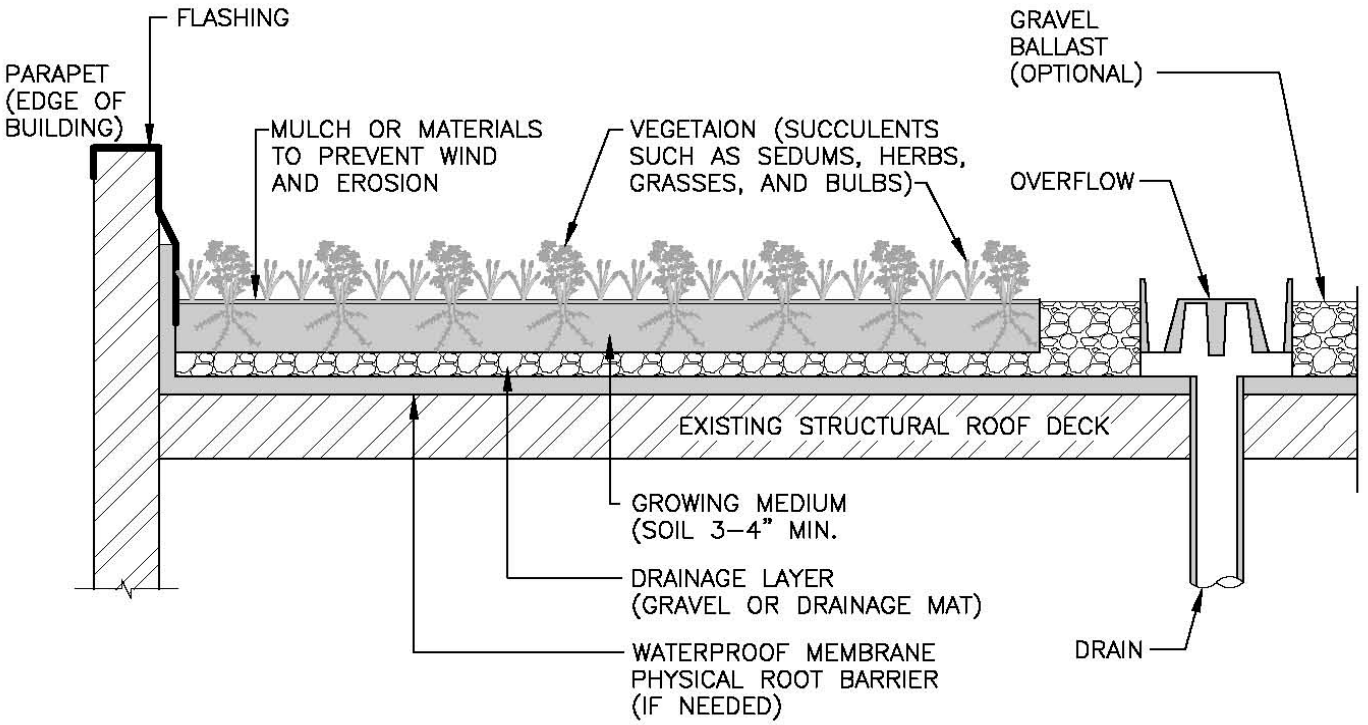
3. Design Requirements

a. Configuration
   (1) Follow manufacturer's and structural engineer's guidelines.

b. Emergency Overflow
   (1) A positive outlet for overflow shall be provided.

4. Design Schematics

VEGETATED ROOF



"EXTENSIVE" TYPE SHOWN

SECTION

M. Water Quality Device

1. Summary

Description:	Storm water pretreatment unit.
Types:	Filtration; Settling; Hydrodynamic Separator.
Pretreatment Required:	No. This BMP can provide pretreatment and spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	Provide test results on pollutant removal efficiency from the independent testing of: http://www.njcat.org/verification-process/technology-verification-database.html

2. Sizing Calculations

a. Select water quality device unit/model based on manufacturer's recommendations.

3. Design Requirements

a. Configuration

(1) The geometry of the water quality device shall promote the trapping of floatables, sediments and capture of a slug pollutant load from accidental spills of toxic materials.

(2) The water quality device shall be designed to prevent surcharging in pipes upstream of the device.

b. Emergency Overflow

(1) A bypass overflow shall be designed to convey the 10-year peak discharge at a minimum without release of trapped sediments and pollutants.

(2) The outlet from the overflow shall not be submerged under normal conditions.

N. Sediment Forebay

1. Summary

Description:	Storm water pretreatment practice.
Types:	Wet basin; Dry basin; Level spreader.
Pretreatment Required:	No. This BMP can provide pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	Count permanent pool volume if sized to meet water quality standards.

2. Sizing Calculations

a. Size for pretreatment using equation given in "Calculating Storage Volumes and Release Rates, Pretreatment."

3. Design Requirements

a. Siting

(1) A sediment forebay is typically used with a detention or retention basin.

(2) Where more than one inlet pipe is required, the calculated forebay volume shall be pro-rated by flow contribution of each inlet.

b. Configuration

(1) The sediment forebay shall be a separate sump, which can be formed by grading.

(2) The length-to-width ratio shall be a minimum of 1.5:1 and a maximum of 4:1.

(3) The overflow berm or spillway shall be designed to prevent erosion.

4. Design Schematics

See "Detention Basin" and "Retention Basin" BMPs.

O. Spill Containment Cell

1. Summary

Description:	Storm water pretreatment practice.
Types:	Lined wet basin.
Pretreatment Required:	No. This BMP can provide pretreatment and spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	Count permanent pool volume if sized to meet water quality standards.

2. Sizing Calculations

a. Size for pretreatment using equation given in "Calculating Storage Volumes and Release Rates, Pretreatment."

3. Design Requirements

a. Siting

(1) Where spill containment is required, all inlets shall enter the spill containment cell unless the inlet collects storm water exclusively from non-hot-spot areas (i.e. office parking, courtyard, roof.)

b. Configuration

(1) The maximum depth shall be 4 feet.

(2) The length-to-width ratio shall be a minimum of 3:1, and a maximum of 4:1 to allow for adequate hydraulic length yet minimize scour velocities.

(3) The minimum hydraulic length shall be equal to the length specified in the length-to-width ratio.

(4) The minimum diameter of the transfer pipe between the spill containment cell and the basin shall be 12 inches.

(5) The overflow structure from the spill containment cell shall be sized for the peak inflow from a 10-year rainfall event.

(6) The top-of-berm elevation between the spill containment cell and the basin shall be a minimum of 1 foot below the outer berm elevation.

(7) The spill containment cell shall have a minimum 1-foot-deep sump below the inlet pipe for sediment accumulation.

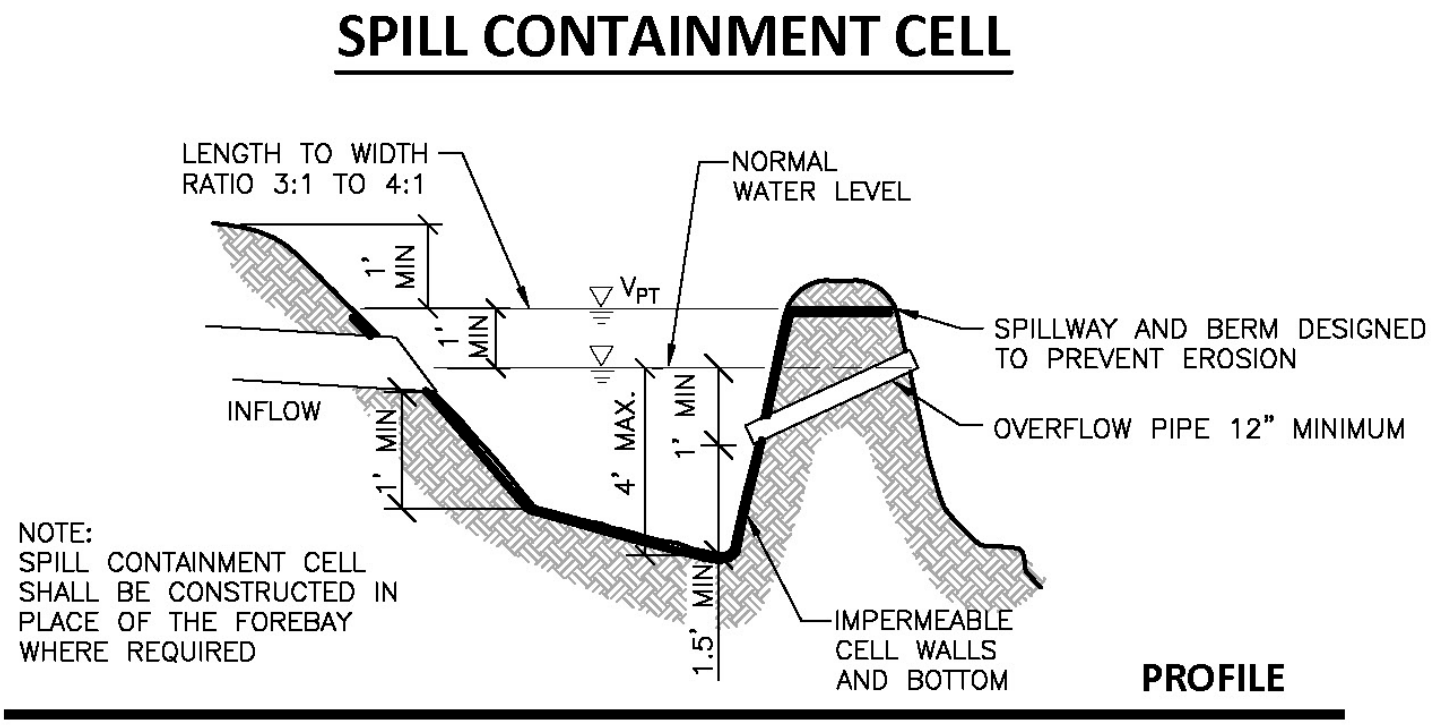
(8) The outlet structure from the spill containment cell shall be designed to draw water from the central portion of the water column within the cell to trap floatables and contain sediments. The inlet side of the structure shall be located a minimum of 1 foot below the normal water level, and a minimum of 1.5 feet from the bottom of the spill containment cell. Minimum depth of the permanent pool is 2.5 feet.

Spill Containment Cell (continued)

c. Materials

(1) The spill containment cell shall be lined with impermeable materials extending up to the design high water elevation. A minimum 18-inch-thick clay layer, or an impermeable liner protected with a minimum 12 inches of soil cover are acceptable alternatives. Maximum allowable permeability shall be 1 x 10^{-7} centimeters per second as determined by the geotechnical consultant for clay placement, or manufacturer's certificate for liner products.

4. Design Schematic



P. Water Quality Swale

1. Summary

Description:	Lined storm water filter designed to provide spill containment; May be allowed on small sites in lieu of extended detention.
Types:	Dry swale.
Pretreatment Required:	Yes. This BMP can also provide pretreatment and spill containment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate.
Water Quality:	Count storage volume if sized to meet water quality standards.

2. Sizing Calculations

a. Size for pretreatment using equation given in "Calculating Storage Volumes and Release Rates, Pretreatment."

3. Design Requirements

a. Siting
   (1) Water quality swales can be used where spill containment is required on small sites or in lieu of a spill containment cell.
   (2) Where spill containment is required, all inlets shall enter the water quality swale unless the inlet collects storm water exclusively from non-hot-spot areas (i.e. office parking, courtyard, roof).

b. Configuration
   (1) The swale shall be designed for a maximum water depth of 3 feet.
   (2) The swale shall have a minimum bottom width of 2 feet and a maximum bottom width of 8 feet.
   (3) Side slopes shall be 3:1 (H:V) or flatter.
   (4) Minimum thickness of the sand filter shall be 24 inches with a minimum of 6 inches of stone bedding.

c. Inlet Design
   (1) Inlets shall enter a water quality device or forebay.

d. Outlet Design
   (1) The outlet structure shall be constructed within a catch basin and be designed to draw water from the central portion of the water column within the catch basin to trap floatables and contain sediments in a minimum 2-foot sump.
   (2) The rim elevation of the catch basin shall be designed high enough to contain the required volume of water within the swale (pretreatment volume, water quality volume, etc.)
   (3) The swale and outlet shall be designed to pass the 10-year peak discharge.

e. Emergency Overflow
   (1) A positive outlet for overflow shall be provided a few inches from the top of the storage unit and sized to safely discharge the peak flow from the 10-year design storm when the storage unit is full.

Water Quality Swale (continued)

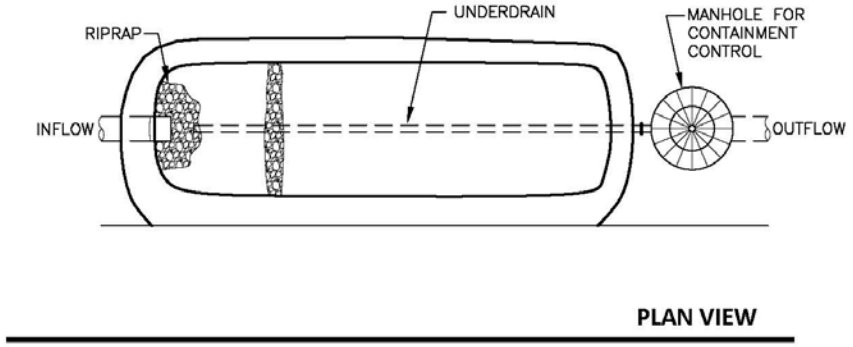
f. Materials

(1) A 4-inch perforated underdrain shall be placed along the center length of the swale and bedded in stone.

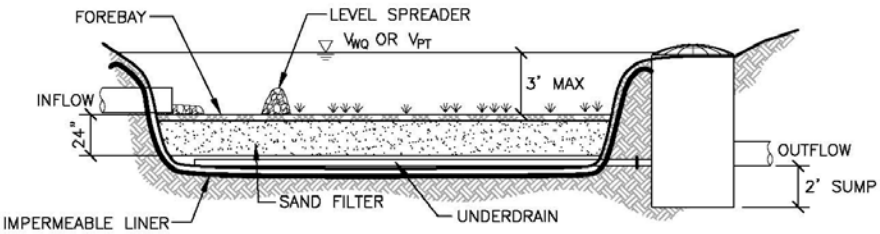
(2) The water quality swale shall be lined with impermeable materials extending up to the design high water elevation. A minimum 18-inch-thick clay layer, or an impermeable liner below the stone layer are acceptable alternatives. Maximum allowable permeability shall be 1×10^{-7} centimeters per second as determined by the geotechnical consultant for clay placement, or manufacturer's certificate for liner products.

4. Design Schematics

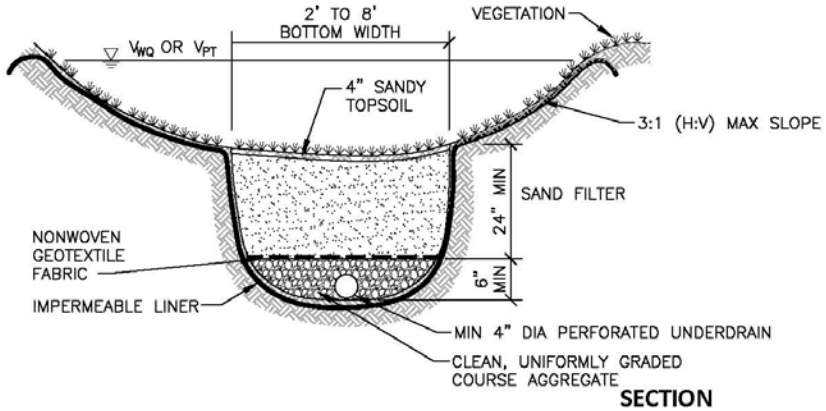
WATER QUALITY SWALE



PLAN VIEW



PROFILE



SECTION

R. Vegetated Swale

1. Summary

Description:	Storm water conveyance designed to slow, filter and infiltrate storm water.
Types:	Dry swale; Wetland swale.
Pretreatment Required:	No. This BMP provides pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	Count storage volume behind check dams (if any).
Rate Reduction:	Due to longer time-of-concentration for swale.
Water Quality:	Count storage volume behind check dams; Count as being met if vegetated swale meets filter strip length and slope requirements.

2. Sizing Calculations

a. Channel

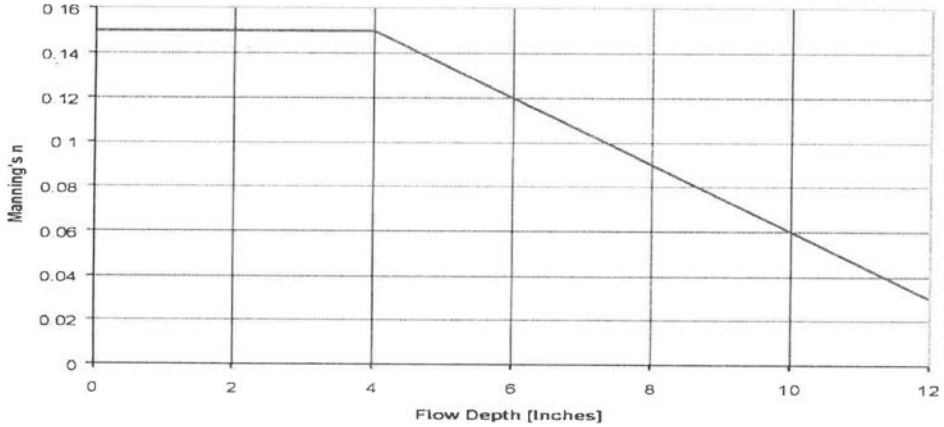
(1) The vegetated swale shall be sized to pass the 10-year peak flow.
(2) Calculate 10-year peak flow rate using the equations given in "Calculating Runoff."
(3) Size swale using Manning's Equation:

$$Q = \frac{1.49 A R^{\frac{2}{3}} S^{\frac{1}{2}}}{n} \quad (4.22)$$

where:
Q = discharge (cubic feet per second)
A = wetted area (square feet)
R = hydraulic radius (feet)
S = slope (feet per foot)
n = Manning's roughness coefficient

(4) Select the more conservative (higher) value of Manning's roughness coefficient from ***Table 13*** or ***Figure 2*** below.

Figure 2 – Manning's Roughness Coefficients for Vegetated Swales



Source: Figure 7.62, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (Schueler and Claytor, 1996.)

Vegetated Swale (continued)

(5) Check that flow velocities are within acceptable limits. The minimum velocity for open channels shall be 1.5 feet per second. The maximum velocity shall be 4 feet per second.

b. Volume Behind Check Dam (if used)

(1) Calculate the wedge-shaped storage volume behind each check dam.

Storage Volume (cubic feet) = 0.5 x Length of Swale Impoundment Area per Check Dam (feet) x Depth of Check Dam (feet) x [Top Width of Check Dam (feet) + Bottom Width of Check Dam (feet)] / 2

3. Design Requirements

a. Siting

(1) Vegetated swales can be used for drainage areas up to 5 acres. Drainage areas greater than this may require open channels.

b. Configuration

(1) The swale shall have a minimum bottom width of 2 feet and a maximum bottom width of 8 feet.

(2) The maximum bottom width to depth ratio for a trapezoidal swale shall be 12:1.

(3) Side slopes shall be 3:1 (H:V) or flatter.

(4) Longitudinal slope shall be a minimum of 1% and a maximum of 6%. Flatter slopes may be allowed on permeable soils.

c. Check Dam Design

(1) Check dams may be used along vegetated swales with longitudinal slopes greater than 3%, or to encourage ponding and infiltration on flatter slopes.

(2) Maximum ponding depth behind check dams shall be 18 inches.

(3) Check dams shall be keyed into the bottom and sides of the swale a minimum of 1-foot on all sides. The height of the key must exceed the 10-year water surface elevation by a minimum of 6 inches on both sides.

(4) The center of the check dam crest must be below the sides of the check dam by a minimum of 12 inches.

d. Materials

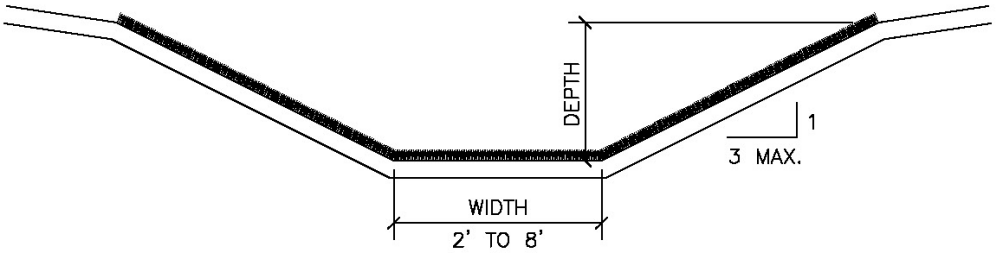
(1) Establishment of vegetation shall follow the guidelines outlined in ***Table 16*****.**

Table 16 - Permanent Stabilization Treatment for Vegetated Swales

Swale Bottom Treatment	Swale Grade
Seed and Mulch	0.3% to 0.5%
Standard Mulch Blanket	0.5% to 1.5%
High Velocity Mulch Blanket or Sod	1.5% to 3.0%
Turf Reinforcement Mat or Check Dams	3.0% to 6.0%
Specific Design Required	> 6.0%
Source: *Michigan Department of Transportation Drainage Manual,* 2006.	

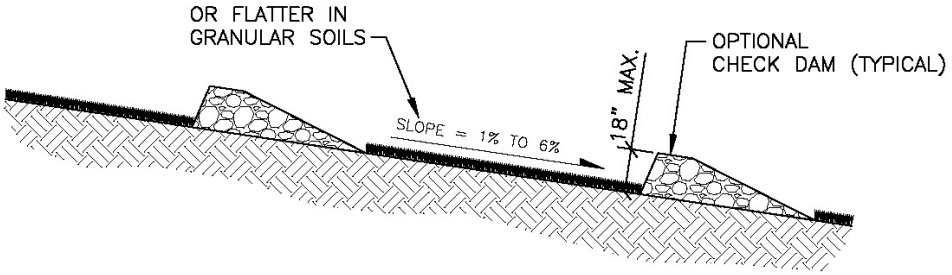
4. Design Schematics

VEGETATED SWALE

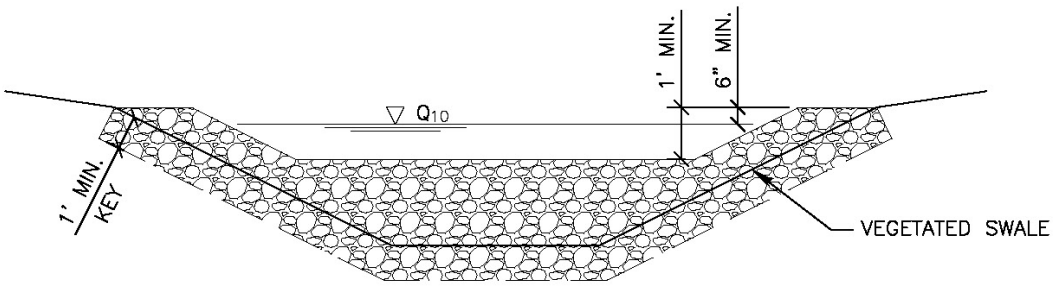


MAX. WIDTH TO DEPTH RATIO = 12:1

SECTION



PROFILE



CHECK DAM DETAIL

R. Vegetated Filter Strip

1. Summary

Description:	Overland flow path designed to slow and filter storm water.
Types:	Turf grass; other dense herbaceous groundcover vegetation.
Pretreatment Required:	No. This BMP provides pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	Adjust time-of-concentration.
Water Quality:	Count as being met if filter strip meets area, length and slope requirements.

2. Sizing Calculations

a. Calculate the area contributing storm water runoff.

b. Calculate the minimum required filter strip area by the equation:

$$A_{fs} = \frac{A}{6} \tag{4.28}$$

where:
A_{fs} = area of filter strip (square feet)
A = contributing drainage area (square feet)

c. Calculate minimum required longitudinal length based on slope and type of vegetation using the graphs in ***Figures 3a*** through ***3d***.

3. Design Requirements

a. Siting

(1) Maximum upstream drainage area shall generally be 100 feet impervious or 200 feet pervious up-gradient.

b. Configuration

(1) The upstream edge of the filter strip shall be level and at an elevation at least 1 inch below the adjacent pavement.

(2) A level spreader may also be required to evenly distribute flow across filter strip.

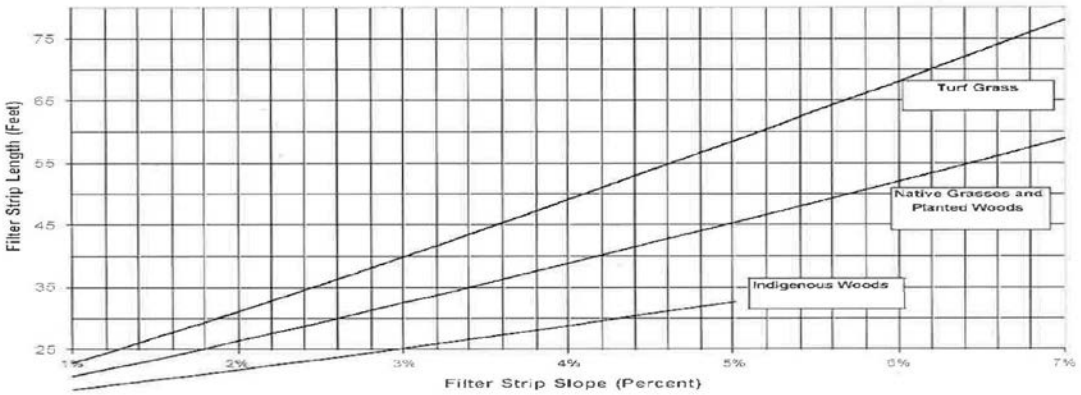
(3) Slopes shall range from a minimum of 1% to a maximum of 8%. Optimal slopes range from 2% to 5%.

(4) The maximum lateral slope shall be 1%.

(5) Berms and curbs may be installed along the sides of the filter strip parallel to the direction of flow to prohibit runoff from laterally bypassing the filter strip.

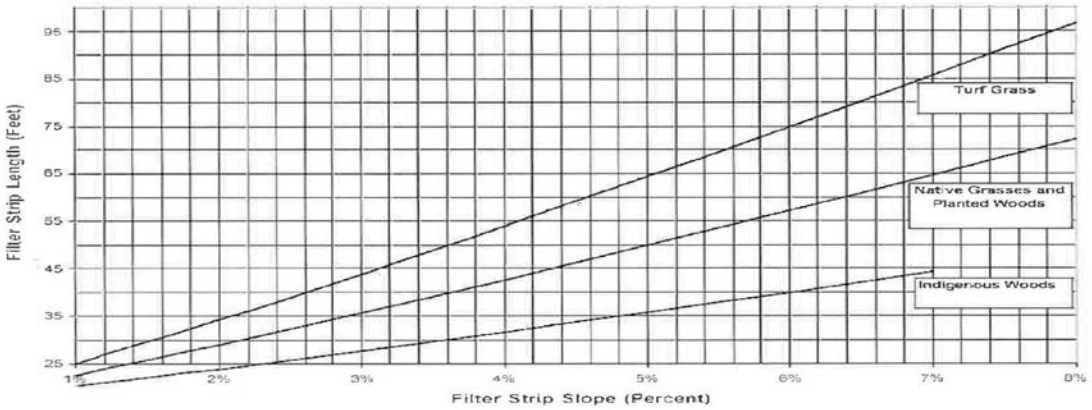
Vegetated Filter Strip (continued)

Figure 3a – Filter Strip Length (Sandy soils with HSG A)



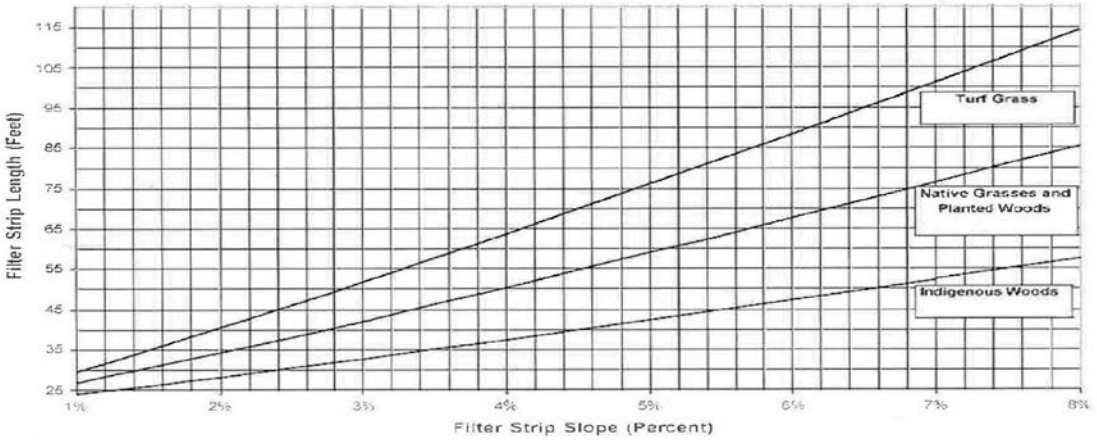
Source: Figure 7.52, *Low Impact Development Manual for Michigan,* SEMCOG, 2008.
(*New Jersey Storm Water Best Management Practices Manual*, 2004)

Figure 3b1 – Filter Strip Length (Sandy Loam soils with HSG B)



Source: Figure 7.53, *Low Impact Development Manual for Michigan,* SEMCOG, 2008.
(*New Jersey Storm Water Best Management Practices Manual*, 2004)

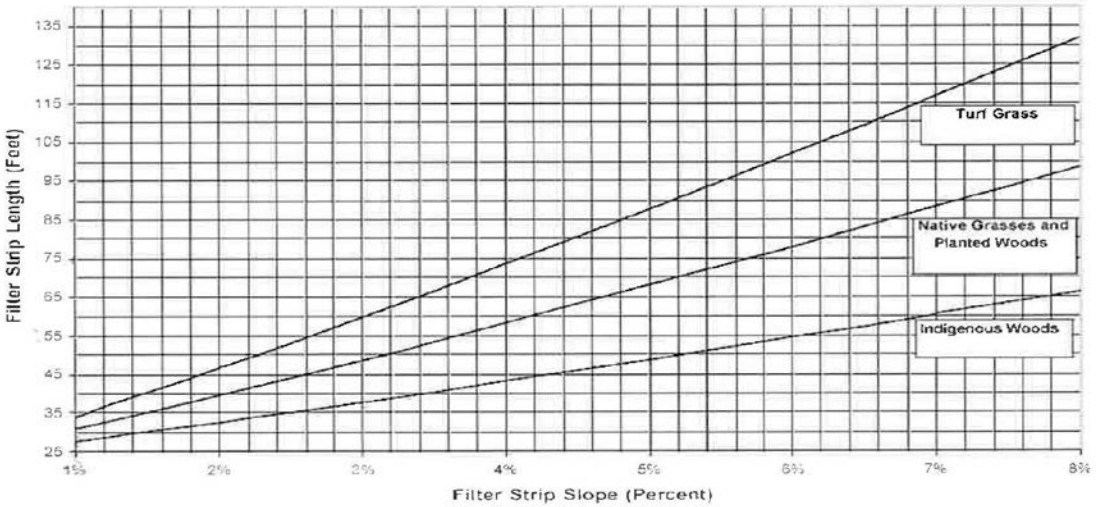
Figure 3b2 – Filter Strip Length (Loam, Silt-Loam soils with HSG B)



Source: Figure 7.54, *Low Impact Development Manual for Michigan,* SEMCOG, 2008.
(*New Jersey Storm Water Best Management Practices Manual*, 2004)

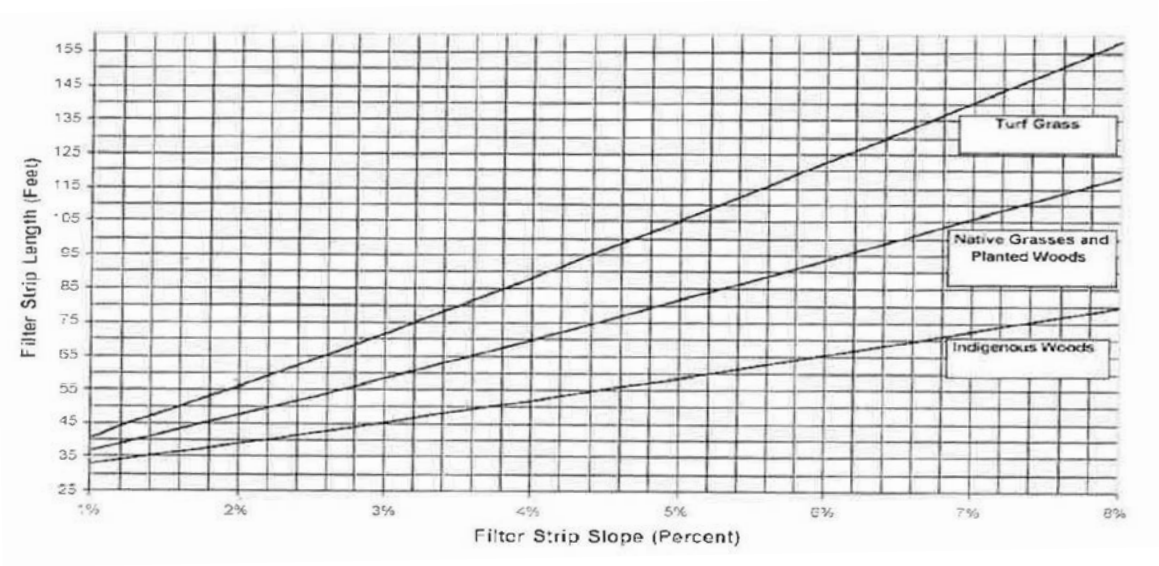
Vegetated Filter Strip (continued)

Figure 3c – Filter Strip Length (Sandy Clay Loam soils with HSG C)



Source: Figure 7.55, *Low Impact Development Manual for Michigan,* SEMCOG, 2008.
(*New Jersey Storm Water Best Management Practices Manual*, 2004)

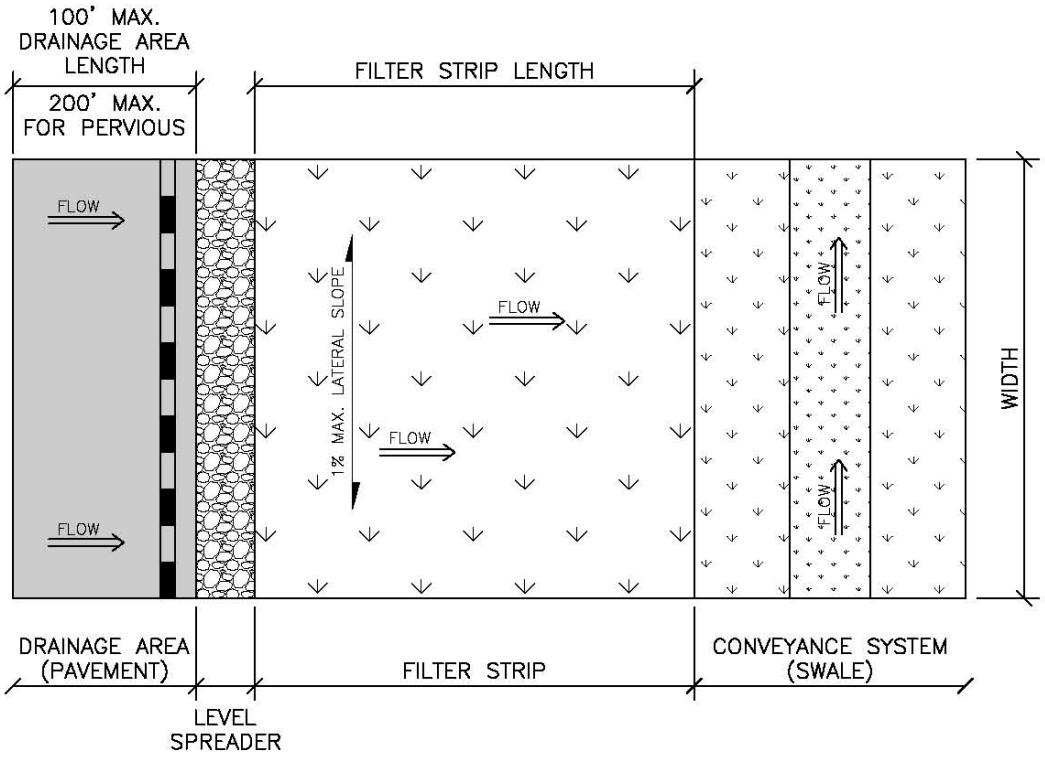
Figure 3d – Filter Strip Length (Clay Loam, Silty Clay, Clay soils with HSG D)



Source: Figure 7.56, *Low Impact Development Manual for Michigan,* SEMCOG, 2008.
(*New Jersey Storm Water Best Management Practices Manual*, 2004)

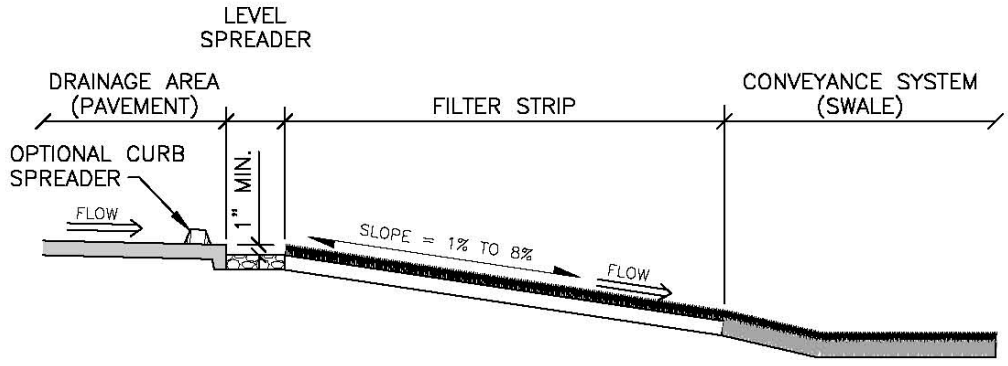
4. Design Schematics

VEGETATED FILTER STRIP



MIN. FILTER STRIP AREA = 1/6 DRAINAGE AREA.

PLAN VIEW



PROFILE

S. Level Spreader

1. Summary

Description:	Used with other BMPs to disperse concentrated storm water flows.
Types:	Inflow (prior to BMP); Outflow (at outlet of BMP).
Pretreatment Required:	No. This BMP provides pretreatment.
Maintenance Plan:	Yes.
Calculation Credits:	
Volume Reduction:	None.
Rate Reduction:	None.
Water Quality:	None.

2. Sizing Calculations

a. The level spreader shall be sized to pass the 10-year peak flow.

b. Calculate 10-year peak flow rate using the equations given in “Calculating Runoff.”

3. Design Requirements

a. Siting

(1) Slopes below outflow level spreaders should be no greater than 8% in the direction of flow to discourage channelization.

b. Configuration

(1) Construct level spreaders in compacted fill or of other non-erodible material.

(2) Minimum length: 10 feet.

(3) A bypass may be required for higher flows.

c. Material

(1) Level spreaders may be constructed of compacted earth, rock, stone, concrete, treated timber or perforated pipe in stone.

APPENDIX 1 WATERSHED POLICY STATEMENTS

- Cedar Creek Watershed
- Ruddiman Creek Watershed

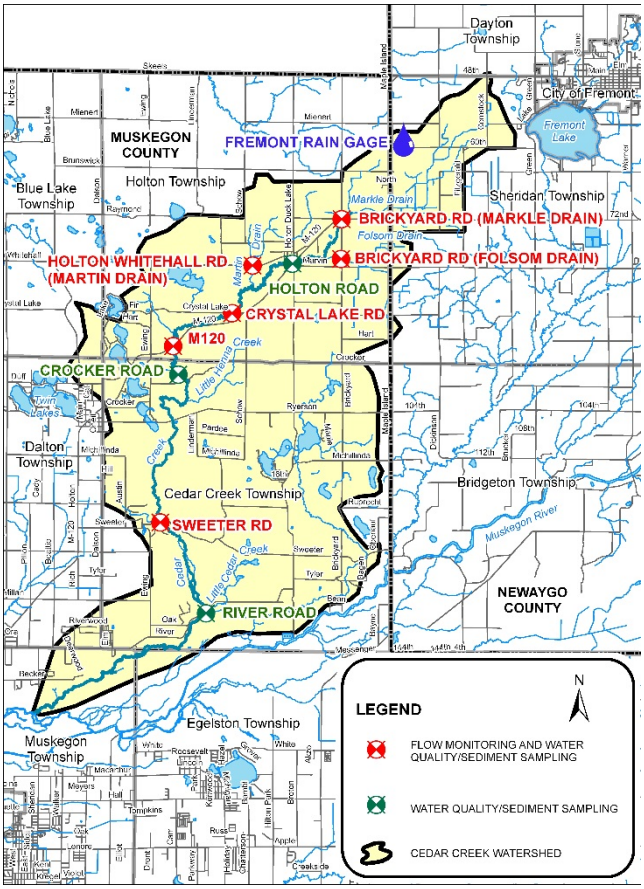
WATERSHED POLICY STATEMENTS

Last Update: August 2016

I. Cedar Creek Watershed

A. BACKGROUND AND PURPOSE

The Cedar Creek watershed is located in portions of Holton, Cedar Creek, Dalton, Egelston and Muskegon Townships in Muskegon County, and extends into Dayton Township in Newaygo County. Cedar Creek is a tributary of the Muskegon River, and supports a superb high quality coldwater fishery.



In 2008, the Muskegon River Watershed Assembly received a Michigan Department of Natural Resources / Consumers Energy Habitat Improvement Account Grant to study the effects of hydrologic changes in the Cedar Creek watershed on the coldwater fishery supported by Cedar Creek.

Conclusions are taken from the study report “Protection and Restoration of Natural Hydrologic functions of Cedar Creek, Muskegon and Newaygo Counties, Michigan” prepared for the Muskegon River Watershed Assembly and dated March 28, 2011.

The purpose of the design criteria included in this section is to protect the coldwater fishery supported by Cedar Creek from the detrimental effects of changes in hydrology due to urbanization, and mitigate the effects of previous hydrologic changes in the upper watershed.

B. CONCLUSIONS

Conclusions from the report relative to stormwater management policy for planned new developments and redevelopments are summarized below:

1. New development predicted between 1998 and 2030 produces a measurable increase in 2-year watershed yields. The greatest change to land use in the Cedar Creek watershed in an increase in the amount of urbanization. Urban land use the in the Cedar Creek watershed is expected to double between 1998 and 2030 (Fongers, 2004). Modeling results indicate that watershed yields will increase by 12% on average upstream of M-120 due to urbanization, and exceed very stable existing/pre-settlement yield values downstream of M-120. This is important because although the increase shown downstream of M-120 is slight, it is the conversion of groundwater flow to surface runoff that has the real impact. In summary, increased urbanization will further degrade hydrologic conditions in Cedar Creek and controls will be needed to prevent this.

2. Stormwater management policy guidelines base on LID standards should be effective at reversing the impact of urbanization in the Cedar Creek watershed. A policy that provides for no net increase in the volume of runoff from a 2-year storm between post-development pre-settlement (woods and meadow) conditions, and 24-hour extended detention of the 1-year storm where soils are not conducive to infiltration is effective to maintain watershed yields after build-out at existing values, and may provide some reduction in watershed yield. This is sufficient to meet fisheries goals downstream of M-120. However, the hydrology upstream of M-120 is already highly altered and has impacted upper reaches of Cedar Creek.

3. Regionally distributed detention upstream of Brickyard Road in conjunction with LID practices for future development is required to meet the fishery target. Because the upper watershed already has extensive agriculture and existing urban development, and because soils in these two subwatersheds naturally produce higher yield values, controls on new development alone are not enough to reduce watershed yields to below the coldwater fishery target of 0.0075 cfs/acre.

C. DESIGN CRITERIA

It is important that Holton, Cedar Creek, Dalton, Egelston and Muskegon Townships provide review authority to the Muskegon County Drain Commissioner by resolution, or codify in an ordinance, site plan review per the *Muskegon County Site Development Rules* of all development subject to township review.

The following criteria shall apply for all new developments and redevelopments subject to review under these standards and located within the Cedar Creek watershed:

1. Standard design criteria for channel protection with an emphasis on infiltration and urban trees.

2. Standard design criteria for coldwater fisheries shall be applied throughout the Cedar Creek watershed.

D. REGIONAL STORMWATER MANAGEMENT

Implementation of a regional stormwater management basin or basins upstream of Brickyard Road along the Markle and Folsom Drains is an important objective for the Cedar Creek watershed.

II. Ruddiman Creek Watershed

A. BACKGROUND AND PURPOSE

The Ruddiman Creek watershed is located in portions of the Cities of Muskegon, Norton Shores, Roosevelt Park and Muskegon Heights. Ruddiman Creek discharges to Muskegon Lake and is located with the Muskegon Lake Area of Concern (AOC). Ruddiman Creek is presently not meeting its designated uses for wildlife, other indigenous aquatic life, and as a warm water fishery due primarily to a poor macroinvertebrate community. Ruddiman Creek is also not meeting its designated uses for fish consumption, and total and partial body contact.

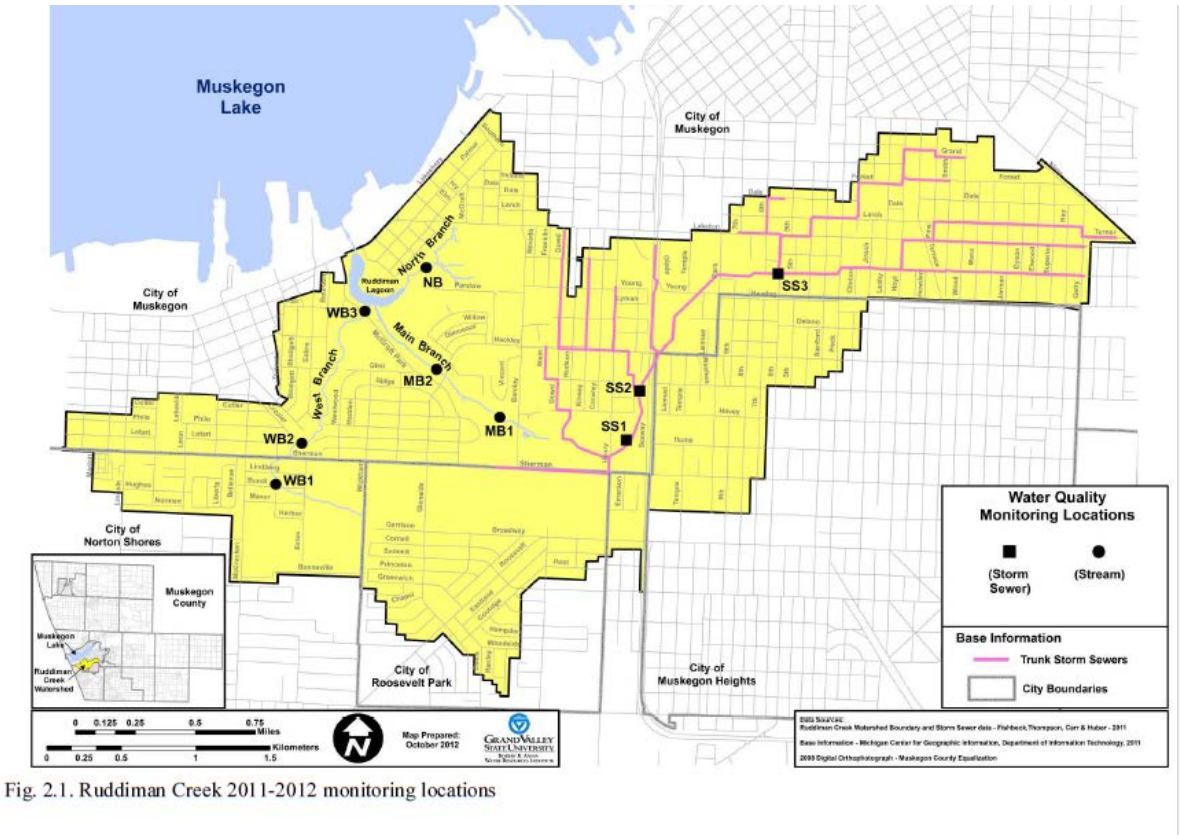


Fig. 2.1. Ruddiman Creek 2011-2012 monitoring locations

In 2010, the Grand Valley State University (GVSU) Annis Water Resources Institute (AWRI) received a FY 2010 Great Lakes Restoration Initiative (GLRI) grant to conduct studies to support a Ruddiman Creek Implementation-Ready Total Maximum Daily Load (TMDL) for biota to address the wildlife, other indigenous aquatic life, and warmwater fishery designated uses.

Conclusions are taken from the final report "Studies to Support an Implementation-Ready TMDL for Ruddiman Creek" dated February, 2013. The technical information included in the report was used to support the Michigan Department of Environmental Quality (DEQ) in the development of a TMDL for biota.

The poor macroinvertebrate community was attributed primarily to the flashiness of the watershed hydrology (Nederveld, 2009), therefore a hydrologic surrogate was used for the biota TMDL. The relationship between flashiness and Directly Connected Impervious Area (DCIA) was used to develop TMDL targets in terms of percent reduction in DCIA needed to reduce flashiness and improve biota.

A spreadsheet application referred to as a Scoping Tool was developed to relate P-51 macroinvertebrate scores with a Richards-Baker Flashiness Index (FI). The Scoping Tool was also used to relate changes in the amount of DCIA to changes in the FI by subwatershed. A BMP inventory sheet is included to account for progress made towards meeting the TMDL.

The purpose of the design criteria included in this section is to account for reductions in DCIA to reduce the flashiness of stormwater runoff associated with urbanization to meet TMDL targets and improve biota in Ruddiman Creek.

B. CONCLUSIONS

The Ruddiman Creek watershed is highly urbanized; impervious cover from developed land is over 50%, far exceeding the 10-15% threshold that has been suggested to cause biotic impairment in streams (Wang et al. 2001). As a consequence, the tributaries in the Ruddiman Creek watershed are subject to altered hydrology, characterized by high flashiness. The unnatural flow regime can physically dislodge benthic organisms; mobilize sediment, causing habitat impairment; and transport previously buried or sequestered contaminants, rendering them bioavailable to organisms (cf. Cooper et al. 2009; Johnson et al. 2011).

In terms of sediment, the primary form of sediment transported by storm flows is suspended sediment. Monitoring indicated that all branches of Ruddiman Creek meet the "Good to Moderate" threshold (≤ 80 mg/L) for annual mean suspended sediment concentrations (SSC) suggested by Alabaster and Lloyd (1982) for protection of fish communities. However, short term increases in SSC during storm events are much higher and may cause impacts to aquatic communities. Improvements in watershed hydrology resulting from BMPs are projected to reduce SSC by 25-50%.

C. TMDL

A biota TMDL for Ruddiman Creek has not been accepted by the United States Environmental Protection Agency (EPA), and therefore has not been implemented by the DEQ. However, loading capacities identified in the study are still recommended to restore the identified designated uses. Loading capacities for each branch of Ruddiman Creek are summarized in Table 5.3 from the report:

Branch	Current Percent DCIA	Fraction DCIA Reduced*	WLA + LA	MOS	LC
Main	21%	0.35	13.5%	1.2	**12%**
North	7.5%	0.52	3.6%	1.2	**2.9%**
West	16%	0.68	5.0%	1.2	**2.8%**

DCIA = Directly Connected Impervious Area
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
MOS = Margin of Safety
LC = Load Capacity (the greatest amount of DCIA the watershed can support without violating the stream's aquatic life criteria)
*Modeling a Benchmark Scenario identified the reduction in DCIA needed to achieve reductions in FI resulting in minimum acceptable P51 macroinvertebrate scores.

D. DESIGN CRITERIA

The following criteria shall apply for all new developments and redevelopments subject to review under these standards and located within the Ruddiman Creek watershed:

1. Standard design criteria for water quality and channel protection with an emphasis on reducing DCIA. **An increase in DCIA is not allowed.** The design engineer must treat any additional DCIA so it is effectively "reduced."

2. DCIA is considered effectively "reduced" when:

    a. Impervious surfaces are physically removed and replaced with pervious surfaces.
    b. Impervious surfaces are disconnected from the storm sewer system by routing runoff to pervious area meeting minimum size, length and slope requirements (e.g., a rain barrel with an overflow directed to yard, away from the storm sewer).
    c. Impervious surfaces are disconnected from the storm sewer system by routing runoff to an infiltration BMP sized for the channel protection volume.
    d. An underdrained LID BMP (e.g., rain garden, porous pavement, green roof) is engineered and implemented for channel protection and volume reduction with a hold time no less than 72 hours.

E. SCOPING TOOL

For redevelopments (and new developments if applicable) impacting existing DCIA, the design engineer shall complete the BMP Inventory Sheet in the Scoping Tool spreadsheet application and submit this documentation with the design calculation package.

APPENDIX 2 ACRONYMS ABBREVIATIONS & DEFINITIONS

A. Acronyms

ASTM	American Society for Testing and Materials
BMP	Best Management Practice
CAD	Computer Aided Design
CN	Curve Number
ET	Evapotranspiration
EPA	Environmental Protection Agency
GASB	Governmental Accounting Standards Board
GIS	Geographic Information System
HSG	Hydrologic Soil Group
LID	Low Impact Development
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
MS4	Municipal Separate Storm Sewer
NAISC	North American Industry Classification System
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
O&M	Operation and Maintenance
PA	Public Act
SEMCOG	Southeast Michigan Council of Governments
SESC	Soil Erosion and Sedimentation Control
SWPPI	Storm water Pollution Prevention Initiative
TMDL	Total Maximum Daily Load
TR-55	Technical Release 55
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

B. Units

ft (′)	feet	hr	hour
in (″)	inches	H:V	horizontal to vertical
ac	acre	in/hr	inches per hour
cfs	cubic feet per second	mg/L	milligrams per liter
cft	cubic feet	min	minute

DEFINITIONS

County: County of Muskegon, State of Michigan.

County Register of Deeds: The Muskegon County Register of Deeds.

County Road Commission: The Muskegon County Road Commission.

Design Engineer: The licensed professional engineer retained by the Proprietor to design the site plan for a plat or any other land development, including storm water management and drainage.

Drain Commissioner: The Drain Commissioner of the County of Muskegon, State of Michigan.

Health Department: The Muskegon County Health Department.

Proprietor: Any person, landowner, firm, association, partnership, corporation, or combination of any of them, who submits a site plan for drainage review (may also be referred to as the Developer).

Review Engineer: The engineer appointed by the Drain Commissioner to review the storm water management and drainage elements of a plat or any other land development.