CASS COUNTY
DRAIN COMMISSIONER

SITE DEVELOPMENT RULES

Procedures and Design Standards for Storm Water Management

Cass County Drain Commissioner
120 N. Broadway
Cassopolis, Michigan 49031

Jan 2025

TABLE OF CONTENTS

TABLE OF CONTENTS

PART 3: STORM WATER DESIGN STANDARDS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF WORKSHEETS

LIST OF FIGURES

TABLE OF CONTENTS

LIST OF APPENDICES

LETTER OF INTENT

CASS COUNTY DRAIN COMMISSIONER
PURSUANT TO SECTION 105
OF ACT 288 OF PUBLIC ACTS
OF MICHIGAN OF 1967

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 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 without of these subdivisions.

IT IS HEREBY ORDERED that the Cass 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, are hereby adopted and shall be followed in the processing of all subdivision plats, and all other land developments (such as condominiums, planned unit developments, manufactured housing communities, and other residential, commercial, industrial, or institutional developments) which impact established county or intercounty drains under the jurisdiction of the Cass County Drain Commissioner pursuant to the Michigan Drain Code (Act 40 of the Public Acts of 1956, as amended), or for which the Cass County Drain Commissioner provides support to other state, county, or local reviewing agencies.

IT IS HEREBY FURTHER ORDERED that the effective dates of the following rules shall be the 1st day of June 2024.

Jeff VanBelle
Cass County Drain Commissioner

ABBREVIATIONS

A. *Acronyms*

ASTM – American Society for Testing and Materials
BMP – Best Management Practice
CAD – Computer Aided Design
CN – Curve Number
EPA – Environmental Protection Agency
GASB – Governmental Accounting Standards Board
HSG – Hydrologic Soil Group
LID – Low Impact Development
MDNRE – Michigan Department of Natural Resources and Environment
MDOT – Michigan Department of Transportation
MS4 – Municipal Separate Storm Sewer
MSL – Mean Sea Level
NAISC – North American Industry Classification System
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resource Conservation Service
OSHA – Occupational Safety and Health Administration
PA – Public Act
SEMCOG – Southeast Michigan Council of Governments
SESC – Soil Erosion and Sedimentation Control
SWPPI – Storm Water Pollution Prevention Initiative
TSS – Total Suspended Solids
USDA – United States Department of Agriculture
USGS – United States Geological Survey

B. *Units*

′ – feet
″ – inches
cfs – cubic feet per second

DEFINITIONS

Drain Commissioner: The Drain Commissioner of the County of Cass, State of Michigan.

Engineer: The engineer appointed by the Drain Commissioner to review the drainage of a plat or any other land development.

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).

Health Department: The Van Buren & Cass County District Health Department.

County Register of Deeds: The Cass County Register of Deeds.

County Road Commission: The Cass County Road Commission.

AUTHORITY

A. Land Division Act (formerly Subdivision Control Act)

1. All plats recorded with the Register of Deeds must conform to the 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 drainage or storm water management 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.
2. 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.
3. 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. Condominium Act

The general standards set forth herein will be applied by the Drain Commissioner in review of site condominium plans prepared under the Condominium Act (Act 59, PA 1978, as amended.)

C. Mobile Home Commission Act

The general standards set forth herein will be applied by the Drain Commissioner in review for plans for mobile home parks prepared under the Mobile Home Commission Act (Act 96, PA 1987.)

D. Michigan Drain Code

All developments within an established drainage district under the Michigan Drain Code (Act 40, PA 1956, as amended) shall conform to the requirements herein.

E. Soil Erosion and Sedimentation Control (SESC) Section of the Natural Resource and Environmental Protection Act

Earth changes requiring a soil erosion permit (Part 91, Act 451, PA 1994, as amended), and that are part of a development approved pursuant to these rules, shall be reviewed for compliance with the block grading plan and “disturbance areas” identified on the site plan.

F. Review Authority Granted by Local Municipalities

All developments in townships, cities, or villages, where review according to these rules is required, shall conform to the requirements herein. The Drain Commissioner’s review of private drainage systems will focus on the discharge of storm water offsite, and the accommodation of surface water from upstream areas drained by the private system.

G. Provisions for Requirements in Addition to Minimum Standards

1. 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.
2. The Drain Commissioner reserves the right to determine site-specific requirements other than those herein, based upon review of the plans.
3. Any deviations from these standards shall be subject to approval by the Drain Commissioner.

APPLICABILITY

A. 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.
- Parcel divisions along an existing county road (no common private drives).

B. Redevelopment

If redevelopment is proposed on any existing site, the storm water management system must be brought up to the current standard for the redeveloped or newly constructed portion of the site. Runoff associated with any new construction or reconstruction on the site must be managed according to these rules.

C. Local Unit Review

In general, site plan review shall be performed by the Drain Commissioner or his/her Engineer to avoid:

- Non-uniformity in drainage review between local units.
- Local unit priorities, such as reviewing plans for compliance of water and sewerage systems with local codes, result in drainage view having a lower priority.
- Approval of developments without adherence to the Drain Commissioner's standards and subsequent drainage problems resulting in the Drain Commissioner mediating the drainage disputes.

However, the Drain Commissioner will accept a drainage review from a local unit if the following conditions are satisfied:

- The drainage system for the development is not proposed to be dedicated to the Drain Commissioner under the applicable provisions of the Michigan Drain Code.
- The drainage system for the development does not directly outlet to a county drain.
- The road system in the development is intended to be private.
- The local unit has a storm water management ordinance, or has passed a resolution that requires all developments within the local unit be designed to the minimum standards outlined herein.
- The engineering review letter prepared on behalf of the local unit and submitted to the Drain Commissioner must state that a professional engineer, licensed in the State of Michigan, reviewed the plans for conformance with these standards.

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.

FEES

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

PART 1:
PROCEDURES FOR PLAN SUBMISSION AND APPROVAL

I. PRELIMINARY PLAT OR SITE PLAN REQUIREMENTS

A. Submission Requirements

A Site Plan Review Checklist for information required on the drawings is included in ***Appendix 1***.

1. Submittal

a. Two (2) prints and one (1) electronic file in .pdf format of the preliminary plat or site plan.

b. Application for Drain Commissioner's Approval in ***Appendix 1***.

c. Location and site feature information listed on the Site Plan Review Checklist in ***Appendix 1.***

d. Design Calculation Package with information included on the Site Plan Review Checklist in ***Appendix 1***. (Upstream watershed calculations, BMP design calculations, and design summary notes may be submitted with construction drawings if a two-step review process is used by the Proprietor.)

4. Staged Development

a. 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.

b. Each phase shall be self sufficient from the standpoint of drainage.

c. 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.

B. Storm Water Discharge Requirements

1. 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.

2. Local Requirements

Proposed drainage 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.

3. Discharge of Storm Water Offsite

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

b. Discharge shall not cause downstream erosion.

c. Additional impacts (such as increased temperature, pollutant load, or severe alterations to groundwater recharge) may also need to be mitigated.

d. If improvements to the downstream conveyance system, or flooding rights are required, it is the responsibility of the Proprietor to secure necessary easements from downstream property owners (refer to Part 1 section entitled “Easements”).

e. 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 design and construct, or 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.

C. Preliminary Plat or Site Plan Approval

1. Approval

a. The Drain Commissioner will approve or reject a preliminary plat or site plan within thirty (30) days of its submittal. If the preliminary plat or site plan is not approved as originally submitted, the Commissioner will notify the Proprietor in writing, setting forth the reasons for withholding approval. If the preliminary plat or site plan as submitted meets all requirements, one approved copy will be returned to the Proprietor. Approval of the preliminary plat or site plan is required before the Drain Commissioner will proceed with review of final construction plans.

b. Payment of all fees is prerequisite to approval (refer to section entitled "Fees"). Payment of an engineering review deposit may be required by the Drain Commissioner at the time of preliminary plat or site plan submittal.

2. Changes and Resubmission

a. Approval of the preliminary plat or site plan by the local governing body is also 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 or the proposed storm water management plan, 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.

b. 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.

c. Resubmission is required even though the original layout may have already been approved by the Drain Commissioner.

3. Expiration of Preliminary Approvals

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.

II. CONSTRUCTION DRAWING REQUIREMENTS

A. Submission Requirements

1. Submittal

a. Two (2) complete sets of construction drawings and one (1) electronic file in .pdf format.

b. Application for Drain Commissioner's Approval in ***Appendix 1***.

c. Additional information listed on the Site Plan Review Checklist in ***Appendix 1.***

d. Specifications for construction of storm water management facilities to be turned over to the Drain Commissioner (publicly owned).

2. Restrictive Covenants

A copy of restrictive covenants or master deed language related to drainage shall be provided to the Drain Commissioner prior to construction drawing approval and recorded prior to final plat approval or release of recording deposit.

a. Block Grading Plan

A block grading plan shall be incorporated in the restrictive covenants of the plat or master deed of the site development to ensure proper drainage of individual lots. 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."

b. Minimum Floor and Opening Elevations

Minimum building opening elevations shall be established to eliminate the potential of structural damage and flooding of building interiors. Minimum opening elevations shall be incorporated in the restrictive covenants of the plat, including bench mark references.

It is the responsibility of the Proprietor to provide a bench mark (MSL datum) within 400 feet of any lot to use as a reference for establishment of minimum floor and opening elevations.

The restrictive covenant shall state:

> "The lowest allowable floor elevations are set at 2-feet or more above the highest known ground water elevation. The lowest allowable opening elevations are set 1-foot or more above the 100-year floodplain or 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 Cass County 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. Bench mark locations and elevations are indicated on the Block Grading Plan."

c. 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:

> "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."

d. 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 his 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 feature that may interfere with drainage or the maintenance of the drainage system."

3. Maintenance Plan and Agreement

a. Private Development

A Maintenance Plan shall be submitted with construction drawings for all private developments and be included with an executed Maintenance Agreement with provisions for local unit intervention in the legally binding documents such as the property deed or condominium master deed. A Maintenance Plan template and Maintenance Agreement are included in ***Appendix 2***.

B. Construction Drawing Approval

1. Approval

a. For plats, review of construction drawings by the Drain Commissioner will not proceed until preliminary plat approval has been granted.

b. After the drawings have been reviewed by the Drain Commissioner, approval or rejection will be provided to the Proprietor in writing within thirty (30) days.

c. Payment of all fees is prerequisite to approval (refer to section entitled "Fees"). Payment of an engineering review deposit may be required by the Drain Commissioner at the time of construction drawing submittal unless previously required for preliminary review.

2. Changes and Resubmission

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 be required as a result, such revisions shall be made by the Proprietor and the drawings resubmitted to the Drain Commissioner for approval.

3. Expiration of Approval

Approval of construction drawings by the Drain Commissioner's office is valid for one (1) calendar year, or up to two (2) calendar years if allowed by the local governing body. 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 review fees.

C. Submission of Construction Record Drawings

Two (2) complete sets of construction record drawings (paper copies), one (1) electronic file in .pdf format, and one (1) set of AutoCAD drawing files meeting Cass County Information Systems Department digital submission requirements shall be submitted to the Drain Commissioner with a letter of transmittal for all developments reviewed under these rules. At a minimum, the following "as-built" information is required to be included on construction record drawings:

a. Horizontal location of all drainage structures and footing drain connection points relative to a coordinate point or lot corner. Alternately, locations may be shown by road stationing with offsets.

b. Final grading and volume of all detention/retention facilities and integrated BMPs with verification that they meet or exceed approved storage capacities.

c. Pipe inverts, length and slope, manhole and catch basin rims, top of berm, and spillway elevations.

d. Details of inlet structures (including opening areas and elevations).

III. FINAL PLAT REQUIREMENTS

A. Submission Requirements

A Submittal Checklist for Section 425 and 433 Agreements is included in ***Appendix 3***.

1. True Plat

The Land Division Act requires that a true plat be delivered to the Drain Commissioner for review. Such final plats must be prepared in accordance with the requirements of the Land Division Act.

2. Preliminary Plat Approval

a. 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.

b. If the Proprietor does not present the final plat to the Drain Commissioner for approval within two (2) years after preliminary plat approval, resubmittal of the preliminary plat and/or construction plans may be required in light of new information which may become available in the interim.

3. Completed Work

Prior to approval of the final plat, the Drain Commissioner shall require that one of the following provisions is met:

a. Work Completed Prior to Final Approval

Certification from the Proprietor's engineer that the county drains and watercourses shown on the plat have been improved in accordance with the approved construction drawings; or

b. Work Completed After Final Plat Approval

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. Failure to fulfill terms of an agreement executed under this provision will result in appointment of a Board of Determination to rule on necessity for the drain(s). Expenses incurred subsequent to said appointment will be assessed against lands within the plat still owned by the Proprietor.

(1) Surety

The surety shall consist of a cash deposit, a certified check or an irrevocable letter of credit in the amount of 130% of the uncompleted portion of the project. An Irrevocable Commercial Letter of Credit is included in ***Appendix 3***.

(a) Construction Contract as Basis for Required Surety

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

(b) Engineer's Estimate as Basis for Required Surety

In the event the Proprietor has not contracted for the construction of the storm water management system and SESC measures (e.g., Proprietor is the contractor), the Proprietor's 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.

(c) Rebate

A rebate to the Proprietor shall be made as the work progresses, in the amount of the ratio of work completed to the entire said construction cost. The percentage of work complete shall be determined by the Drain Commissioner.

(d) Release of Surety

If, upon completion of the final inspection, all punch list items are addressed and the Drain Commissioner determines the proposed drain practical, the Drain Commissioner may issue a letter granting final acceptance and shall subsequently release the balance of any surety deposit to the developer. If the Drain Commissioner determines the proposed drain impractical, pursuant to Section 52 of the Michigan Drain Code, the Drain Commissioner shall notify the developer in writing, provide the reasons for determining the proposed drain impractical, and refund the balance of any funds remaining from deposits by the developer.

B. Final Plat Approval

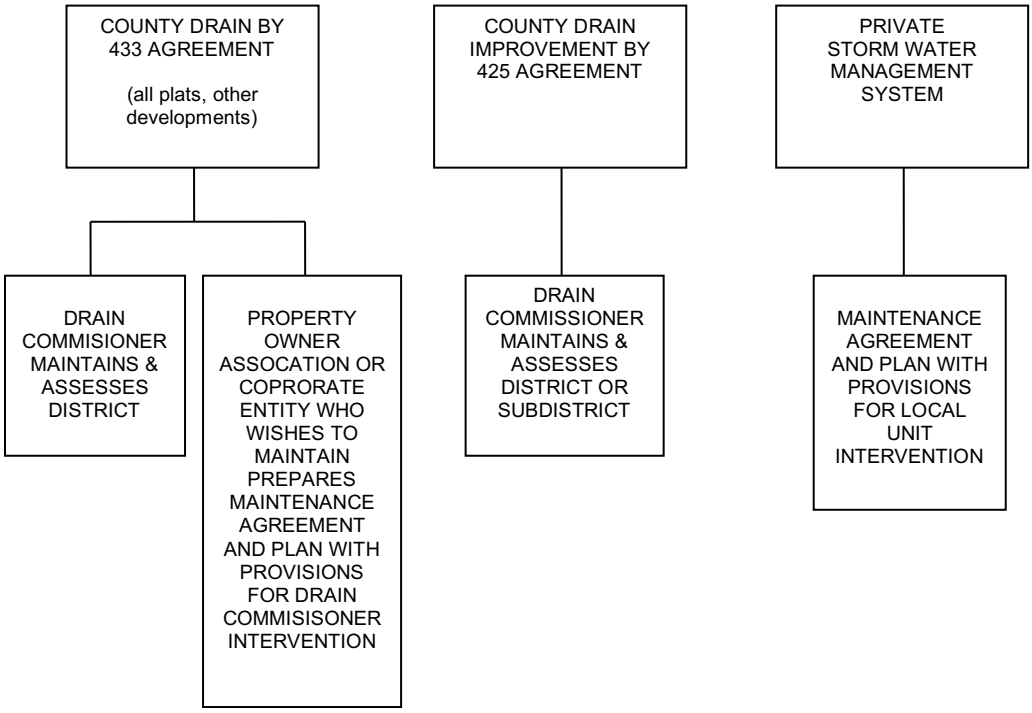
Final subdivision plat review will be completed by the Drain Commissioner's office within ten (10) days of submission by the Proprietor. If the plat is not acceptable, written notice of rejection and the reasons therefore will be given to the Proprietor and the clerk of the related municipality. If the Drain Commissioner approves the plat, he will affix his signature to it and the plat will be executed.

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

IV. DRAINS UNDER THE JURISDICTION OF THE DRAIN COMMISSIONER

A. Responsibility for Storm Water System Ownership and Maintenance

A summary flow chart is shown below.



System Ownership and Operation Flowchart

1. Plats

All plats shall be established as public drainage under the jurisdiction of the Drain Commissioner.

2. Other Developments

All other developments with public roads shall be established as public drainage under the jurisdiction of the Drain Commissioner.

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

3. 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.

4. Maintenance

a. By Water Resources Commissioner

The Drain Commissioner shall be responsible for maintenance of all established county drains, including storm water BMPs dedicated as components of the storm water management system. The costs for maintenance shall be assessed to the drainage district.

In general, the Drain Commissioner shall not accept integrated storm water BMPs (i.e. rain barrels for individual houses) as part of the county drain system.

b. By Private Entity

A Maintenance Plan 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. The Maintenance Plan shall be included with an executed Maintenance Agreement in the subdivision agreement or legally binding documents such as the property deed or condominium master deed. A Maintenance Plan template and Maintenance Agreement are included in ***Appendix 3***.

B. Easements

1. Existing Easements

The liber and page 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. 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 will be indicated on the plans and designated as (insert name) Drain.

2. Proposed Easements

An easement (or release of right-of-way), 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.

a. Location

(1) Within a Plat or Multi-Lot Site Development

All established county drains, including non-structural and structural storm water BMPs for which storm water calculation credits are sought, located within the plat or multi-lot site development, shall have granted easements.

(a) Drainage 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] [Storm Water Management BMP] to the (insert development name) Drain Drainage District."

Separate, recordable easements must be provided in a form acceptable to the Drain Commissioner. Acceptable easement forms are included in ***Appendix 3***. 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 Developer releasing an easement to the drainage district, the Developer 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.

(i) Exceptions

No easements are required for the following BMPs:

- Minimize Soil Compaction and Total Disturbed Area
- Protect Sensitive Areas (including Riparian Buffers)
- Storm Water Disconnection
- Capture Reuse
- Native Revegetation (including Riparian Buffer Restoration)
- Pervious Pavement
- Soil Restoration
- Vegetated Roof

(2) Outside the Plat or Site Development

(a) County Drain Easements

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. An acceptable release of right-of-way form for county drains is included in ***Appendix 3***. Recordable drain easements shall be submitted to the Drain Commissioner prior to construction drawing approval and recorded prior to final plat approval.

(i) Exceptions

Easements will not be required:

- Through public rights-of-way (i.e. county roads).
- When the discharge is directly to an established county drain or municipal drainage system.
- When the discharge is directly to an adequate outlet, defined as a river, stream, ditch, ravine, pond, lake, wetland, or depression where the allowable discharge rate and volume under these standards cause no adverse impact to downstream property owners (refer to Part 2 section entitled "Adequate Outlet").

(ii) A Certification of Adequate Outlet is required when storm water is proposed to be discharged into a watercourse, waterbody, or drainage way. A standard form is included in ***Appendix 3***.

(b) Flooding Easements

When concentrated storm water is proposed to be discharged over, onto, or across private property (other than that owned by the developer), 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. An acceptable Flooding Easement form is included in ***Appendix 3***. Such an agreement shall be submitted to the Drain Commissioner prior to construction drawing approval and recorded prior to final plat approval.

(i) Exceptions

Easements will not be required when the rate and volume of the discharge meets adequate outlet requirements and the Proprietor determines that no adverse impacts will occur to downstream property owners (e.g. runoff is not concentrated if it was not before) (refer to Part 2 section entitled "Adequate Outlet").

(ii) A Certification of No Net Increase of Storm Water is required when storm water is proposed to be discharged over, onto, or across private property, and drainage or flooding easements are not obtained. A standard form is included in ***Appendix 3.***

b. 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:

(1) Open Channels

Open channels (ditches) and water courses (e.g., a definable stream bed) shall have a minimum of 15 feet on each side of the top of bank and a total minimum width of 40 feet.

(2) Enclosed Drains

Easement widths for pipes shall conform to the following table. Burial depths are to the invert of the proposed pipe:

Burial (feet)	Easement Width
0-7	20 feet
7.1-12	30 feet
12.1-17	40 feet
>17.1	50 feet

(3) LID Storm Water BMPs

A minimum of 10 feet around the perimeter of a LID storm water BMP (rain garden, swale, bio-swale, infiltration trench, etc.) must be granted to access and maintain the BMP.

(4) Detention and Infiltration (Retention) 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.

(5) Exceptions

(a) Generally, the above widths shall govern; however, if the engineer determines that additional right-of-way is required for proper construction, or because of special circumstances, such facts shall be made known to the Proprietor upon review by the engineer.

(b) Exceptions to the above requirements may be made only at the discretion of the Drain Commissioner.

C. Permits for County Drains

1. Utilities

If any utilities are to be located within the drainage easement of the proposed development, the Proprietor's engineer shall present plans detailing such utilities to the Drain Commissioner for his 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. An Application and Permit to Cross or Parallel a County Drain is included in ***Appendix 4*** (refer to section entitled "Fees" for Drain Use Permit fees).

2. Modifications

a. General

A separate application is required for modifications (deepening, widening, relocation, etc.) to a county drain including installation of crossings, and shall be presented at the same time as construction drawings. An Application and Permit to Install a Crossing or Modify a County Drain is included in ***Appendix 4*** (refer to section entitled "Fees" for Drain Use Permit fees).

b. Tiling and Extensions

Agreements for tiling or adding a branch or extension to a county drain shall follow the procedures under Section 425 Application and Petition.

3. Tapping

a. General

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. An Application and Permit to Connect to a County Drain is included in ***Appendix 4***. There are no fees associated with connecting to a county drain.

b. Footing Drains

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

c. 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.

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.

1. Section 425 Application and Petition

A Submittal Checklist for Section 425 and 433 Agreements is included in ***Appendix 3***.

a. Use

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. Under this paragraph, the Proprietor must petition the Drain Commissioner or Intercounty Drainage Board for permission to construct or improve the additional drainage for public use.

b. Submittals

(1) Application/Petition

The Proprietor shall submit an Application to Lay Out a Drainage District and a Petition to Locate, Establish, and Construct a Drain. An acceptable application/petition is included in ***Appendix 3***.

(2) Legal Descriptions

The Proprietor's engineer or surveyor shall provide centerline descriptions of the drains or branches and a complete legal description of the drainage area affected. The description shall list each parcel and the acreage located within the drainage subdistrict. In addition, the engineer shall complete an apportionment data sheet for the subdistrict.

(3) Certification

The Proprietor's engineer shall include a sealed and dated statement attesting to the adequacy of existing receiving drains. A standard form for Certification of Adequate Outlet is included in ***Appendix 3***.

c. Costs

(1) Maintenance Fee

Prior to construction drawing approval, the Proprietor shall deposit into the maintenance account for the drain a non-refundable maintenance fee in the amount required by Section 433 of the Michigan Drain Code (refer to Part 1 section entitled "Section 433 Agreement").

(2) Recording Deposit

An additional recording deposit shall be submitted for administrative expenses of establishing a district, including legal review of documents, any recording fees incurred by the district, final inspection costs, and publication of the drainage district (refer to section entitled "Fees"). Any remaining deposit will be returned to Proprietors of good standing upon satisfactory completion of all submittal requirements.

2. Section 433 Agreement

A Submittal Checklist for Section 425 and 433 Agreements is included in ***Appendix 3***.

a. Use

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 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.

b. Submittals

(1) Agreement

(a) General

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 in coordination with the Drain Commissioner and stipulate conditions of transfer and responsibilities of parties. An acceptable Section 433 Agreement form is included in ***Appendix 3***.

(b) Signing and Recording

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 Proprietor's engineer shall provide centerline descriptions for each drain or branch to be dedicated.

(b) Drainage District

The Proprietor's engineer shall provide metes and bounds description of the contributing drainage area (drainage district) benefiting from such. A 24" by 36" drainage district map showing the drainage district boundary line, lot and parcel lines with numbering,

and all 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.

(c) Assessment Roll
A breakdown of individual areas in acres shall be provided by municipality for each parcel, and for railroad, state and county road, and municipal street rights-of-way. The Proprietor's engineer shall complete an assessment roll for the new district, submitted on paper and in electronic Microsoft Excel format, for future drain maintenance in the development. The roll shall include benefit factors for each lot in the development that is not common-owned property (e.g. parks or open space). Benefit factors shall be based on use of roads, lot size, topography, etc. The sum of the benefit factors for each parcel shall equal 1.00, and percentages for each parcel shall be carried to two (2) decimal places.

(3) Certification
The Proprietor's engineer shall include a sealed and dated statement attesting that 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. A standard form for Certification of Adequate Outlet (Exhibit B to 433 Agreement) is included in ***Appendix 3***.

c. Costs

(1) 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 construction drawing approval. 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, pursuant to Section 196 of the Michigan Drain Code.

(2) Recording Deposit
An additional recording deposit shall be submitted for administrative expenses of establishing a district, including legal review of documents, any recording fees incurred by the district, final inspection costs, and publication of the drainage district (refer to section entitled "Fees"). Any remaining deposit will be returned to Proprietors of good standing upon satisfactory completion of all submittal requirements.

E. Construction

1. Insurance Coverage

The Proprietor shall maintain adequate insurance coverage for his own employees, his contractors and subcontractors, and their employees during construction. Prior to issuance of a grading (SESC) permit, the Proprietor shall submit satisfactory evidence of public liability and property damage insurance coverage as set forth by the State of Michigan in compliance with the Drain Commissioner's Insurance Certificate Requirements (refer to Appendix 4).

2. Indemnity

The Proprietor shall hold the Drain Commissioner and his agents harmless for acts of omission, negligence, or error by the contractor(s) and subcontractor(s), the Proprietor's engineer, or the Proprietor. Costs incurred by the Drain Commissioner to defend against criminal or trespass actions, resulting from activities of any of the parties named above, as well as judgments awarded by any court of law, shall be paid by the Proprietor.

3. Documentation

Governmental accounting standards (GASB Statement 34) require the county to report the value of their drain infrastructure. Prior to issuance of a grading (SESC) permit, the Proprietor shall submit documentation relative to the contract covering the work to be performed including the cost of construction with an itemized breakdown.

4. Preconstruction Meeting

The Drain Commissioner may request that a preconstruction meeting of all involved parties be held.

5. Inspections

a. By Proprietor

The Proprietor shall retain a qualified inspector, supervised by a registered professional 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.

b. 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 Engineer are to verify the proper construction of the drainage system. Inspection by the Drain Commissioner or his Engineer shall not relieve the Proprietor's engineer or the municipal engineer of their obligations.

c. By Others

Other agencies may periodically inspect progress for regulatory purposes. The presence of such inspector does not release the Proprietor or his engineer from obligations defined elsewhere in these rules.

d. Final Inspection and Determination of Practicability

The Drain Commissioner will complete a final inspection jointly with the County Road Commission for the purpose of final acceptance of construction and determination of practicability of the county drain.

6. Repair Bond

Upon completion of construction, the Proprietor will post a repair bond or letter of credit in the amount of $5,000 or 10% of the construction cost, whichever is less, to guarantee repairs of any defects which may show up after substantial completion of the project as a result of poor workmanship or defective materials. This deposit will be held for one (1) year after the date of final acceptance of the storm water facilities. This deposit will be returned to the Proprietor, provided all storm water facilities are clean, unobstructed and in good working order. An acceptable Repair Bond form is included in ***Appendix 3***.

7. Post-Construction Certification

A post-construction letter of certification from the professional engineer responsible for the design that certifies construction of the system in accordance with the approved construction drawings shall be submitted to the Drain Commissioner. An acceptable Certification form is included in ***Appendix 3***.

8. Construction Record Drawings

Construction record drawings shall be submitted by the Proprietor to the Drain Commissioner in accordance with the submission requirements (refer to Part 1 section entitled "Submission of Construction Record Drawings"), along with the Post-Construction Certification and the final plat if construction is completed prior to final plat approval.

PART 2:
STORM WATER DESIGN PROCEDURE

I. PURPOSE

It is the purpose of these storm water design standards to establish minimum storm water management requirements to meet the following objectives:

- Ensure that storm water drainage systems and 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 artificially induced flood damage.
- Minimize the degradation of existing watercourses.
- Prevent an increase in non-point source pollution.
- Maintain site hydrology to avoid detrimental changes in the balance between storm water runoff, groundwater recharge and evapo-transpiration.

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).

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter2.pdf

II. DESIGN PROCESS

The storm water site design process is summarized in ***Table 1***. This process requires definition of the following:

- Sensitive Areas
- Volume Control Criteria
- Storm Water Management Zones
- Adequate Outlet
- Special Cases
- Selection of Best Management Practices

Table 1 – Design Process Flow Chart

Step	Description	Check	Tools
1	Locate site in watershed and determine storm water management zones and special cases.		Table 3 Worksheet 2 Appendix 5
2	Designate "disturbance" areas and identify sensitive areas on site.		
3	Identify soil types, pre-development and existing land uses for curve number calculations.		Green Calculator
4	Identify existing flow paths to determine time of concentration.		Green Calculator
5	Layout site, protecting sensitive areas and leaving room for BMPs.		
6	Identify developed land uses for curve number calculations including **non-structural BMPs**.		Green Calculator
7	Calculate time-of-concentration for developed site.		Green Calculator
8	Select and size **structural BMPs** to meet required stream protection volume.	If calculated stream protection volume is not sufficient then return to Step 5. If site constraints preclude meeting the required volume, apply for approval of extended detention approach.	Table 5 Green Calculator Figure 4
9	Check peak flows for 10-year and 25-year event (flood control). Check adequate outlet.	If peak developed discharge exceeds allowable peak discharge, calculate required detention storage volume, select **structural BMPs**.	Worksheet 1 Green Calculator Figure 5
10	Check safe passage of 100-year flood.		
11	Check that minimum water quality volumes are met.	If not already met through stream protection and flood control measures, select and size **structural BMPs** to meet.	Green Calculator
12	Select and size **structural BMPs** for pre-treatment and spill containment (where necessary).		Table 4 Table 5

A. Sensitive Areas

Steps 1 and 2 of the design process (***Table 1***) require that the site be assessed in regard to its location in the watershed and inventoried for existing on-site resources and/or special conditions (sensitive areas) that may pose a challenge and/or opportunity for storm water management. A County Watershed Map is included as ***Appendix 5***. For the purpose of these rules, sensitive areas include:

- Floodplains (and flood prone areas)
- Riparian areas
- Wetlands
- Rivers, streams and natural drainage ways
- Lakes and ponds
- Soils and topography (steep, erodible, dunes)
- Geology (karst)
- Groundwater supplies (springs, wellhead protection areas)
- Vegetation (woodlands, other sensitive ecosystems)
- Historic Sites

Identification of sensitive areas and "disturbance areas" on the site plan is required in Part 1 of this manual. "Disturbance Areas" are categorized as:

- No disturbance area
- Minimal disturbed area
- Construction traffic area
- Topsoil stockpiling and storage area

The watershed-scale assessment is completed by identifying the Storm Water Management Zones and Special Cases that may modify the required storm water volume controls as discussed in the following sections.

B. Volume Control Criteria

Volume-based criteria is essential to mitigate the impacts of urban runoff. Adequate controls are required to reduce channel erosion, maintain groundwater recharge, prevent overbank flooding and meet pollutant removal goals through the use of:

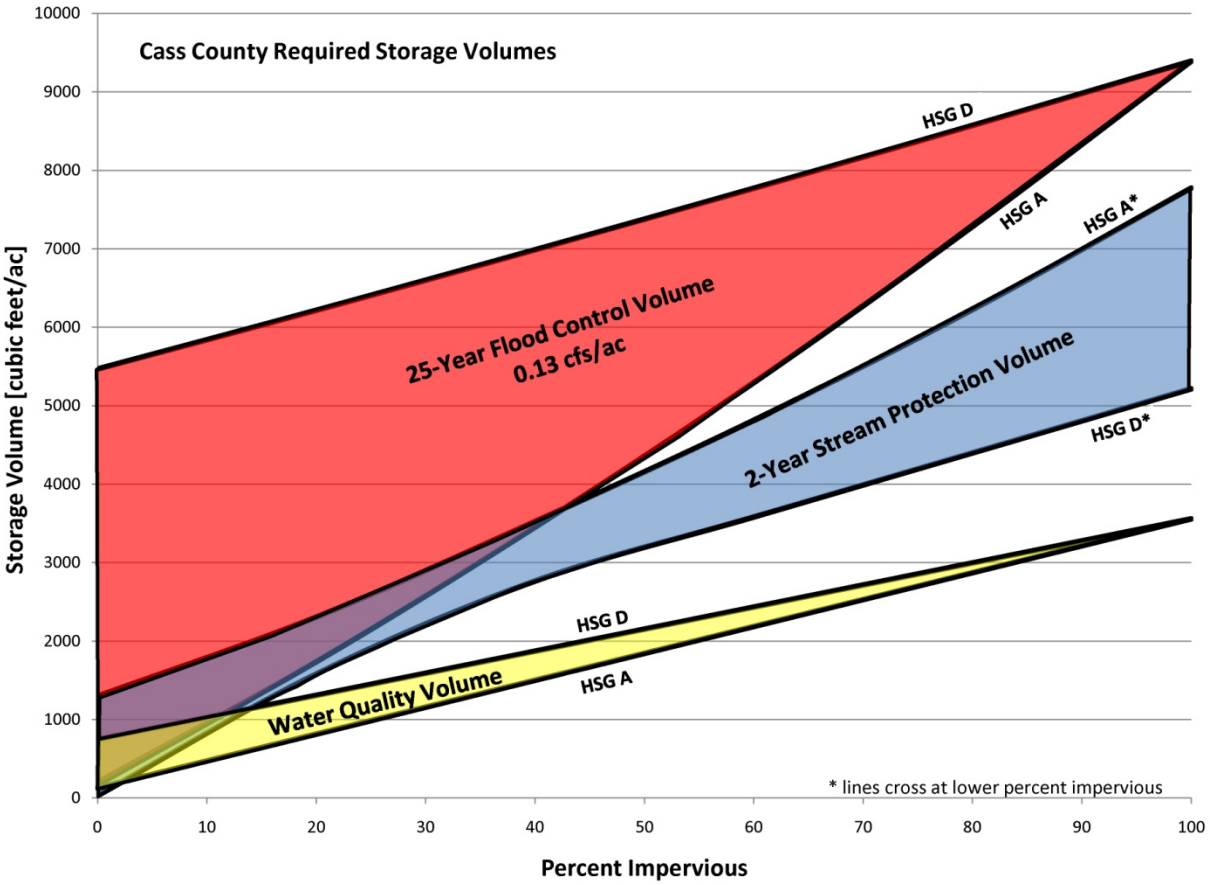
- Stream Protection Volume
- Flood Control Volume
- Water Quality Volume
- Pre-treatment Volume

A summary of standard sizing criteria is provided in ***Table 2***. A comparison of the required storage volumes is shown graphically in ***Figure 1***.

Table 2 – Summary of Standard Sizing Criteria

Volume Control	Minimum Sizing Criteria
Stream Protection *(volume and peak rate control)*	**(1) Onsite Retention:** No net increase in the pre-development runoff volume and rate from the disturbed portion of the site for the 2-year, 24-hour rainfall event. **OR** if site constraints preclude (1): **(2) Extended Detention:** Storage volume and release rate determined by extended detention of the 1-year, 24-hour rainfall event for a period of 24 hours.
Flood Control *(peak rate control)*	**If Stream Protection (1) is provided:** Detention of the 25-year, 24-hour rainfall event with a maximum release rate not to exceed the pre-developed 25-year peak runoff rate. **OR** **If Stream Protection (2) is provided:** Detention of the 25-year, 24-hour rainfall event with a 0.15 cfs/acre maximum release rate.
Extreme Flood	Overland flow paths must assure safe passage of 100-year flood events.
Water Quality	Treat runoff from the first 1.0-inch of rain from the directly connected impervious area and disturbed pervious area through settling (permanent pool or extended detention), infiltration, or filtration.
Pre-treatment	Settling basins (forebay): Provide 15% of the water quality volume. **OR** Vegetated Filter Strips and Grassed Swales meeting minimum length, slope and vegetated cover requirements. **OR** Proprietary Treatment Systems

Figure 1 - Comparison of Required Storage Volumes



1. Stream Protection Volume

Retention of a stream protection volume is required to control urban storm water runoff for the smaller, more frequent 1- to 2-year rainfall events (bankfull flood) that have a greater impact on the stability of headwater (or low-order) streams. Retention of the increase in volume for a 2-year storm between pre-developed and post-development conditions is required. Volume control for stream protection may also provide additional benefits by promoting groundwater recharge (that can provide for more stable stream base flows and cooler water temperatures), sustaining wetland hydrology and maintaining floodplain boundaries.

The 2-year storm was selected since 95% or more of the annual average runoff volume will be controlled, including all storms of a lesser frequency (encompassing the bankfull event). A pre-development condition is defined as a maximum runoff condition associated with “meadow” for all but existing woods. Using pre-developed in lieu of existing conditions is necessary to aid in the stability of headwater streams that are presently experiencing degradation. The storage provided by the selected criteria will also serve to reduce peak flow rates for larger rainfall events.

Where retention is not possible due to site constraints, (see Special Cases section below), extended detention of the stream protection volume may be approved. Detention of the total 1-year runoff volume for a period of 24 hours is required to mitigate the impact of an increased volume of flow at the bankfull discharge. The idea is that storm water runoff will be stored and released in such a gradual manner (significantly less than the bankfull discharge rate) that critical erosive velocities during the bankfull and near-bankfull events will seldom be exceeded in downstream channels. The smaller storm is selected to avoid releasing extended volumes of runoff from the 2-year storm at the bankfull discharge rate, since it is better to have a higher peak for a much shorter duration at that point.

2. Flood Control Volume

Although site-based storm water runoff rate control may help protect the area immediately downstream from a development site, the increased volume of runoff and the prolonged duration of runoff from multiple development sites can actually increase peak flow rates and duration of flood flows in downstream watercourses. Replicating pre-settlement runoff volumes for small (2-year) storms will substantially reduce the problem of frequent flooding. When 2-year volume control is provided, detention of storm water runoff for the 25-year flood event with a corresponding pre-settlement release rate is required to maintain peak flow rates and floodplain levels in downstream watercourses.

Where 2-year volume control is not provided, detention of the 25-year event with an allowable release rate of 0.15 cfs/acre is required. This approach is overly conservative with the allowable release rate to prevent the increase in peak flow rates further downstream as explained in the previous paragraph.

The peak discharge for the extreme flood event must be checked to verify that either infrastructure, overland flow routes and/or floodplains are present to safely convey the storm water runoff. Overland flows for the 100 year 24-hour storm shall be identified for all sites. Provisions shall be made to ensure no adverse impacts offsite or internal to the site.

3. Water Quality Volume

Water quality volume is required to treat the “first flush” of storm water runoff that typically carries with it the highest concentration of pollutants. Capturing the runoff from the 90% annual non-exceedance storm is required to effectively treat all runoff from a majority (90%) of storms in a given year. In Cass County (Michigan Climatic Zone 8), the 90-percent storm is equivalent to 1.0 inch of rain.

Capturing and treating runoff from the 90% annual non-exceedance storm has been found to generally meet pollutant load targets of:

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

A majority of these pollutants build up on the surface of roadways, driveways, and parking areas. Directly connected disturbed pervious surfaces (primarily lawns) can also contribute pollutant load (i.e. nutrients due to overuse of fertilizer; nutrients and bacteria due to overuse by wild/domestic animals). Impervious surfaces that meet the definition of “disconnected” (see Storm Water Disconnection BMP in Part 3) can be omitted from water quality calculations.

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

- Permanent pool
- Extended detention
- Infiltration
- Filtration

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 is defined as holding the storm water runoff volume and releasing it gradually over a longer period of time, typically 48 hours, than provided by conventional detention basins. The minimum extended detention time is 24 hours, and is defined as the time between the centroids of the inflow and outflow hydrographs. The storage volume provided by extended detention can be counted as water quality volume.

The volume of storm water runoff infiltrated into the ground through a storm water BMP can be counted as water quality volume. Guidelines for determining this volume are specified in the calculation credits for each structural infiltration BMP.

The volume of storm water runoff routed through a BMP that provides filtration (i.e. an underdrained 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 for slope, length, and vegetative cover for a maximum allowable drainage area to filter strip ratio of 6:1.

4. Pre-Treatment Volume

Pretreatment provides for the removal of fine sediment, trash and debris, and is required to preserve the longevity and function of storm water best management practices, particularly infiltration practices. A minimum pre-treatment volume equivalent to 15% of the water quality volume is required for sediment forebays using gravity. This approximates 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. Other methods of pre-treatment including the use of water quality devices and vegetated filter strips or grassed swales are allowed.

Pre-treatment is required for all infiltration BMPs (except pervious pavement), filters and detention basins, and may be necessary for some storm water reuse systems.

C. Storm Water Management Zones

The need for storm water runoff volume control, described in the previous section, will vary depending upon the location of the development within the watershed. Defining storm water management zones provides a reasonable way to apply the volume controls to account for the variability of potential downstream impacts. Storm water management zones and applicable criteria for each are summarized in ***Table 3***.

Zone A requires the greatest water resource protection. Zone A may include urbanizing rural areas or redeveloping older neighborhoods that discharge to a headwater stream, wetland, pond, ravine, or depression where increases in storm water runoff rate and volume may negatively affect stream stability, wetland hydrology, and floodplains. Stream protection, flood control, and water quality volumes are all required in Zone A. All areas that are not designated as Zones B or C will be designated as Zone A.

Zone B areas, if delineated in a storm water master plan, discharge to rivers and larger streams where full stream protection volume control is still required, but where peak rate reduction for flood control to the standard specified for Zone A is not required. Zone B includes areas along existing flood-prone watercourses where floodplain expansion may be required in lieu of onsite storm water detention.

Zone A-B is used to provide a conservative approach to storm water management when a storm water master plan has not been completed to accurately define Zone B. The requirements of Zone A must be met in Zone A-B. All areas that are not designated as Zone C will be designated as Zone A-B. (Zone A-B is so named because a single storm water management approach is applied to both headwater (1st and 2nd order) streams (Zone A), and intermediate streams and rivers (Zone B), that require stream protection.)

Zone C requires a lesser amount of storm water runoff control. Zone C is comprised of lands that discharge to a river, lake, or municipal regional storm water facility where peak rate control to the standard specified for Zone A or Zone A-B is not required. Volume control (onsite retention) is required in Zone C to the extent it is practical. Peak rate reduction for flood control is required only to the extent determined necessary to prevent flooding of the local infrastructure between the proposed development and the Zone C water body. Water quality volume is required to be met. Zone C water bodies generally include: the Great Lakes, inland lakes and 5th order and higher rivers. They may be more specifically defined in a storm water master plan. In Cass County, Zone C water bodies are:

- Inland lakes
- St. Joseph River

The Drain Commissioner shall make the final determination of storm water management zone. Individual townships and municipalities may complete storm water master plans that include storm water management zone boundaries in greater detail for their respective jurisdictions (see Part 2 section entitled “Special Cases” – Storm Water Master Plans).

Table 3 – Storm Water Management Zones

Criteria	Zone A-B	Zone C
Zone Determination	Site discharges to a stream, low-order river, ravine, wetland, pond, or depression. All areas not determined to be Zone C.	Site discharges to a river, lake, depression, or regional storm water facility where Zone A-B stream protection and flood control criteria have been determined to be not necessary.
Stream Protection *(may also provide for groundwater recharge, wetland hydrology, and floodplain protection)*	**Meet Standard Sizing Criteria:** (1) Onsite retention: No net increase in the pre-development runoff volume and rate from the disturbed portion of the site for the 2-year, 24-hour rainfall event. (2) Extended detention: Where site constraints preclude meeting criterion (1) provide 24-hour extended detention of the 1-year rainfall event.	Incorporate onsite retention to the extent practical.
Flood Control	**Meet Standard Sizing Criteria:** If criterion (1) is used for stream protection, no net-increase in the pre-development 25-year peak runoff rates. If criterion (2) is used for stream protection, also provide detention of the 25-year rainfall event with a maximum release rate of 0.15 cfs/acre.	None, unless required due to limited conveyance system (storm sewer or ditch) capacity between development and Zone C water body.
Water Quality	**Meet Standard Sizing Criteria:** Water quality control will likely be provided by meeting either stream protection criteria (1) or (2). If not, meet the minimum water quality standard specified for Zone C.	**Meet Standard Sizing Criteria:** Treat runoff from the first 1.0 inch of rain from the directly connected impervious area and disturbed pervious area. None, if provided for in a regional facility.

D. Adequate Outlet

The design criteria specified for each storm water management zone will generally provide for an adequate outlet in terms of the receiving waterbody. However, existing drainage system infrastructure, or a lack thereof, may not be adequate for increases in discharge rate, duration, volume, or concentration that might otherwise be allowed. The following requirements must be met to avoid adverse impacts to downstream properties. An Adequate Outlet Worksheet is provided as ***Worksheet 1***.

1. Existing infrastructure (storm sewer, culverts, and ditches)

Post-development discharge shall not exceed the capacity of the existing drainage system. The adequate outlet standard is generally considered to be met by the following measures:

a. Provide 2-year volume control with 25-year peak rates no greater than pre-developed.

b. Provide 25-year detention requirements (0.15 cfs/acre).

c. Do not exceed release rate allowed per storm water master plan.

d. For a downstream drainage system or county drain that is inadequate to handle the proposed discharge from the site development, it is the Proprietor's responsibility to upsize the existing conveyance system, or establish a county drain to provide the needed design level of flood protection.

2. Offsite ponds, wetlands, and depressions

Discharge rate and volume shall not cause adverse impact to offsite property due to water levels of greater height, area, and duration. The no net increase of storm water standard is generally considered to be met by the following measures:

a. Provide 2-year volume control and check that any rise in 100-year level causes no adverse impact.

b. For increased discharge rate and volume from the site, flooding easements are required.

Worksheet 1
ADEQUATE OUTLET WORKSHEET

Project: _____ **Date:** _____

Location: _____ **By:** _____

Watershed Sub Basin: _____

Discharge to	Control Provided *(Check all that apply)*	Certificate
Streams, rivers, ravines, lakes *Describe:*_____ _____ _____	___ Minimum storm water discharge standards met.	**Adequate Outlet**
Existing infrastructure (storm sewer, culverts and ditches) *Describe:*_____ _____ _____	___ 2-year volume control and 25-year peak rate no greater than pre-developed. ___ 25-year detention requirements (0.13 cfs/acre). ___ Maximum release rate allowed per storm water master plan.	**Adequate Outlet**
	___ Proprietor will improve downstream county drainage system.	
Offsite ponds, wetlands and depressions *Describe:*_____ _____ _____	___ Volume standards met and no adverse impact from any increase in 100-year level.	**No Net Increase of Storm Water**
	___ Proprietor will obtain flooding easements.	

E. Special Cases

The standard criteria outlined above may not be necessary or suitable for certain sites. In addition, some types of BMPs may be totally unsuitable for consideration in special land use areas and should be excluded from application. A worksheet to document the special cases that apply to the proposed development is included as ***Worksheet 2***. The special cases most frequently encountered include:

- Site Constraints
- Redevelopment
- Storm Water Hot Spots
- Cold-water Streams
- Storm Water Master Plans
- Federally Regulated Communities (MS4s)

1. Site Constraints

Site constraints may inhibit the ability of the developer to provide full retention of the 2-year volume difference onsite. In many cases, infiltration will likely be used as the primary means of retention. Site constraints that limit the use of infiltration may include:

- Poorly draining soils
- Bedrock
- Karst geology
- High groundwater or the potential to mound groundwater around buildings
- Well-head protection areas
- Brownfield sites and areas of soil or groundwater contamination

a. Additional Criteria

A waiver of the required retention volume (stream protection criterion 1) may be granted due to site constraints. The developer must show the following to use the extended detention stream protection criterion (2):

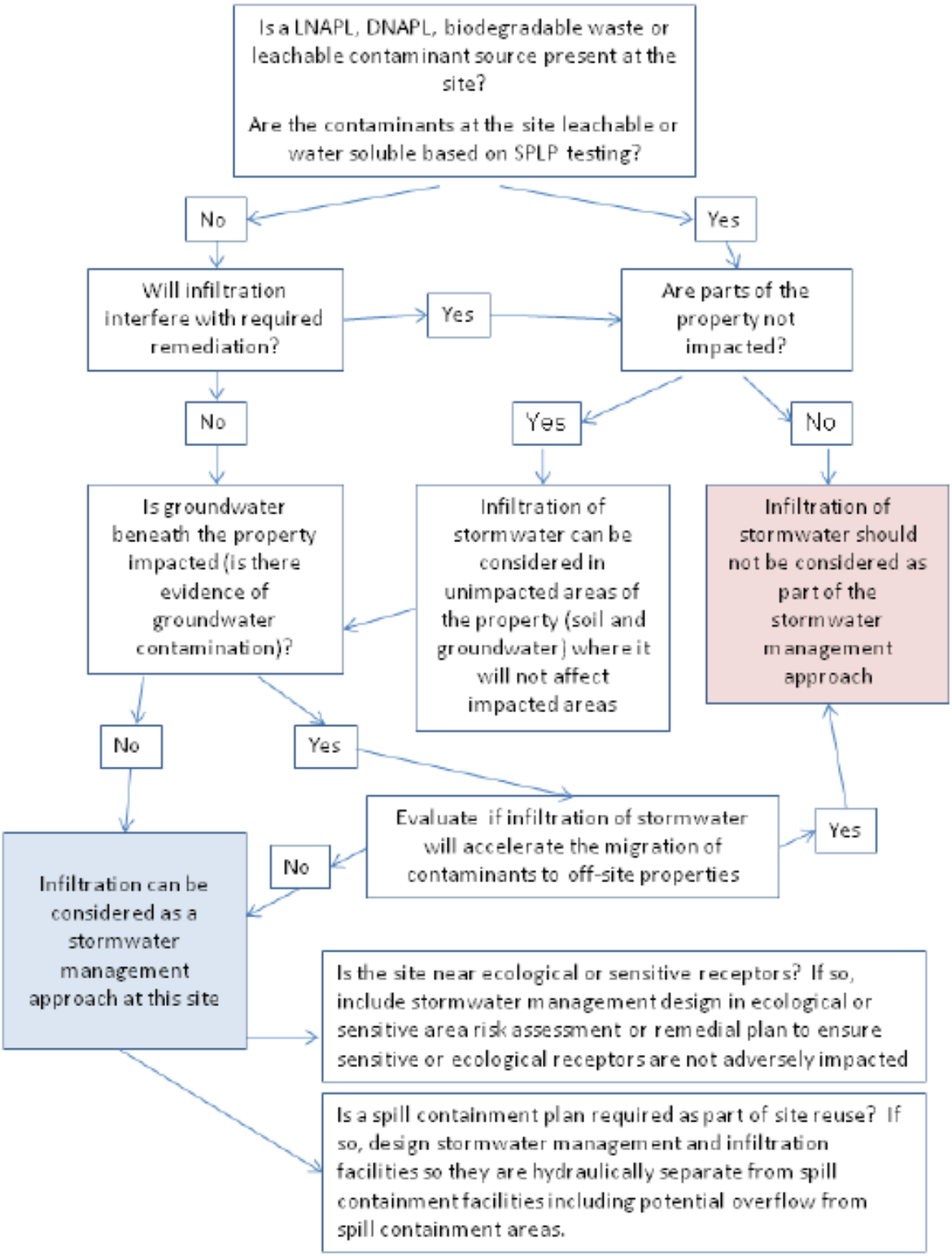
- The LID design process (Table 1) was followed.
- Volume reduction is maximized to the greatest extent practicable.
- The cost to implement additional volume reduction BMPs is prohibitive or would force noncompliance with local zoning ordinances.

b. Required Strategies

It should be noted that the presence of poorly draining soils on a site does not automatically preclude meeting the 2-year retention criteria since required volumes will be smaller, and BMPs that do not rely on infiltration such as tree planting (evapotranspiration) and storm water reuse can be employed.

2. Redevelopment

Decision Flowchart for the Use of Stormwater Infiltration at Brownfield Sites



3. Storm Water Hot Spots

Land use activities considered to be storm water hot spots are included in ***Table 4***. These activities 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). The transfer and storage areas of proposed developments meeting the definition of storm water hot spots must meet spill containment volume requirements.

a. Additional Criteria

Spill containment is required for storm water hot spots to provide for capture and containment of a slug discharge of pollutants from an accidental spill. The spill containment volume is equivalent to the pre-treatment volume with a minimum of 400 gallons required.

Measures meeting spill containment standards must have an impermeable barrier between the treated material and the groundwater and have provisions for the capture of oil & grease and sediments.

b. Required Strategies

Specific storm water management strategies for hot spots include the following:

- Infiltration of runoff from parking lots and road surfaces is discouraged in favor of a surface water discharge.
- Storm water disconnection from parking lots and road surfaces is not permitted.
- Porous pavements that infiltrate into the groundwater are not permitted because they do not allow for any pre-treatment or spill containment.
- Perforated pipes for infiltration are not permitted because of the difficulty in isolating an accidental spill.

Table 4 – Storm Water Hot Spots

2007 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 (i.e. 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 (i.e. photofinishing laboratory))
	Salvage Yards and Recycling Facilities
	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 Water Resources Commissioner (i.e. 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=2007	

4. Cold-water Streams

The MDNRE designates cold-water trout streams. These perennial streams require an adequate and stable base flow to maintain their cold water designation and support the fishery. Designated trout streams are indicated on the County Watershed Map in ***Appendix 5***.

a. Required Strategies

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 (direct, or indirect through upstream headwaters):

- 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.

5. Storm Water Master Plans

a. Additional Criteria

Developments may be located within a storm water master plan study area. Accepted storm water master plans are available from the Drain Commissioner.

Criteria in older storm water master plans predating this manual must be checked against the criteria in this manual to ensure that the requirements herein are being met.

Storm water master plans completed to refine the criteria herein must meet certain minimum requirements to be considered for acceptance by the Drain Commissioner. A guidance document entitled “Minimum Requirements for Storm Water Master Plans” is available from the Drain Commissioner. The township or local municipality is encouraged to complete storm water master plans within their jurisdictions.

6. Federally Regulated Communities (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) located in urban areas may have regulated storm water discharges under the EPA NPDES MS4 program. Areas located within a regulated MS4 are indicated on the County Watershed Map in ***Appendix 5***.

a. Additional Criteria

Proposed developments located within a Municipal MS4 boundary must meet the requirements of the community’s storm water ordinance and/or Storm Water Pollution Prevention Initiative (SWPPI).

Developments located outside of a Municipal MS4 boundary, but inside the County MS4 boundary only need to comply with the SWPPI if they discharge to a county drain or county road drainage system.

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	25	25	520	463	18.0	4.0	40.6 (36.0, 46.0)	10.0 (8.0, 10.0)	◆◆◆	99.2	18.5
Composite	10	10	202	174	42.4	8.0	85.7 (75.0, 101.3)	18.0 (12.8, 19.2)	◆◆◆	178.8	36.5
Detention Basin	32	33	411	436	24.1	10.5	68.0 (57.4, 76.2)	24.3 (21.8, 27.0)	◆◆◆	129.0	49.6
Grass Strip	19	19	361	282	20.0	10.0	44.0 (39.0, 48.0)	19.0 (15.5, 21.0)	◆◆◆	90.0	35.0
Grass Swale	24	24	442	418	9.2	11.0	28.6 (23.0, 35.0)	24.0 (19.0, 26.0)	◇◇◆	67.5	46.7
LID	3	3	131	62	25.5	13.0	51.0 (32.0, 54.0)	29.5 (15.0, 49.3)	◇◇◇	87.5	82.0
Media Filter	25	25	400	377	22.0	3.9	56.4 (46.0, 61.9)	9.0 (6.4, 10.0)	◆◆◆	120.0	22.8
Porous Pavement	9	9	404	248	36.8	15.0	93.7 (75.0, 126.0)	26.0 (20.6, 27.0)	◆◆◆	243.0	53.2
Retention Pond	56	56	923	933	15.0	4.3	47.2 (40.0, 54.0)	11.7 (10.0, 12.3)	◆◆◆	139.8	28.0
Wetland Basin	22	22	492	486	13.1	4.7	31.0 (26.4, 35.5)	14.1 (11.6, 15.2)	◆◆◆	75.9	31.0
Wetland Basin/ Retention Pond	78	78	1415	1419	14.0	4.5	38.9 (35.6, 43.6)	12.0 (11.1, 13.0)	◆◆◆	110.3	29.6
Wetland Channel	12	12	199	178	13.0	8.0	22.0 (18.0, 24.0)	17.0 (13.0, 19.0)	◇◆◆	98.4	40.5

F. Selection of Best Management Practices

Select appropriate storm water BMPs from the Storm Water BMP Summary Matrix included in ***Table 5.*** The BMP or combination of BMPs selected must meet required volume and peak rate criteria. The need for pre-treatment is indicated for each type of BMP. Those BMPs that can be selected to provide water quality volume control, pre-treatment and spill containment are also indicated. Operation and maintenance requirements are summarized for each BMP in terms of the need for a maintenance plan, easement, and/or restrictive covenant.

Finally, each best management practice is designed in accordance with the guidelines provided in the BMP Fact Sheets comprising Chapters 6 and 7 of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008) and supplementary design criteria provided in Part 3 of this manual.

Table 5 - Storm Water BMP Summary Matrix

	Treatment				Operation and Maintenance	
Storm Water BMP	Pre-Treatment Required	Provides Water Quality	Provides Pre-Treatment	Provides Spill Containment	Maintenance Plan Required	Easement Required
Minimize Disturbed Area						
Protect Natural Flow Paths			X		Y	Y
Protect Sensitive Areas						
Storm Water Disconnection					Y	
Bioretention / Rain Garden	Y	X			Y	Y
Capture Reuse	Y	X		X	Y	
Constructed Filter	Y	X		X	Y	Y
Detention Basins	Y	X*			Y	Y
Infiltration Practices	Y	X			Y	Y
Level Spreader			X		Y	Y
Native Revegetation			X		Y	
Pervious Pavement		X			Y	
Planter Box		X			Y	Y
Soil Restoration						
Vegetated Filter Strip		X	X		Y	Y
Vegetated Roof			X		Y	
Vegetated Swale / Bioswale		X	X		Y	Y
Water Quality Device			X	X	Y	Y
Storm Sewer				X	Y	Y
Culvert or Bridge					Y	Y
Open Channel					Y	Y
Spill Containment Cell		X	X	X	Y	Y

NOTES: Y = Yes; X = BMP may be used to meet treatment criteria; X* = does not include DRY detention basins

PART 3:
STORM WATER DESIGN STANDARDS

I. SOILS INVESTIGATION

A. Qualifications

Soils investigation by a qualified geotechnical consultant is required when it is necessary 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 classifications.
- Existing soil borings, wells or geotechnical report on the site.
- Onsite septic percolation testing within 200 feet of the proposed BMP location and on the same contour.
- Regional groundwater data (Michigan Groundwater Mapping Project website http://gwmap.rsgis.msu.edu/).
- Cyclical groundwater levels (http://waterdata.usgs.gov/mi/nwis/gw).

C. Test Pit / Soil Boring Requirements

A test pit (excavated hole) or soil boring (minimum 2-inch diameter drilled hole using a bucket auger, probe, split-spoon sampler, or Shelby tube) is allowed for geotechnical investigation. Test pits may typically be selected for shallower investigations in locations where groundwater is sufficiently low, and must comply with applicable OSHA safety standards. The minimum number of test pits or soil borings shall be determined from ***Table 6***.

Table 6 – Minimum Number of Soil Tests Required

Type of BMP	Test Pit / Soil Boring	Depth of Test Pit / Soil Boring	Field Permeability Test
Linear infiltration BMP	1 soil boring per 100 linear feet of BMP; 2 minimum	10 feet below proposed bottom	1 test per soil boring
Linear infiltration BMP (> 500 feet)	1 soil boring per 500 linear feet of BMP; 4 minimum	10 feet below proposed bottom	1 test per soil boring
Infiltration BMP	1 soil boring per 5,000 square feet of BMP bottom area; 2 minimum	10 feet below proposed bottom	1 test per soil boring
Detention BMP	1 soil boring per 10,000 square feet of BMP 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 infiltration basin).

E. Field Permeability Testing

Field permeability testing is generally not required, but may be performed to determine if a design infiltration rate higher than indicated in ***Table 7*** may be used. The Water Resources Commissioner reserves the right to request that field permeability testing be performed on questionable sites. Acceptable field tests include:

- Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers (ASTM D-3385)
- Percolation Tests

The methodologies and procedures outlined on pages 440-441 in Appendix E of the *Low Impact Development Manual for Michigan* (SEMCOG 2008) shall be followed for each test.

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_appendixE.pdf

An additional factor of safety of two (2) shall be applied to the permeability test results by the following equation:

Permeability-test infiltration rate (inches/hour) / 2 = Design infiltration rate (inches/hour)

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.

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

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

F. Design Infiltration Rates

Where field permeability testing is not performed, the design infiltration rates provided in ***Table 7*** shall be used to size BMPs.

Table 7 – 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)	Hydrologic Soil Group[1]
Gravel*	0.40*	10*	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: Rawls, Brakensiek and Saxton, 1982 (*Maryland Stormwater Design Manual*, Maryland Department of Environment, 2000, Appendix D.13, Table D.13.1)
[2]Source: Rawls 1998 (*Site Evaluation for Stormwater Infiltration (1002),* Wisconsin Department of Natural Resources, Conservation Practice Standards, 2004, Table 2)
*Not included in original tables. Source: Masserman, Joel W., *A Design Manual for Sizing Infiltration Ponds*, Washington State Department of Transportation Commission, 2003, Table 8 - Estimated Long-Term Infiltration Rate

Table 7 provides design values of the effective water capacity (Cw) and the minimum infiltration rate (i) of the specific soil textural groups. The effective water capacity of a soil is the fraction of the void spaces available for water storage, measured in inches per inch. The minimum infiltration rate is the final rate that water passes through the soil profile during saturated conditions, measured in inches per hour. The soil textures presented in ***Table 7*** correspond to the soil textures of the USDA Soil Textural Triangle included as ***Figure 2***. The values for design infiltration rate are modified from the original Table D.13.1 in the *Maryland Stormwater Manual* based on design values recommended by other sources (Massman, 2003 and WDNR, 2004) to be more reflective of long-term infiltration rates.

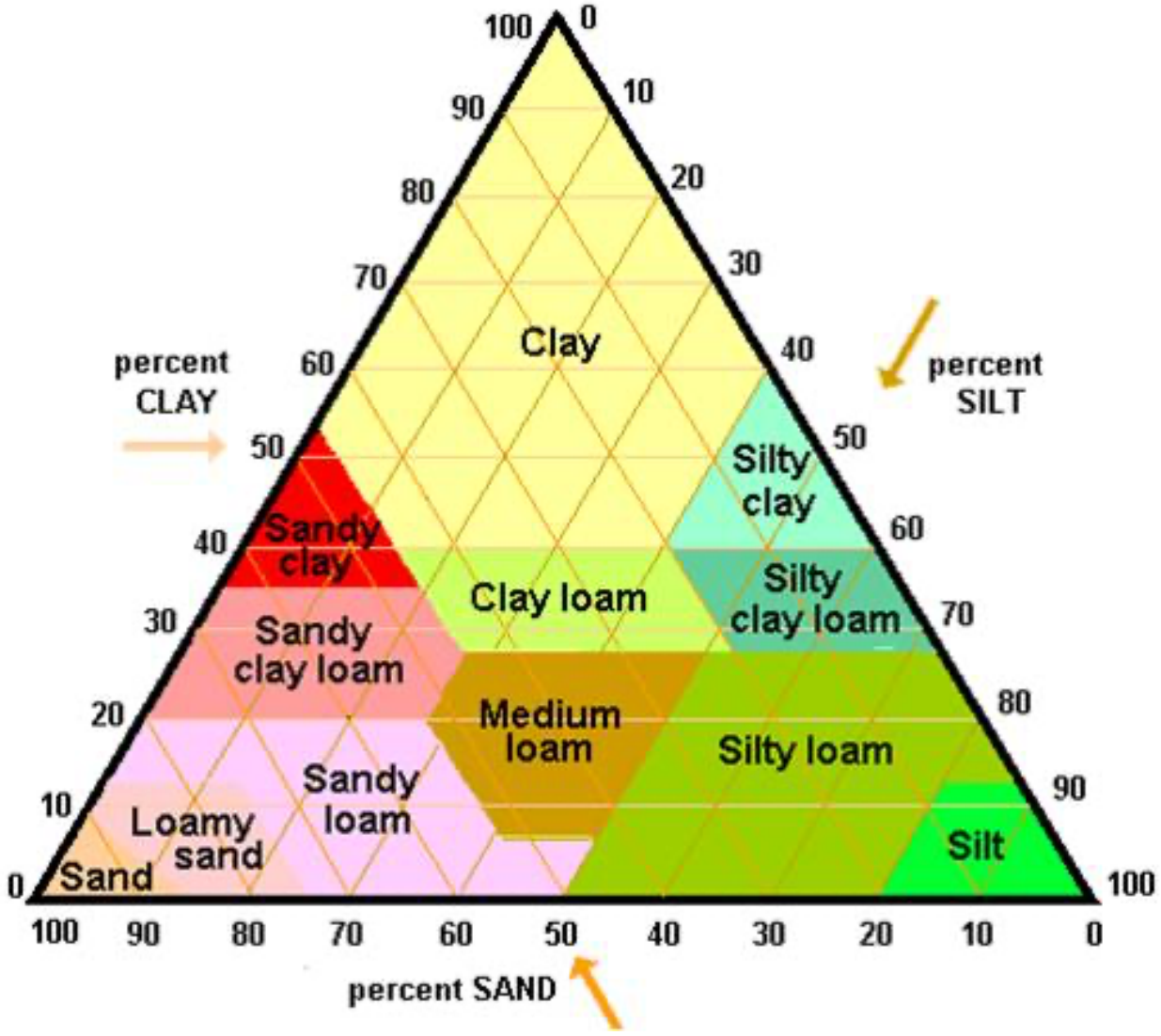
The least permeable soil horizon within four (4) feet below the proposed BMP bottom elevation shall be used to select the design infiltration rate.

G. Minimum Allowable Infiltration Rate

Soil textures with design infiltration rates less than 0.24 inches per hour are deemed not suitable for infiltration BMPs. Modifications to the BMP design through the use of underdrains or subsoil amendment, or selection of an alternative BMP shall be required.

For design infiltration rates between 0.10 and 0.24 inches per hour, BMP design may include an underdrain placed at the top of the storage bed layer.

Figure 2 - USDA Soil Textural Triangle



II. CALCULATION METHODOLOGY

A. Calculating Runoff

1. Rainfall Loss Equations and Runoff Coefficients

a. The Runoff Curve Number Method, developed by the NRCS, shall be used to calculate storm water runoff. The resulting formulas are as follows:

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

where:
Q_V = surface runoff volume (inches)
P = rainfall (inches)
S = potential maximum retention after runoff begins (inches)

and where:

$$S = \frac{1000}{CN} - 10$$

Surface runoff volumes are calculated separately for impervious and pervious areas.

b. Curve Number (CN) values shall be taken from Technical Release No. 55 (TR-55). Standard values are summarized in ***Table 8*** for convenience.

Table 8 – Curve Numbers (CNs) from TR-55

Cover Description		**Curve Number**			
Cover Type	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Woods	Fair	36	60	73	79
	Good	30	55	70	77
Meadow		30	58	71	78
	Fair	49	69	79	84
Open spaces (grass cover)	Good	39	61	74	80
Paved parking lot, roof, driveway, etc.		98	98	98	98

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

(1) Pre-development conditions shall consist of a "Meadow" cover type for all existing land covers other than woods. For existing woods use the "Woods" cover types for "good" hydrologic conditions.

(2) Open space in "fair" condition shall be used for post-development pervious areas that are not receiving non-structural and restorative structural BMP credits.

c. A Unit Hydrograph-based Method shall be used to generate peak storm water runoff rates.

d. An antecedent moisture condition of II, reflective of normal soil moisture, shall be used with the NRCS or Modified Michigan Unit Hydrograph Method.

e. Other methodologies and computer models listed in Chapter 9 of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008) may also be accepted with the following limitations.

(1) The Rational Method shall only be used to generate peak discharges to size conveyance systems for sites less than 120 acres where it is not necessary to calculate volume reduction of flows entering the conveyance system. The peak runoff rate is given by the equation:

$$Q = CIA$$

where:
Q = peak runoff rate (cubic feet per second)
C = the runoff coefficient of the drainage area
I = the average rainfall intensity for a storm with a duration equal to the time of concentration of the drainage area (inches per hour)
A = the drainage area (acres)

(2) Runoff coefficients for various land uses and surface types are included in ***Table 9***.

Table 9 – Rational Method Runoff Coefficients

Type of Development	Runoff Coefficients
Business	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single family	0.30 to 0.50
Multi-units (detached)	0.40 to 0.60
Multi-units (attached)	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Park, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard	0.20 to 0.35
Unimproved	0.10 to 0.30
Character of Surface	
Pavement	
Asphalt and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil	
Flat 2%	0.05 to 0.10
Average 2% to 7%	0.10 to 0.15
Steep 7%	0.15 to 0.20
Lawns, Heavy Soil	
Flat 2%	0.13 to 0.17
Average 2% to 7%	0.18 to 0.22
Steep 7%	0.25 to 0.35

Source: *Design and Construction of Sanitary and Storm Sewers*, American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

2. Time of Concentration

a. When a Unit Hydrograph Method is used to calculate flow: Travel time shall be calculated using NRCS TR-55 methodology as outlined below.

(1) The flow path is split into three sections – sheet flow, shallow concentrated flow, and open channels. In each flow regime the velocity and/or travel time are computed. The time-of-concentration is then the sum of the travel times.

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

$$\frac{0.007(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$$

where n is Manning's factor, L is the flow length (feet), P_2 is the 2-year precipitation depth, and s is the slope (feet/foot). Multiply this value by 60 minutes per hour to obtain travel time in minutes.

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

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

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 60 seconds per minute to obtain travel time in minutes.

(c) Open channel flow uses Manning's equation to calculate the velocity based on slope, flow area, and wetted perimeter. The flow length (feet) is then divided by the velocity (feet per second) and a conversion factor of 60 seconds per minute to obtain travel time in minutes.

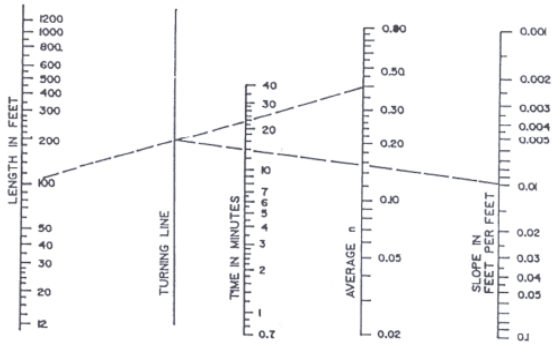
b. BMP residence time shall be calculated as the storage volume divided by the 10-year peak flow rate.

c. When the Rational Method is used to calculate flow: Overland flow time may be calculated using the nomograph shown as ***Figure 3***. A minimum of 15 minutes shall be used. Channel flow may be calculated using Manning's equation.

Figure 3 - Nomograph to Compute Time of Concentration for Overload Flow

The following is a table used for determining n

TYPE OF SURFACE	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



Example: N=0.40, L=100', S=0.01 feet/foot and tc=13.6 minutes

Chart is printed from the following equation.

$$tc = \left(\frac{2\,Ln}{3\sqrt{S}}\right)^{X} \qquad X = \frac{1}{2.14}$$

Taken from ENGINEER'S NOTEBOOK

"Time of concentration for overland flow" W.S. Kerby, J.M Asce, Hydrologist, Servis, Van Doren & Hazard, Engineers, Topeka, Kansas.

The variables needed to compute time of concentration for a proposed development are its length, slope, and surface retardants. These variables can be computed from field survey notes.

The length L is the distance from the extremity of the development area in a direction parallel to the slope until a defined channel is reached. The units are in feet. Overland flow will become channel flow within 1,200 feet in almost all cases. Time of concentration is the sum of overland flow and channel flow.

The slope S is the difference in elevation between the extremity of the drainage area and the point in question divided by the horizontal distance. The units are in feet/foot.

The surface retardants coefficient, n, is the average surface retardants value of the overland flow.

3. Rainfall

1. The rainfall duration-frequency table provided by the ***NOAA Precipitation Frequency Data Server (PFDS)*** shall be used with the Rational Method to determine a rainfall intensity for a rainfall duration equal to the time-of-concentration.

2. The 24-hour rainfall amounts provided in the ***NOAA Precipitation Frequency Data Server (PFDS)*** shall be used with the Runoff Curve Number Method.

3. A Type II rainfall distribution shall be used when a unit hydrograph approach is used.

B. Calculating Storage Volumes and Release Rates

1. Stream Protection using Onsite Retention (1)

$$Vsp = V2dev - V2pre$$

where:
Vsp = minimum required stream protection volume (cubic feet)

and

$$V2dev = A(Qv_{dev\text{-}perv} + Qv_{dev\text{-}imp}) /12$$

$$V2pre = A(Qv_{pre\text{-}perv} + Qv_{pre\text{-}imp}) /12$$

where:
V2dev = runoff volume of the 2-year, 24 hour storm for proposed development conditions
V2pre = runoff volume of the 2-year, 24-hour storm under pre-development conditions
A = contributing disturbed site area (acres)
Qv = surface runoff volume (inches) by Runoff Curve Number Method
12 = factor to convert inches to feet

The stream protection volume must be retained onsite. This may be accomplished through infiltration, storm water reuse, interception, and/or evapotranspiration.

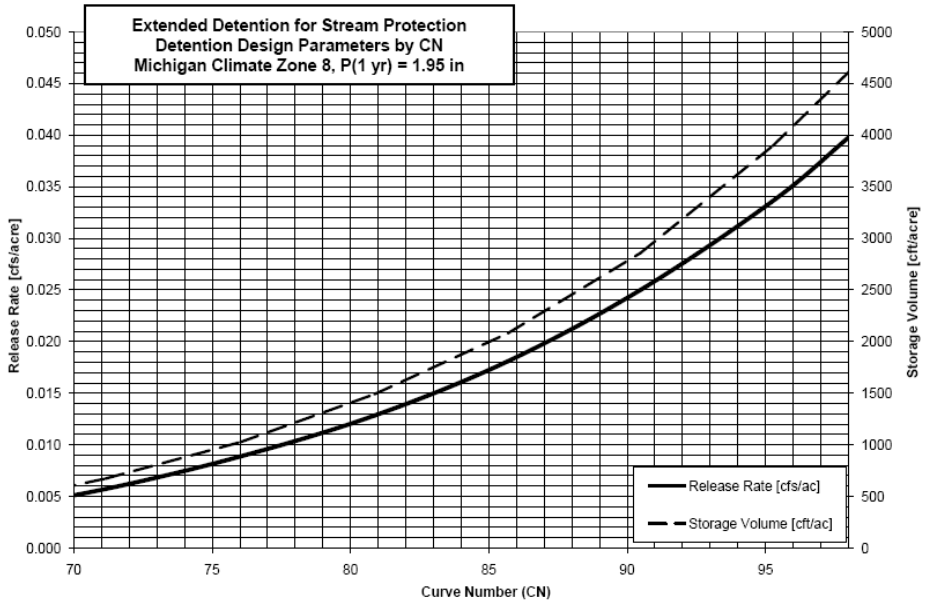
The Green Calculator is a Microsoft Excel spreadsheet application that uses a unit hydrograph-based storm water runoff method with NRCS Curve Numbers (CN) and time-of-concentration formulas. It calculates required treatment volumes and detention release rates for individual site drainage areas and allows the user to select non-structural and structural BMPs to meet required runoff rates and volumes. Output is graphed as hydrographs and summarized in tabular form for a range of rainfall frequencies (2, 5, 10, and 25 year). A copy is provided with this manual.

2. Stream Protection using Extended Detention (2)

Extended detention of the total runoff from the 1-year, 24-hour rainfall event to achieve a 24-hour lag between the centroid of the outflow hydrograph and the inflow hydrograph is required when the second stream protection approach is used. The resulting storage volume and maximum allowable release rate are determined from reservoir routing. Multiple simulations were performed for the "Curve Number Method" as described in *Lower Grand River Watershed, Stormwater Management for Stream Protection: Development of Michigan Statewide Rating Curves for Extended Detention Control of the Stream Protection Volume*, FTC&H, 2009.

Required release rates and storage volumes per acre are calculated for CN values of 70 to 98 and can be selected from the curves provided in ***Figure 4***.

Figure 4 - Extended Detention Curves for Stream Protection



Source: *Lower Grand River Watershed, Stormwater Management for Stream Protection: Development of Michigan Statewide Rating Curves for Extended Detention Control of the Stream Protection Volume*, FTC&H, 2009.

3. Flood Control using Detention Basins

The standard flood control criteria consist of detention of the 25-year, 24-hour rainfall event. Maximum allowable release rates are dependent upon which stream protection criteria is selected. If 2-year onsite retention is used, 25-year peak discharge rates must not exceed pre-development peak runoff rates. If 1-year extended detention is used, a 25-year maximum allowable release rate of 0.15 cfs/acre is required. The required storage volume is determined by reservoir routing with the Runoff Curve Number Method. The Green Calculator will compute the required 25-year detention storage volume for the calculated inflow hydrograph given a user-specified release rate.

The Rational Method may be used to determine the volume of detention storage in areas where the standard flood control criteria is not required (Zone C). A Microsoft Excel spreadsheet application calculates the volume of inflow for a range of times and subtracts from that the volume of outflow, assumed to be at a constant rate, over the same time duration. The required storage volume is selected from the cell with the greatest difference between "volume in" minus "volume out." A factor of safety of 1.25 is applied because this method tends to underestimate the storage volume when compared to pond routing. An example is provided in ***Figure 5***.

4. Flood Control using Retention Basins

The detention function of the Green Calculator can be used to calculate the 25-year storage volume required when retention basins are used to provide flood control. The user-specified release rate would be the infiltration rate provided by the soil over the basin bottom as given the following equation:

$$Qout = i(A)(3600)(12)$$

where:
Qout = Average outflow from basin bottom (cubic feet per second)
i = design infiltration rate of soil (inches per hour)
A = Bottom area of basin (square feet)
3600 = factor to convert hours to seconds
12 = factor to convert inches to feet

The Rational Method spreadsheet may be used in the same manner, with the allowable release rate replaced with the average outflow from the basin bottom.

CAUTION: The Green Calculator assumes that the resulting outflow volume is routed offsite when it is really infiltrated. When the detention function is used in this way, the user must be aware that this volume will be wrongly reflected in the discharge hydrographs.

Figure 5 - Sample Detention Basin Sizing Spreadsheet by Rational Method

DETENTION BASIN SIZING
(RATIONAL METHOD)

PROJECT:
JOB NO.:

DATE:
BY:

LOCATION:

CONTRIB. AREA (acres) =
RUNOFF "C" VALUE =
ALLOWABLE CFS/ACRE =
RAINFALL FREQUENCY = 100 YEAR

ALLOWABLE
RELEASE RATE (cfs) = 0

TIME (hrs)	(1) RAINFALL INTENSITY (in/hr)	(2) RAINFALL RUNOFF (cft)	(3) DISCHARGE VOLUME (cft)	(4) STORAGE VOLUME (cft)	(5) STORAGE VOLUME (ac-ft)	(6) TIME TO EMPTY (hrs)
0.17		0	0	0	0.00	0.0
0.25		0	0	0	0.00	0.0
0.33		0	0	0	0.00	0.0
0.5		0	0	0	0.00	0.0
0.67		0	0	0	0.00	0.0
0.75		0	0	0	0.00	0.0
0.83		0	0	0	0.00	0.0
1		0	0	0	0.00	0.0
2		0	0	0	0.00	0.0
3		0	0	0	0.00	0.0
4		0	0	0	0.00	0.0
5		0	0	0	0.00	0.0
6		0	0	0	0.00	0.0
7		0	0	0	0.00	0.0
8		0	0	0	0.00	0.0
9		0	0	0	0.00	0.0
10		0	0	0	0.00	0.0
12		0	0	0	0.00	0.0

NOTES:

(1) Input rainfall intensity, I, in in/hr for the specified design rainfall at each duration (time, t). I = P/t where P is the rainfall in inches.
(2) Rainfall runoff volume is calculated by multiplying the Rational Formula, Q = CIA, by the time, t : V = (It)CA
(3) Discharge volume is calculated by multiplying the discharge rate by the time: Vo = Qo t
(4) Storage volume is calculated by subtracting the discharge volume from the runoff volume.
(5) Storage volume is converted to acre-feet by dividing by 43,560 sft/acre
(6) Time to empty is calculated by dividing the storage volume by the discharge rate.

5. Water Quality

Treatment of runoff by settling (permanent pool or extended detention), infiltration, or filtration is required from directly connected impervious areas and disturbed pervious areas (i.e. lawns). The minimum required water quality volume shall be calculated using the Small Storm Hydrology Method by the following formula:

$$Q = P \times Rv$$

where:
Q = runoff (inches)
P = 90-percent annual non-exceedance rainfall (inches) = 1.0 inch
R_v = area-weighted volumetric runoff coefficient (individual runoff coefficients are given in ***Table 11***.)

Table 11 – Runoff Coefficients for Small Storm Hydrology Method

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

and

$$Vwq = QA(3630)$$

where:
Vwq = minimum required water quality volume (cubic feet)
Q = runoff (inches)
A = contributing area (acres)
3630 = factor to convert acre-inches to cubic feet

If a vegetated filter strip or grassed 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.

6. Pre-treatment

a. Settling Basins (forebay):

$$Vpt = 0.15(Vwq)$$

where:
Vpt = minimum required pre-treatment volume (cubic feet)
Vwq = water quality volume (cubic feet)

b. Vegetated Filter Strips:

Provide a 5-foot minimum sheet-flow length at a maximum slope of 2%.

c. Grassed Swales:

Provide a 15-foot minimum sheet-flow length at a maximum slope of 2%.

d. Proprietary Treatment Systems:

Follow manufacturer's guidelines.

III. NON-STRUCTURAL BEST MANAGEMENT PRACTICES

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

- Minimize Soil Compaction and Total Disturbed Area
- Protect Natural Flow Pathways (including Riparian Buffers)
- Protect Sensitive Areas
- Storm Water Disconnection

Design requirements are provided in BMP Fact Sheets in Chapter 6 of the *Low Impact Development Manual for Michigan* (SEMCOG 2008):

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf

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

Minimize Soil Compaction and Total Disturbed Area

Criteria

This BMP applies to those portions of buildable lots located outside of construction traffic and staging areas and lot building zones that can be maintained as "minimal disturbance areas" or "no disturbance areas" during construction. This BMP does not require a maintenance plan or permanent easement.

1. Identify "minimal disturbance areas" and "no disturbance areas" on site plan and construction drawings.

2. "Minimal" and "no 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.

3. "No disturbance areas" must not be subject to grading or movement of existing soils. Existing vegetation must be present in a healthy condition. Invasive vegetation may be removed.

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

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

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

Minimize Soil Compaction and Total Disturbed Area (continued)

Calculation Credits

Assign a CN reflecting open space in "good" condition, or woods in "fair" 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 "fair" condition. Woods in "good" condition may be used if trees are protected by a local tree ordinance. Exempt from water quality criteria.

Protect Natural Flow Pathways

Criteria

1. Identify all existing natural flow pathways on site plan.
2. Identify natural flow pathways to be protected on site plan and construction drawings.
3. 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.
4. Identify flow pathways designed as part of the storm water management system including strategies such as:
    a. Increased length
    b. Increased roughness
    c. Decreased slope
5. Ensure adequacy of flow pathway for post-development flows.
6. Include natural flow pathways in maintenance plan.
7. Protected natural flow paths on multiple individual private lots must have an easement in accordance with the requirements in Part 1 of this manual.

Calculation Credits

Adjust time-of-concentration. Exempt from water quality criteria.

Protect Sensitive Areas (including Riparian Buffers)

Criteria

This BMP includes protected areas on the development property located on separate out lots or set-asides that prohibit land uses inconsistent with the stated purpose. However, this BMP does not require a maintenance plan or permanent easement.

1. Identify all sensitive areas on site plan.
2. Identify all sensitive areas to be protected on the site plan and construction drawings.
3. 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.
4. Identify municipal/township ordinance requirements, if any, and establish sensitive area standards for development site. In the absence of a local ordinance, Drain Commissioner standards for Riparian Buffers shall consist of:
    a. Variable width depending on topography, minimum 25-foot width (Zone 1)
    b. Naturally vegetated
5. Minimal clearing is allowed for lot access and fire protection.

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, but runoff from the protected area does not need to be managed for water quality, stream protection, or flood control.)

In addition to the guidelines provided in the BMP Fact Sheets, the Water Resources Commissioner has the following requirements for activities proposed within floodplains:

1. The proprietor shall demonstrate that any activity proposed within a 100-year floodplain will not diminish the flood storage capacity.
2. Compensatory storage will be required at a minimum ratio of 1:1 for all lost floodplain storage, unless hydrologic analysis of the watershed indicates no harmful interference at a lower ratio.
    a. The compensating cut must be available during a flood event.
    b. Water must be able to move freely from stream to storage.
    c. Excavation must be adjacent to the floodplain.
    d. Compensating storage shall NOT be provided through channel widening.

Storm Water Disconnection

Criteria

1. 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:

    a. Disconnection must ensure no basement seepage.

    b. 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.

    c. Maximum contributing impervious area flow path length shall be 75 feet.

    d. Maximum contributing impervious area shall be 1,000 square feet per discharge point.

    e. Size of disconnect area shall be twice the size of the contributing impervious area.

    f. Length of disconnect area must be at least the length of the contributing impervious area.

    g. Roof downspouts and curb cuts must be at least 10 feet away from the nearest connected impervious surface to discourage "re-connections."

    h. Slope of disconnect area must be no greater than 5%.

    i. Disconnect area must be a "no disturbance" or "minimal disturbance" area.

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

3. Include storm water disconnect areas in maintenance plan.

Calculation Credits

Weight CN with pervious area. Adjust time-of-concentration, including a 1.25 factor for paved areas flowing onto pervious areas. Exempt from water quality criteria.

IV. STRUCTURAL BEST MANAGEMENT PRACTICES

The Water Resources Commissioner has adopted standards for the following structural BMPs:

- Bioretention / Rain Garden
- Capture Reuse
- Constructed Filter
- Detention Basins
- Infiltration Practices
- Level Spreader
- Native Revegetation
- Pervious Pavement
- Planter Box
- Riparian Buffer Restoration
- Soil Restoration
- Vegetated Filter Strip
- Vegetated Roof
- Vegetated Swale / Bioswale
- Water Quality Devices

BMPs shall be designed in accordance with BMP Fact Sheets in Chapter 7 the *Low Impact Development Manual for Michigan* (SEMCOG 2008):

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter7.pdf

Supplemental Design Requirements are provided herein. Sizing Calculations and Calculation Credits provided in this manual replace direction given on individual BMP Fact Sheets.

The Water Resources Commissioner has also adopted standards for the following additional structural BMPs as defined in this manual:

- Storm Sewer
- Culvert or Bridge
- Open Channel
- Spill Containment Cell

Bioretention / Rain Garden

Supplemental Design Requirements

1. Siting
   a. Soils investigation is required.
   b. A minimum of 4 feet is required between the bottom of the BMP and the highest known groundwater elevation.
2. Materials
   a. Void ratio for the amended soil material shall be based on the USDA soil textural class and Effective Water Capacity in ***Table 7***. A maximum design value of 0.30 shall be used for the void ratio of the amended soil material.

Sizing Calculations

1. Calculate design runoff volume routed to the BMP.
2. The required storage volume shall be equal to the design runoff volume.
3. The bottom area of the BMP shall be used as the infiltration area.
4. Calculate minimum infiltration area required to drain the required storage volume in the specified drawdown time (72 hours total for BMP, 24 hours for surface ponding) using the design infiltration rate of the soil. (This assumes that the actual infiltration rates of the amended/imported BMP materials are greater than or equal to the design rates allowed based on soil type.)

   $$A = [V / (i \times t)] \times 12$$

   where:
   A = minimum infiltration area (square feet)
   V = design runoff volume (cubic feet)
   i = infiltration rate of soil (inches per hour)
   t = maximum allowable drawdown time
   12 = factor to convert inches to feet
5. 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)

Bioretention / Rain Garden (continued)

6. The infiltration volume is counted in the volume credit, and is calculated as:

   Design Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

   Note: The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

7. For underdrained BMP, follow criteria for filter.

Calculation Credits

Volume Reduction:

- Infiltration: Count storage volume and infiltration volume.
- Underdrained: Count storage and infiltration volume between BMP bottom and elevation of underdrain.

Peak Rate Reduction:

- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate). Overflow (rate and volume) is conveyed downstream.

Water Quality:

- Provides through infiltration or filtration.

Capture Reuse

Sizing Calculations

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

2. Obtain average monthly precipitation (inches) and evapo-transpiration (ET) in inches. www.enviroweather.msu.edu

3. Multiply average monthly precipitation by contributing area (acres) and area-weighted Small Storm Hydrology Method runoff coefficient to obtain volume of recharge. Multiply by 3630 to convert acre-inches to cubic feet. Multiply by 7.48 gallons per cubic foot to convert to gallons.

4. 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.

5. Select trial size container or pond volume.

6. 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.

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

Calculation Credits

Volume Reduction:

- Count storage volume provided.

Peak Rate Reduction:

- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate). Overflow (rate and volume) is conveyed downstream.

Water Quality:

- Provides through ultimate infiltration (irrigation), or discharge to wastewater system.

Constructed Filter

Supplemental Design Requirements

1. Siting

   a. Soils investigation is required.

   b. A minimum of 2 feet is required between the bottom of the BMP and the highest known groundwater elevation.

Sizing Calculations

1. Calculate design runoff volume routed to the BMP.

2. Calculate filter surface area required to drain the design volume in the specified drawdown time (72 hours total for BMP; 24 hours for surface ponding) using design infiltration rate of filter media.

$$A = [V \times d_f / (i \times (h_f + d_f) \times t)] \times 12$$

   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 2.5-foot maximum)
   i = infiltration rate of soil (inches per hour)
   h_f = average head; typically ½ of the maximum head on filter media (feet)
   t = maximum allowable drawdown time
   12 = factor to convert inches to feet

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

Calculation Credits

Volume Reduction:
- None given.

Peak Rate Reduction:
- Reduction in peak discharge by routing through BMP (treat like extended detention). Outflow and overflow (rate and volume) are conveyed downstream.

Water Quality:
- Provides through filtration.

Detention Basins

Supplemental Design Requirements

1. Siting
   a. Soils investigation is required.
2. Sizing and Configuration
   a. 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.
   b. At a minimum, the volume of the permanent pool for wet detention basins shall be 2.5 times the water quality volume.
   c. Where water quality and stream protection are provided through detention, these volumes may be included in the flood control volume.
3. Outlet Design
   a. The outlet may be designed using the orifice equation, rearranged to solve for area.

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

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. Pipes or orifice plates shall have a minimum diameter of 4 inches.
   d. 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.
   e. Hoods and trash racks shall be placed on riser pipes. Grate openings shall be a maximum of 3 inches on center.
   f. Riser pipes shall have a minimum diameter of 24 inches. Riser pipes greater than 4 feet in height shall be 48 inches in diameter.

Detention Basins (continued)

g. 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.

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

i. All detention facilities must have a provision for overflow at the high water level. A 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.

$$Q = 2.6LH^{\frac{3}{2}}$$

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)

j. The top of berm elevation shall be a minimum of 1 foot above the design maximum water level.

k. Overflow spillways shall be protected with riprap or a permanent erosion control blanket to prevent erosion of the structure.

4. Sediment Forebay

a. The capacity of the forebay shall be equivalent to the pretreatment volume. Where more than one inlet pipe is required, the calculated forebay volume shall be pro-rated by flow contribution of each inlet.

b. The length-to-width ratio shall be a minimum of 1.5:1 and a maximum of 4:1.

Detention Basins (continued)

Sizing Calculations

1. Calculate required design runoff volume and peak rate (inflow hydrograph).

2. Calculate allowable outflow(s).

3. Route inflow hydrograph through detention pond using stage-storage relation and outlet hydraulics. Storage volume may be calculated by:

    a. Green Calculator

    b. Rational Method Spreadsheet

    c. Other Computer Routing Program

Calculation Credits

Volume Reduction:

- None given.

Peak Rate Reduction:

- Reduction in peak discharge calculated by routing through BMP. Outflow (rate and volume) is conveyed downstream.

Water Quality:

- Dry Pond: Does not provide sufficient treatment.
- Wet Pond: Provides through permanent pool.
- Underground Detention: Does not provide sufficient treatment.
- Constructed Wetlands: Provides through permanent pool.
- Extended Detention: Provides through sufficient particle settling time.

Infiltration Practices

Supplemental Design Requirements

1. Siting

   a. Soils investigation is required.

   b. A minimum of 4 feet is required between the bottom of the BMP and the highest known groundwater elevation.

2. Sizing and Configuration

   a. Infiltration basins that utilize natural depressions with a permanent water level shall be sized based on the horizontal projection of the side slopes above the permanent water elevation to calculate the required infiltration area.

   b. Infiltration basins without an acceptable surface water overflow route shall include a factor of safety of 3 feet of freeboard.

Sizing Calculations

1. Dry wells, leaching basins, infiltration trenches, infiltration beds, infiltration berms:

   a. Calculate design runoff volume routed to the BMP.

   b. The required storage volume shall be equal to the design runoff volume.

   c. Infiltration area shall be defined as:

      (1) Dry Well/Leaching Basin: Bottom and sides (lateral)

      (2) Infiltration Trench: Bottom of trench (length x width)

      (3) Infiltration Bed: Bottom area of the bed

      (4) Infiltration Berm: Ponding area (length of berm x average width of ponding behind berm)

   d. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time (72 hours total for BMP) using the design infiltration rate of the soil.

$$A = [V / (i \times t)] \times 12$$

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

Infiltration Practices (continued)

e. 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

(2) Leaching basins:

Storage Volume (cubic feet) = 2 Πr^2 (square feet) x Depth (feet)

where:
r = radius of leaching basin (feet)
Π = *pi* (approximately 3.14)

(3) Infiltration berm:

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

f. The infiltration volume is counted in the volume credit, and is calculated as:

Design Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

Note: The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

2. Infiltration (retention) basins:

a. Calculate required design runoff volume and peak rate (inflow hydrograph).

b. The infiltration area shall be defined as the bottom of the basin.

c. Calculate minimum infiltration area required to drain design volume in specified drawdown time (72 hours for surface ponding) using estimated design infiltration rate of soil.

$$A = [V / (i \times t)] \times 12$$

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

Infiltration Practices (continued)

d. Calculate storage volume based on minimum allowable infiltration area and allowable depths. Storage volume may be calculated by:

(1) Green Calculator

(2) Rational Method Spreadsheet

(3) Other Computer Routing Program

Calculation Credits

Volume Reduction:

- Count storage volume and infiltration volume.

Peak Rate Reduction:

- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate).

Water Quality:

- Provides through infiltration.

Level Spreaders

Calculation Credits

Volume Retained:

- None given.

Peak Rate Reduction:

- None given.

Water Quality:

- Does not provide sufficient treatment.

Native Revegetation (including Riparian Buffer Restoration)

Criteria

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

2. 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.

3. Identify municipal/township ordinance requirements, if any, and establish riparian buffer protection standards for development site. In the absence of a local ordinance, Water Resources Commissioner standards shall consist of:

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

   b. Native revegetation

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

5. Include native revegetation areas in maintenance plan.

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. Exempt from water quality criteria.

Pervious Pavement

Supplemental Design Requirements

1. Siting

    a. Soils investigation is required.

    b. A minimum of 4 feet is required between the bottom of the BMP and the highest known groundwater elevation.

    c. Runoff from offsite areas shall not be directed onto porous pavement surface.

Sizing Calculations

1. Calculate required design rainfall volume.

2. The required storage volume shall be equal to the design rainfall volume from the contributing surface area (porous pavement, roof).

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

4. Maximum allowable drawdown time shall be 72 hours.

5. 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

6. The infiltration volume is counted in the volume credit, and is calculated as:

    Design Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

    Note: The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

7. For under drained BMP, follow criteria for filter.

Pervious Pavement (continued)

Calculation Credits

Volume Reduction:

- Infiltration: Count storage volume and infiltration volume limited by 2-year rainfall volume on pavement.

Peak Rate Reduction:

- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate).

Water Quality:

- Provides through infiltration or filtration.

Planter Box

Supplemental Design Requirements

1. Siting

   a. Soil infiltration testing is required.

   b. A minimum of 4 feet is required between the bottom of the BMP and the measured groundwater elevation to account for seasonal and cyclical variations in groundwater level.

2. Materials

   a. Void ratio for the amended soil material shall be based on the USDA soil textural class and Effective Water Capacity in ***Table 7***. A maximum void ratio of 0.30 shall be allowed for the amended soil material.

Sizing Calculations

1. Calculate design runoff volume routed to BMP.

2. The required storage volume shall be equal to the design runoff volume.

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

Planter Box (continued)

4. Calculate minimum infiltration area required to drain the required storage volume in specified drawdown time (12 hours total for BMP; 4 hours for surface ponding) using the design infiltration rate of the soil. (This assumes that the actual infiltration rates of the amended/imported BMP materials are greater than or equal to the design rates allowed based on soil type.)

$$A = [V / (i \times t)] \times 12$$

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

5. 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)

6. The infiltration volume is counted in the volume credit, and is calculated as:

   Design Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

   Note: The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

7. For underdrained BMP, follow criteria for filter.

Calculation Credits

Volume Reduction:
- Infiltration: Count storage volume and infiltration volume.
- Filtration: None given.

Peak Rate Reduction:
- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate). Overflow (rate and volume) is conveyed downstream.

Water Quality:

- Provides through infiltration or filtration.

Soil Restoration

This BMP includes soil amendment and/or deep tilling to restore porosity to compacted soils and infiltration beds of other BMPs. However, due to the difficulty of ensuring implementation and longevity, this BMP provides no storm water credit.

Vegetated Filter Strip

Sizing Calculations

1. Calculate area contributing runoff.

2. Calculate the minimum required filter strip area.

3. Calculate minimum required length based on slope and type of vegetation.

Calculation Credits

Volume Reduction:
- None given.

Peak Rate Reduction:
- Adjust time-of-concentration.

Water Quality:
- Provides through infiltration or filtration.

Vegetated Roof

Sizing Calculations

1. 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

Calculation Credits

Volume Reduction:
- Count storage volume limited by 2-year rainfall volume on roof.

Peak Rate Reduction:
- Reduction in peak discharge due to an extended time of concentration through BMP (storage volume divided by 10-year peak flow rate). Overflow (rate and volume) is conveyed downstream.

Water Quality:
- Exempt from water quality criteria.

Vegetated Swale / Bioswale

Sizing Calculations

1. Channel

    a. Calculate 10-year peak flow rate.

    b. Size channel based on Manning's Equation.

    c. Check that flow velocities are within acceptable limits.

2. Volume Behind Check Dam

    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

Calculation Credits

Volume Reduction:
- Vegetated Swale: None given.
- Bioswale: Storage volume behind check dams.

Peak Rate Reduction:
- Adjust time-of-concentration.

Water Quality:
- Provides through infiltration or filtration of runoff if vegetated filter strip area, length, and slope requirements are met.

Water Quality Device

Calculation Credits

Volume Reduction:
- None given.

Peak Rate Reduction:
- None given.

Water Quality:
- Does not provide sufficient treatment.

Storm Sewer

Design Requirements

1. Sizing and Configuration

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

   b. Storm sewer design velocities, capacities, and friction losses shall be based on Manning's equation:

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

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

   c. Acceptable slopes for circular pipe ("n" = 0.013) are included in Table 12. Minimum and maximum grade for other Manning's n values must be calculated based on allowable minimum and maximum velocities (V).

Table 12- Minimum and Maximum Slopes for Storm Sewers
(Manning's "n" = 0.013)

Pipe Size	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

d.

Storm Sewer (continued)

d. Manning's coefficients for closed conduit are included Table 13.

Table 13 - Manning's Roughness Coefficients

Conduit	Manning's 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 corrg.)	
Plain	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 (minor 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: *Design and Construction of Sanitary and Storm Sewers*, American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

e. 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.

f. Storm sewer pipe shall have a minimum diameter of 12 inches.

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

h. Restricted conveyance systems designed to create backflow into storm water storage facilities are not permitted.

Storm Sewer (continued)

2. End Treatment

   Outlet protection shall be provided as necessary to prevent erosion, based on the maximum velocities specified under the Open Channel BMP.

3. Manholes and Catch basins

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

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

   c. Pipe inverts at junctions shall be designed to minimize junction losses (match 0.8 points of pipe diameters).

   d. Minimum inside diameter of all manholes, catch basins, and inlet structures shall be 48 inches.

   e. Inlet structures shall be placed at low points of streets and yards, and be spaced a maximum of 400 feet apart. 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.

   f. 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%.

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

   h. No flow will be allowed across a street intersection.

   i. Perforated catch basins (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.

Storm Sewer (continued)

4. Materials

   a. Storm sewer pipe shall be reinforced concrete or smooth interior wall polyethylene in accordance with MDOT Standard Specifications.

   b. Pipe joints shall be designed to prevent excessive infiltration or exfiltration.

   c. Manholes and catch basins shall be in accordance with MDOT Standard Specifications.

   d. Connections to manholes shall be made with a resilient connector for pipe diameters 24 inches or less.

Calculation Credits

Volume Reduction:

- Solid wall pipe: None given.
- Perforated pipe (meeting slopes for minimum velocity): None given.
- Perforated catchbasins (leaching basins): Count storage volume below outlet pipe invert.

Peak Rate Reduction:

- None given.

Water Quality:

- Does not provide sufficient treatment.

Culvert or Bridge

Design Requirements

1. Sizing and Configuration

   a. Bridges shall be designed to provide a 2-foot-minimum freeboard to the underside (low chord) of the bridge for a 100-year flood.

   b. Footings shall extend at least 4 feet below the bottom of the channel.

   c. Culverts serving a drainage area of less than 2 square miles shall be designed for a minimum 10-year storm in the developed watershed with a maximum outlet velocity of 8 ft/s. A maximum of 1 foot of inlet submergence may be permitted, if this does not backup water out of the easement. The effect of the 100-year storm will be reviewed to ensure no adverse increase in water elevation off of the development property or flooding of structures within the development.

   d. Sizing of culverts and bridges shall include consideration for entrance and exit losses, and tailwater condition.

   e. Minimum diameter of a drive culvert shall be 12 inches.

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

2. End Treatment

   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.

3. Materials

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

Open Channel

Design Requirements

1. Sizing and Configuration

   a. The open channel shall be designed to convey runoff from a 10-year frequency rainfall event with 1-foot of freeboard to top of bank.

   b. Open channel design velocities, capacities, and friction losses shall be based on Manning's equation:

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

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

   c. Manning's Coefficients shall be determined from Table 12. 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.).

   d. Minimum bottom width shall be 2 feet.

   e. Minimum longitudinal slope shall be 0.10%.

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

   g. Open channel flow velocities shall be neither siltative nor erosive. The minimum velocity for open channels shall be 1.5 feet per second. The maximum velocity shall be 4 feet per second. 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.

Open Channel (continued)

3. Connections and Crossings

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

   b. A minimum clearance of 4 feet is required between open channel inverts and underground utilities unless special provisions are approved. In no case will less than 2 feet of clearance be allowed.

Calculation Credits

Volume Reduction:
- None given.

Peak Rate Reduction:
- None given.

Water Quality:
- Does not provide sufficient treatment.

Spill Containment Cell

Design Requirements

1. General

    a. A spill containment cell or equivalent storm water filter shall be used to trap and localize incoming sediments, and to capture slug pollutant loads from accidental spills of toxic materials (spill containment volume).

    b. The spill containment cell can be a wet forebay or an under-drained storm water filter with an impermeable bottom and sides to the design high water level.

2. Sizing and Configuration

    a. The spill containment cell volume shall be equivalent to the pre-treatment volume.

    b. The minimum surface area shall be 25% of the required volume.

    c. The length-to-width ratio for wet forebays shall be a minimum of 3:1, and a maximum of 4:1 to allow for adequate hydraulic length, yet minimize scour velocities. The maximum length-to-width ratio for storm water filters may be as high as 20:1 to allow for incorporation into a swale.

    d. The minimum hydraulic length shall be equal to the length specified in the length-to-width ratio.

    e. The overflow structure from the spill containment cell shall be sized for the peak inflow from a 10-year rainfall event.

    f. The top-of-berm elevation between the spill containment cell and the downstream receiving BMP shall be a minimum of 1 foot below the outer berm elevation.

    g. The spill containment cell shall have a minimum 1-foot-deep sump below the inlet pipe for sediment accumulation.

    h. The outlet structure from a wet forebay 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. The outlet structure from a storm water filter shall be designed within a manhole and be designed to draw water from the central portion of the water column to trap floatables and contain sediments in a sump.

4.

Spill Containment Cell (continued)

5. Materials

The spill containment cell shall be lined with impermeable materials extending up to the design high water elevation. A minimum 18-inch-thick clay later, 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.

Calculation Credits

Volume Reduction:

- None given.

Peak Rate Reduction:

- None given.

Water Quality:

- Used for pre-treatment, but could be sized to meet water quality volume standards through permanent pool or filtration.