Part A.

PURPOSE & INTRODUCTION

Each specific site proposed for development is unique due to soils, land cover, topography, location, etc. These unique characteristics make it difficult if not impossible to develop one set of uniform stormwater standards that is capable of accommodating all variables. Due to this, additional requirements not included in these standards, may be necessary to meet the intent of these rules. Also, waivers or variances from certain provisions of these standards may be requested when it can be demonstrated that this standard cannot be feasibly accommodated. In these situations alternatives consistent with the overall intent of these rules must be proposed for consideration and will be subject to the approval of the Water Resources Commissioner.

This section sets forth specific design and construction standards that will be used by the Water Resources Commissioner in review of proposed stormwater management systems in accordance with the objectives of managing both the quantity (volume and rate) and quality of stormwater runoff. A ***Glossary of Terms*** used throughout this section is provided in ***Appendix A***.

Whereas basin design for flood control is concerned with capturing and detaining relatively infrequent, severe runoff events, such as the 10-, 25-, or 100-year recurrence interval storm, designs for channel protection and water quality control require that the more frequent storm events (e.g. up to the 2-year recurrence interval storm) must be addressed as well. The need for managing smaller storms is directly related to the need to mitigate the impacts of urbanization within Washtenaw County and the accompanying increase in impervious area, which affects surface water quality in two important ways.

First, eroded soil and other pollutants that accumulate on impervious surfaces, such as metals, fertilizers, pesticides, oils and grease, are flushed off by the early stage of runoff, which then carries a shock loading of these pollutants into receiving waterways. By capturing and treating the runoff from the first inch of rain, pollutants that are washed off of the land can be removed from stormwater before it flows offsite.

Second, as recent studies by the MDEQ have shown, development within the County has caused stream flow fluctuations to rise dramatically. As impervious surface area increases and opportunities for infiltration are reduced, the frequency and duration of bankfull flow conditions, typically represented by the 2-year recurrence interval storm event, have intensified. As a result, streams adjust their capacities to convey increased flows, leading to channel and bank erosion and the destruction of aquatic habitat.

Development of sites with impervious surfaces increases the rate and volume of stormwater runoff. Standard detention systems limit the rate of surface water runoff discharge but do not control the additional volume. In order to more closely mimic the natural hydrology of an undeveloped site, infiltration systems must be installed and integrated throughout a site by utilizing the infiltration BMPs listed within these rules:

- Surface Infiltration Basins
- Subsurface Infiltration Beds
- Bioretention Areas
- Rain Gardens
- Pervious Asphalt, Concrete or Pavers
- Infiltration Trenches
- Other BMPs that provide infiltration (vegetated filter strips, bioswales or dry wells)

1. STORMWATER MANAGEMENT REQUIREMENTS [1]

Volume Treatment Considerations

To manage water quality, volume, rate and quantity, site stormwater management methods must be designed to treat the following:

- First flush volume; the runoff from the first inch of rain from the entire contributing watershed as determined by the Rational Method. The methods selected to treat the first flush volume shall be designed on a site-specific basis to achieve either a minimum of 80 percent removal of TSS, as compared with uncontrolled runoff, or a discharge concentration of TSS that does not exceed 80 mg/l. Where site conditions do not generate TSS concentrations greater than 80 mg/l, water quality treatment of the runoff is not required. BMPs may be used individually, or in combination, to achieve the required TSS removal for the site.

- Bankfull volume; the 2-year recurrence interval /24 hour storm event, as determined by the NRCS Method.

[1] Notes:

Individuals seeking to develop land within Washtenaw County are encouraged to contact local governments regarding their local stormwater BMP requirements. Standards in addition to those contained in these Rules may be in effect in special communities or creeksheds.

It is difficult or impossible to develop one set of uniform standards that is capable of accommodating all variables and unique site circumstances. Waivers or variances from special provisions of these standards may be requested, and alternatives consistent with the overall intent of stormwater quantity and quality management may be proposed, subject to the approval of the Water Resources Commissioner.

Infiltration will be required for the ***greater*** of the following:

- The difference between the ***pre-development*** bankfull and ***post development*** bankfull volumes

OR

- The entire first flush volume

- 100-year recurrence interval storm event; as determined by the NRCS Method.

Note: Projects/sites where the required infiltration volume cannot be achieved must increase the required detention volume by up to an additional 20%.

An infiltration system or systems may be an integral part of the storage device that is required to store the 100-year recurrence interval storm or may be a separate system or systems within the development that will provide for the required infiltration volume. Infiltration upstream of the storage device is preferred.

Soil borings and/or soil test pits will be required on all sites to determine the feasibility of infiltration. Where more impervious soils exist, BMPs must be engineered to properly dewater within 48 hours of the storm event. If the required infiltration for a site is unachievable, the developer/applicant must submit written proof and supporting documentation for review by the Water Resources Commissioner, and provide appropriate Best Management Practices to detain/retain the applicable stormwater volume and provide treatment to meet the first flush TSS removal requirements.

Detention/ Retention System Considerations

Controlling both extremely large events to prevent flooding, and more frequent events to mitigate water quality impacts and channel erosion, can be achieved partially through the proper design of detention/retention basins. Among alternatives, wet retention/detention facilities and constructed wetland marsh systems are more effective for achieving control of both stormwater volume and quality. The phosphorus removal capability of wet retention/detention facilities, wetland marsh systems and infiltration systems is superior to other storage BMPs.

BMP Considerations

Extensive literature is available on specific design concepts and alternatives, and selected references are available within this document's appendix. Diagrams and details for bioretention systems, rain gardens, pervious pavement, dry wells, green roofs and water reuse are contained within ***Section V, Design Requirements for Stormwater Management Systems*** of these rules. Several other Non-structural Best Management Practices (BMPs) are references within, ***Section IV, Part D, Sizing Requirements for Non-structural Credits***. For additional information on BMP planning, design and implementation, refer to the SEMCOG ***Low Impact Development Manual for Michigan***- A Reference Guide for Implementers and Reviewers.

2. STORMWATER MANAGEMENT FOR REDEVELOPED SITES

If redevelopment is proposed on any existing site, the stormwater management performance must be brought up to the current standard for the redeveloped or newly constructed portion of the site. The methods of stormwater management must be the Standard method as described in this manual. The following must be addressed:

- If 50% or more of the site is slated for redevelopment, the entire site will be subject to all the requirements of the current standards.
- All portions of the site that are slated for redevelopment will be subject to all the requirements of the current standards. This includes storage of the 100 year recurrence interval storm, bankfull storm flow rate control and the requirement of infiltrating the first flush storm volume for the newly constructed areas.
- Developed portions of the site not slated for construction will have retrofits made to the existing drainage system to provide quality treatment of runoff prior to leaving the site. This may be completed by traditional methods or the addition of mechanical treatment devises.
- Pavement reconstruction in connection with redevelopment will be considered new construction.
- Future development of the site, (within 10 years from WCWRC approval) that in combination results in redevelopment of 50% or more of the site will trigger the entire site as subject to all of the requirements of the current WCWRC Rules.

3. STORMWATER DISCHARGE REQUIREMENTS

- In no event will the maximum design rate of volume of discharge exceed the maximum capacity of the downstream land, channel, pipe or watercourse to accommodate the flow. It is the proprietor's/developer's obligation to meet this standard. Should a stormwater system, as built, fail to comply, it is the proprietor's responsibility to design and construct, or to have constructed at his/her expense, any necessary additional and/or alternative stormwater management facilities. Such additional facilities will be subject to the Water Resources Commissioner's review and approval.

- The allowable release rate from a facility designed for the flood control storage volume will not exceed 0.15 cfs per acre of the property being drained.
- A description of the drainage course that will be utilized as the stormwater outlet and evidence that it is adequate for the proposed discharge shall be provided. It is noted that controlling flow to a rate that is equal to or below the pre-development rate may not be considered to be evidence of adequacy. ***The Engineer's Certificate of Outlet, Appendix L***, must be provided including the signature and seal of the professional engineer responsible for determining adequacy.
- If no adequate watercourse exists to effectively receive a concentrated flow of water from the proposed development, additional measures must be taken. These measures may include volume control, acquisition of easements from downstream property owners, off- site stormwater infrastructure construction, etc. If easements are required, it is the responsibility of the developer to secure any necessary easement(s) from downstream property owners. ***Typical Easement Language*** is provided in ***Appendix I***. ***See Appendix N, Legal Opinion Regarding Need for Easements Downstream of Drainage District Outlets.***
- Discharge should outlet within the watershed where flows originate, and generally may not be diverted to another watershed.

Part B. SIZING REQUIREMENTS– STANDARD METHOD COMPUTATIONS

1. STANDARD METHOD OVERVIEW

When calculating runoff using the Standard Method a two-step approach will be used.

Step 1.

Determine the first flush volume with the Rational Method. This method was chosen due to the underestimation of volume that the NRCS Curve Number Method yields for runoff less than one (1) inch.

Step 2.

Determine the bankfull and 100-year recurrence interval volumes with the NRCS Curve Number Method.

When determining the 100-year recurrence interval volume there are two assumptions that will be made.

Assumption 1.

Pre-development runoff volume will be the runoff from the site prior to development at a release rate of 0.15 cfs/acre.

Assumption 2.

The amount of post-development runoff volume equals the increase in runoff leaving the site above the pre-development release rate of 0.15 cfs/acre.

2. RUNOFF DETERMINATION – CURVE NUMBER METHOD

Introduction

The curve number method is the standard methodology and must be used to determine volumes for all developed sites. The hydrographs and equation shown in Figure 2 visually express the amount of required infiltration, post-development runoff and pre-development runoff at a fixed release rate of 0.15 cfs/acre. The amount of runoff (Vd) that must be managed via detention basins or through additional BMPs is expressed as the 100-year recurrence interval volume (V100) less the required infiltration (Vinf) and less the pre-development runoff (Vp) volume. It is acceptable, often cost-effective (and preferred) to manage the detention volume (Vd) using infiltration also.
The equation can be simply expressed as:

EQUATION

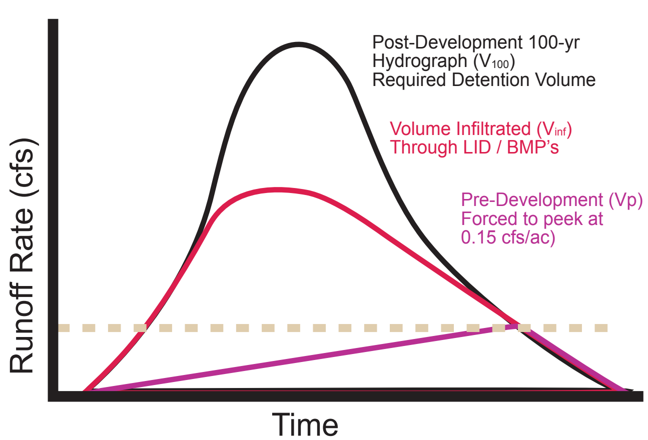
Detention Volume = 100-year Hydrograph Volume – Volume Infiltrated – Pre-development 100-year Hydrograph Volume

OR

$$V_d = V_{100} - V_{inf} - V_p$$

Runoff Calculations

The Runoff Curve Number Method, developed by the Natural Resources Conservation Service (NRCS), 1986, is perhaps the most commonly used methods for estimating runoff volumes. In this method, runoff is calculated based on precipitation, curve number, watershed storage, and initial abstraction. When rainfall is greater than the initial abstraction, runoff is calculated by:



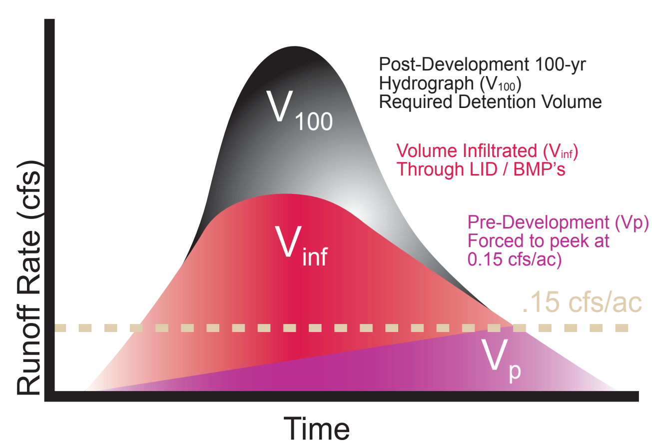


Figure 2. Detention Volume Hydrograph

EQUATION

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q= runoff (in.)

P= rainfall (in.)

Ia= initial abstraction (in.)

S= potential maximum retention after runoff begins (in.)

Initial abstraction (Ia) includes all losses before the start of surface runoff: depression storage, interception, evaporation, and infiltration. Ia can be highly variable but NRCS has found that it can be empirically approximated by:

EQUATION

$$I_a = 0.2S$$

Therefore, the runoff equation becomes:

EQUATION

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

Finally, S is a function of the watershed soil and cover conditions as represented by the runoff curve number (CN).

EQUATION

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

To account for the allowable release rate of 0.15 cfs/ac, a modification to the SCS method was created to incorporate the time of concentration for the 100-year storm event calculations, where time of concentration can be calculated by:

EQUATION

$$T_c = \frac{L}{V*3600}$$

T_c= time of concentration (hr)

L= length of flow path (ft)

V= velocity (fps)

This method utilizes the MDEQ unit peak flow rate calculation procedure described in the document, ***Computing Flood Discharges for Small Ungaged Watersheds by Richard Sorrell (2010). Equation 9.1*** in the Computing Flood Discharges document was used in order to convert the unit hydrograph peak flow value (Qp), expressed in units of cfs per square mile per inch of runoff into a corresponding inch of runoff:

EQUATION

$$Q_p = 238.6(T_c)^{-0.82}$$

The hydrograph peak flow value (Q_p) is used to then approximate the pre-development runoff (V_p), where (V_p) holds a linear relationship between flow rates and flow volumes, noted as:

EQUATION

$$\frac{V_{100} - V_p}{V_{100}} = \frac{\Delta}{Q_p}$$

The rearrangement of the equation yields:

EQUATION

$$V_p = V_{100} - \frac{V_{100}\Delta}{Q_p}$$

V_p= pre-development 100-year volume (cf)

V_{100}= post-development 100-year volume (cf)

Δ = estimation of the difference between pre-development 100-yr and post-development 100-yr flow (cfs)

To simplify the NRCS method, the change (Δ) in flow (Q_p) is used to determine the final 100-yr storm detention requirement based on peak flow (PF) from the site in cubic feet per second where:

EQUATION

$$PF = \frac{Q_p\, QA}{640}$$

The change (Δ) in flow can be quantified with the Area (A) in acres expressed as:

EQUATION

$$\Delta = PF - 0.15A$$

A = area (acres)

The 100-yr detention volume (V_{det}) can then be determined via substitution of (V_p) into the following:

EQUATION

$$V_{det} = \frac{\Delta}{Q_p} V_{100} - V_{inf}$$

V_{inf} = infiltration volume provided at the site (cf)

V_{det}= detention volume (cf)

Therefore, runoff can be calculated using only the curve number, rainfall and time of concentration. Curve numbers determined by land cover type, hydrologic condition, antecedent runoff conditions (ARC – sometimes referred to as antecedent moisture condition), and hydrologic soil group (HSG), see Table 4. Curve numbers for various land covers are based on an average ARC for annual floods and Ia = 0.2S. When estimating the ***pre-development*** bankfull runoff, use the curve number associated with Good Condition Woods or Meadow. A table can be found in Urban Hydrology for Small Watersheds (NRCS,1986) and various other references as well as ***Section IV, Part E, Standard Method Runoff Volume Worksheets*** within these Rules. ***See Worksheets 1 through 13*** titled ***Standard Method Site Runoff Calculations*** at the end of this section for a step-by-step procedure to determine runoff volumes.

Hydrologic Soil Groups

Soil properties influence the process of generating runoff from rainfall and must be considered in methods of runoff estimation. When runoff from individual storms is the major concern, the properties can be represented by a hydrologic parameter that reflects the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influences of both the surface and the horizons of the soil are therefore included.

Four hydrologic soil groups are used. The soils are classified on the basis of water intake at the end of long-duration storms occurring after prior wetting, an opportunity for swelling, and without the protective effects of vegetation. In the definitions of the groups that follow, the infiltration rate is the rate at which water enters the soil at the surface and is controlled by surface conditions. The transmission rate is the rate at which the water moves in the soil and is controlled by the horizons.

The hydrologic soil groups, as defined by NRCS soil scientists, are:

Group A

Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

Group B

Soils having moderate infiltration rates when thoroughly wetted and consisting of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C

Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water infiltration.

Group D

Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

For a full description on soil type see the MDEQ document, ***Computing Flood Discharges for Small Ungaged Watersheds*** by Richard Sorrell. For a list of acceptable curve numbers adapted from TR-55 see Table 4.

Surface runoff is based on soil class survey unless field testing and/or observations indicate otherwise.

Land Cover Types

In the NRCS method of runoff estimation, the effects of the surface conditions of a watershed are evaluated by means of land cover and land treatment classes. Land cover is the watershed cover and it includes every kind of vegetation, litter and mulch, fallow (bare soil) as well as non-agricultural uses such as water surfaces (lakes, wetlands, etc.) and impervious surfaces, such as roads, roofs, etc.

Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring and terracing and management practices like grazing control and crop rotation. The classes consist of cover and treatment combinations actually to be found on watersheds.

For a full description on land cover types and the associated curve numbers see MDEQ document, ***Computing Flood Discharges for Small Ungaged Watersheds*** by Richard Sorrell.

Table 4. Commonly used curve numbers (CNs) from TR-55 (AMC2)

Cover Description	Curve Numbers for Hydrologic Soil Group			
Cover Type and Hydrologic Condition	A	B	C	D
Fully developed urban areas (vegetation established) Open space (lawns, parks, golf course, cemeteries, etc.):				
Poor condition (grass cover <50%)	68	79	86	89
Fair conditions (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover >75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc. (excluding right-of-ways)	98	98	98	98
Streets and Roads:				
Paved; curbs and storm sewers (excluding right-of-way)	98	98	98	98
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Pasture, grassland or range - continuous forage for grazing				
Poor	68	79	86	89
Fair	49	69	79	84
Good	39	61	74	80
Meadow**- continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Brush - brush-weed-grass mixture with brush the major element				
Poor	48	67	77	83
Fair	35	56	70	77
Good	30	48	65	73
Woods - grass combination (orchard or tree farm)				
Poor	57	73	82	86
Fair	43	65	76	82
Good**	32	58	72	79
Woods				
Poor	45	66	77	83
Fair	36	60	73	79
Good	30	55	70	77
Farmsteads- buildings, lanes, driveways and surrounding lots	59	74	82	86

**= Use Woods (good) or Meadow when estimating the pre-development bankfull runoff

3. RUNOFF DETERMINATION – COMPUTER BASED METHODS

More precise methodologies for predicting runoff, such as runoff hydrographs, are widely available, and may be required by the Water Resources Commissioner for sizing the drainage systems on large sites and/or smaller sites that are deemed potentially problematic. It is in the applicant's best interest to discuss acceptable alternatives for these or other unusual situations prior to site layout calculations. Acceptable alternative methods may include:

- U.S. Army Corps of Engineers HEC-HMS
- Natural Resources Conservation Service WinTR-20 and WinTR-55
- U.S. EPA's Stormwater Management Model (SWMM)
- Continuous Simulation (HSPF)
- Source Loading and Management Model (SLAMMr)

Unless a continuous simulation approach to drainage system hydrology is used, all design rainfall events will be based on the NRCS Type II distribution, with an antecedent moisture condition 2 (AMC 2). Computations of runoff hydrographs that do not rely on a continuous accounting of antecedent moisture conditions will assume a conservative wet antecedent moisture condition.

Computer programs such as HEC-HMS and NRCS UD-21 as well as MDEQ permit applications and other relevant information can be downloaded from the MDEQ website. ***See Worksheets 1 through 13*** for more information to determine the proposed development site runoff volume.

Note: Often a single, area-weighted curve number is used to represent a watershed consisting of multiple land cover types with different curve numbers. While this approach is acceptable if the curve numbers are similar, if the difference in curve numbers is more than 5, the use of weighted curve number will significantly reduce the estimated amount of runoff from the watershed. This is especially problematic with pervious/impervious combinations: "combination of impervious areas with pervious areas can imply a significant initial loss that may not take place." (NRCS, 1986) Therefore, the runoff from different land cover types must be calculated separately and then combined. At a minimum, runoff volume from pervious and directly connected impervious areas should be estimated separately for storms less than approximately 4 inches (New Jersey Department of Environmental Protection, 2004 and Pennsylvania Department of Environmental Quality, 2006). When impervious areas are effectively disconnected from the drainage system, some runoff can be absorbed by pervious surfaces. To account for this, the Worksheets at the end of this section include credits for disconnection.

Part C. COMPUTATIONAL REQUIREMENTS – STRUCTURAL CREDITS

The following structural Best Management Practices (BMP) can be utilized to reduce the amount of detention/retention required. In addition, bioretention, rain gardens, pervious pavement, infiltration basins, subsurface infiltration beds, infiltration trenches, vegetated swales, dry wells, green roofs and water reuse can all be used to meet some or all of the first flush/bankfull infiltration requirement for sites with A, B and some C soil types. ***See Section V, Design Requirements for Stormwater Management Systems and Section V, Part D, Item 2, Soil Infiltration Testing Guidelines. Refer to Worksheets 1 through 13*** at the end of this section to calculate the runoff volumes and credits associated with structural BMPs.

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. A safety factor of two (2) must be used in the design of stormwater infiltration systems. Therefore a measured infiltration rate of 0.5 inches per hour should generally be considered as a rate of 0.25 inches per hour in design.

Infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) ***See Section V, Part D, Item 5, Infiltration BMP Guidelines.***

BIORETENTION BASINS & RAIN GARDENS

(can be used to meet infiltration and storage requirements)

Infiltration Area Calculation

The Infiltration Area is the bottom area of a Bioretention Basin or Rain Garden defined as:

(Area of Bioretention Basin or Rain Garden at Ponding Depth + Area of Bioretention Basin or Rain Garden at Bottom) Divided by two= Infiltration Area (Average Area)

This is the area to be considered when evaluating the Loading Rate to the Bioretention Basin or Rain Garden.

Note: The Infiltration Period for infiltration BMPs is the time during which the bed is receiving runoff and is capable of infiltrating at the design rate. The infiltration period has been conservatively estimated as 6 hours.

Volume Reduction Calculations

The storage volume of a Bioretention Basin or Rain Garden is defined as the sum total of the surface and subsurface void volumes beneath the level of discharge invert. Intermedia void volumes may vary considerably based on design variations.

The volume of a Bioretention Basin or Rain Garden has three components:

1. Surface Storage Volume (ft^3) = Bed Area (ft^2) x Maximum Design Water Depth (ft)
2. Soil Storage Volume (ft^3) = Length (ft) x Width (ft) x Depth (ft) x Void Ratio of Storage Material (%)
3. Infiltration Volume (ft^3) (using 6 hours for infiltration credit)

Total Bioretention Basin or Rain Garden Volume (ft^3) = Surface Storage Volume (ft^3) + Subsurface Storage + Infiltration Volume (ft^3)

PERVIOUS PAVEMENT

(can be used to meet infiltration and storage requirements)

Infiltration Area Calculations

The minimum infiltration area must be based on the following equation:

Minimum Infiltration Area = Contributing impervious area (including pervious pavement) / 8*

** The denominator or minimum infill area may be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A (rapidly draining).*

Volume Reduction Calculations

Runoff volume = Depth* (ft) x Area (ft^2) x Void Space (i.e. 0.30 maximum for aggregate)

**Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.*

Infiltration Volume (ft^3) = Bed bottom area (ft^2) x [Infiltration design rate (in/hr) x Infiltration period* (6hr)] x (1'/12")

INFILTRATION BASINS, TRENCHES AND SUBSURFACE BEDS

(can be used to meet infiltration and storage requirements)

Infiltration Area Calculations

The minimum infiltration area must be based on the following equation:

Minimum surface area = Contributing impervious area/ 8*

**May be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A (rapidly draining).*

Volume Reduction Calculations

The following equation can be used to determine the approximate storage volume of an Infiltration Basin:

Storage Volume (ft^3) = Average bed area (ft^2) x Maximum design water depth (ft)

Subsurface storage/infiltration bed volume (ft^3) = Infiltration area (ft^2) x Depth of underdrain material (ft) x Void ratio of storage material used (%)

** Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.*

Infiltration Volume (ft^3) = Bed bottom area (ft^2) x [Infiltration design rate (in/hr) x Infiltration period* (6hr)] x (1'/12")

DRY WELLS

(can be used to meet infiltration and storage requirements)

Infiltration Area

A Dry Well may consider both bottom and side (lateral) infiltration according to design.

Volume Reduction Calculations

The storage volume of a Dry Well is defined as the volume beneath the discharge invert. A Dry Well storage area must dewater within 48 hours of a storm event based on infiltration

Note: The Infiltration Period for infiltration BMPs is the time during which the bed is receiving runoff and is capable of infiltrating at the design rate. The infiltration period has been conservatively estimated as 6 hours.

rates from field testing. The following equation can be used to determine the approximate storage volume of an aggregate Dry Well:

Storage Volume = Dry well area (ft^2) x Dry well water depth (ft) x 30% (filled with open-graded stone)

**Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.*

Infiltration Volume (ft^3) = Bed bottom area (ft^2) x [Infiltration design rate (in/hr) x Infiltration period* (6hr)] x (1'/12")

BIOSWALE

(can be used to meet infiltration requirements)

Volume Reduction Calculations

If check dams are utilized within the Bioswale, the volume behind each check dam can be estimated from the following:

Storage Volume (ft^3) = 0.5 x (Length of Swale Impoundment Area per Check Dam) x (Depth of Check Dam) x [(Top Width of Check Dam) + (Bottom Width of Check Dam)] /2

GREEN ROOFS

(can be used to meet infiltration and storage requirements)

Volume Reduction Calculations

Green roof covers may have both retention and detention volume components. The effectiveness of green roof covers will vary according to the design and the regional pattern of rainfall and will require local weather data for calculations. The green roof runoff credit will be determined by subtracting the difference between a standard roof and the proposed green roof runoff volumes.

Peak Rate Mitigation

Vegetated roof covers have a large influence on runoff peak rates derived from roofs. A general rule for vegetated roof covers is that rate of runoff from the covered roof surface will be less than or equal to that of open space on typical soils (i.e. NRCS curve number of about 65) for storm events with total rainfall volumes up to 3 times the maximum media water retention assembly.

WATER REUSE

(can be used to meet infiltration and storage requirements)

Volume Reduction

After water need is determined, use Table 5 to choose which structure will be large enough to contain the amount of water to be reused. The amount stored in the container is equal to the volume reduction. Where containers are used, the plans must list the volume for each container and show the connection point, for field verification. Approximated storage volumes can be estimated as:

Table 5

Container	Volume
Rain Barrel	40-125 Gallons each
Cistern/ Above Ground Tank	200-12,000 Gallons

Peak Rate Mitigation

Overall, capture and reuse takes a volume of water out of site runoff and puts in back into the ground. This reduction in volume will translate to a lower overall peak rate for the site.

Part D. COMPUTATIONAL REQUIREMENTS - NON-STRUCTURAL CREDITS OR “SELF-CREDITING” BMPS

The use of Non-Structural BMPs is an important part of a project’s stormwater management system and deserves to be properly credited in the calculation process. However, these Non-Structural BMPs must be correctly implemented to be effective. The use of these calculation credits for Non-Structural BMPs must be documented fully to the WCWRC.

The following Non-Structural BMPs are “self-crediting” in that the use of these BMPs automatically provides a reduction in impervious area and/or stormwater runoff (e.g., smaller curve number) and a corresponding reduction in the stormwater management requirements set forth by these Rules. When “self-crediting” BMPs are applied on a site, **the land cover area is not considered in the calculations** as a runoff contributor, therefore reducing the required amount of infiltration and/or storage. Additionally, the use of these BMPs may be affected by other regulations/guidance (Master Plans, zoning, subdivision, etc.).

These BMPs are strongly encouraged:

- Protect Natural/Special Value Features
- Protect/Conserve/Enhance Riparian Areas
- Protect/Utilize Natural Flow Pathways
- Preserve Open Space (e.g. clustering)
- Reduce Street Width/Area
- Reduce Parking Width/Area

Although these BMPs are self-crediting and are not further elaborated in these recommended procedures, ***Worksheet 12, Natural Resources Inventory*** has been provided and should be completed by applicants when these self-crediting BMPs are being proposed.

The following Non-Structural BMPs provide a quantitative stormwater benefit and are strongly recommended in addition to the aforementioned “self-crediting” Non-Structural BMPs.

- Minimize Disturbed Area
- Protection of Existing Trees (part of minimizing disturbance)
- Re-Vegetate and Re-Forest Disturbed Areas
- Rooftop Runoff (downspout) Disconnection
- Disconnection of Impervious Areas (Non-Roof)

For calculating volume peak rate reductions due to these non-structural BMPs, the NRCS method must be used in all cases except “Minimize Disturbed Area”, which may be used with both the Rational method and the NRCS method.

Part E. STANDARD METHOD RUNOFF VOLUME WORK SHEETS

W1 Determining Post-Development Cover Types, Areas, Curve Numbers, and Runoff Coefficients

Total Site Area = ____________________ac

Total Site Area Excluding "Self- Crediting" BMPs = ____________________ac[A]

Rational Method Variables[B]

Cover Type	Soil Type	Area (ft^2)	Area(ac)	Runoff Coefficient (c)	(C) (Area)

Total - ∑(C)(Area) = ____________________

Area Total - ∑ac or ∑sf = ____________________

Weighted C - ∑(C)(Area)/∑ac or ∑sf = ____________________

NRCS Variables[C]

Pervious Cover Type	Soil Type	Area (ft^2)	Area(ac)	Curve Number	(CN) (Area)

Total - ∑(CN)(Area) = ____________________

Area Total - ∑ac or ∑sf = ____________________

Weighted CN - ∑(CN)(Area)/∑ac or ∑sf = ____________________

NRCS Variables[C]

Impervious Cover Type	Soil Type	Area (ft^2)	Area(ac)	Curve Number	(CN) (Area)

Total - ∑(CN)(Area) = ____________________

Area Total - ∑ac or ∑sf = ____________________

Weighted CN - ∑(CN)(Area)/∑ac or ∑sf = ____________________

[A] Use this area for the remainder of the runoff calculations

[B] Required for first flush runoff calculations

[C] Required for bankfull and 100-year runoff calculations

W2 Standard Method Runoff Volume Calculations

First Flush Runoff Calculations (V_{ff})

A.

$$V_{ff}=(1")\left(\frac{1'}{12"}\right)\left(\frac{43560 ft^2}{1 ac}\right)AC$$

$$V_{ff}=(1")\left(\frac{1'}{12"}\right)\left(\frac{43560 ft^2}{1 ac}\right)(\_\_\_\_\_)(\_\_\_\_\_)$$

$$V_{ff}=\_\_\_\_\_\_ ft^3$$

A = Total Site Areas (ac) excluding “Self-Crediting” BMPs from Worksheet 1
C= Weighted Runoff Coefficient from Worksheet 1

W3 Standard Method Runoff Volume Calculations

Pre-development Bankfull Runoff Calculations ($V_{bf\text{-}pre}$)

A.

2 year/24 hour storm event — $P = 2.35in$

B.

The pre-development land cover will be **Good Cover Woods or Meadow.** Determine the associated soil hydrologic group for the entire site and choose the curve number. — $CN =$ ____

C.

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

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

$S =$ _____ in

D.

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

$$Q = \frac{(2.35 - (0.2)(\_\_))^2}{(2.35 + (0.8)(\_\_))}$$

$Q =$ ________ in

E.

Total Site Area (sf) excluding "Self- Crediting" BMPs — $Area =$ ________ sf

F.

$$V_{bf\text{-}pre} = Q\left(1/12\right)Area$$

$$V_{bf\text{-}pre} = (\_\_)\left(1/12\right)(\_\_)$$

$V_{bf\text{-}pre} =$ __________ ft^3

W4 Standard Method Runoff Volume Calculations

Pervious Cover Post-Development Bankfull Runoff Calculations ($V_{bf\text{-}per\text{-}post}$)

A.

2 year/24 hour storm event — $P = 2.35 in$

B.

Pervious Cover CN From Worksheet 1 — $CN =$ ____

C.

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

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

$S =$ _____ in

D.

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

$$Q = \frac{(2.35 - (0.2)(\_\_))^2}{(2.35 + (0.8)(\_\_))}$$

$Q =$ ________ in

E.

Pervious Cover Area from Worksheet 1 — $Area =$ _________ sf

F.

$$V_{bf\text{-}per\text{-}post} = Q(1/12)Area$$

$$V_{bf\text{-}per\text{-}post} = (\_\_)(1/12)(\_\_)$$

$V_{bf\text{-}per\text{-}post} =$ ___________ ft^3

W5 Standard Method Runoff Volume Calculations

Impervious Cover Post-Development Bankfull Runoff Calculations ($V_{bf\text{-imp-post}}$)

A.

2 year/24 hour storm event

$P = 2.35in$

B.

Impervious Cover CN From Worksheet 1

$CN =$ ____

C.

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

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

S = _____ *in*

D.

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

$$Q = \frac{(2.35 - (0.2)(\_\_))^2}{(2.35 + (0.8)(\_\_))}$$

$Q =$ _________*in*

E.

Impervious Cover Area from Worksheet 1

Area =_________*sf*

F.

$$V_{bf\text{-imp-post}} = Q(1/12)Area$$

$$V_{bf\text{-imp-post}} = (\_\_)(1/12)(\_\_)$$

$V_{bf\text{-imp-post}} =$ ____________ft^3

W6 Standard Method Runoff Volume Calculations

Pervious Cover Post-Development 100-year Storm Runoff Calculations ($V_{100\text{-per-post}}$)

A.

100-year Storm Event $P = 5.11 in$

B.

Pervious Cover CN From Worksheet 1 $CN =$ ____

C.

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

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

$S =$ ____ in

D.

$$Q_{100\text{-per}} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$Q_{100\text{-per}} = \frac{(5.11 - (0.2)(\_\_))^2}{(5.11 + 0.8\ (\_\_))}$$

$Q_{100\text{-per}} =$ ________ in

E.

Pervious Cover Area from Worksheet 1 $Area =$ _________ sf

F.

$$V_{100\text{-per-post}} = Q\left(\frac{1}{12}\right) Area$$

$$V_{100\text{-per-post}} = (\_\_)\left(\frac{1}{12}\right)(\_\_)$$

$V_{100\text{-per-post}} =$ __________ ft^3

W7 Standard Method Runoff Volume Calculations

Impervious Cover Post-Development 100-year Storm Runoff Calculations ($V_{100\text{-imp-post}}$)

A.

100-year Storm Event $P = 5.11 in$

B.

Impervious Cover CN From Worksheet 1 $CN =$ ____

C.

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

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

$S =$ ____ in

D.

$$Q_{100\text{-imp}} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$Q_{100\text{-imp}} = \frac{(5.11 - (0.2)(\_\_))^2}{(5.11 + 0.8\ (\_\_))}$$

$Q_{100\text{-imp}} =$ ____________ in

E.

Impervious Cover CN From Worksheet 1 $Area =$ __________ sf

F.

$$V_{100\text{-imp-post}} = Q\left(1/12\right) Area$$

$$V_{100\text{-imp-post}} = (\_\_)\left(1/12\right)(\_\_)$$

$V_{100\text{-imp-post}} =$ ____________ ft^3

W8 Standard Method Runoff Volume Calculations

Determine Time of Concentration for Applicable Flow Types ($T_{c\text{-}hrs}$)

Flow Type	K	Change in Elevation	Length (L)	Slope % (S)	$S^{0.5}$	$V=K*S^{0.5}$	Tc=L/(V*3600)
Sheet Flow*	0.48						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Waterway	1.2						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						
Small Tributary	2.1						

** Sheet flow cannot exceed 300 feet. Anything beyond this is considered waterway.*

Total Time of Concentration ($T_{c\text{-}hrs}$) = ________

W9 Standard Method Runoff Volume Calculations

Runoff Summary & Onsite Infiltration Requirement

A. Runoff Summary from Previous Worksheets

First Flush Volume (V_{ff}) ____________ ft^3

Pre-Development Bankfull Runoff Volume ($V_{bf\text{-}pre}$) ____________ ft^3

Pervious Cover Post-Development Bankfull Volume ($V_{bf\text{-}per\text{-}post}$) ____________ ft^3

Impervious Cover Post-Development Bankfull Volume ($V_{bf\text{-}imp\text{-}post}$) ____________ ft^3

Total BF Volume ($V_{bf\text{—}post}$)

____________ ft^3

Pervious Cover Post-Development 100-year Volume ($V_{100\text{-}per\text{-}post}$) ____________ ft^3

Impervious Cover Post-Development 100-year Volume ($V_{100\text{-}imp\text{-}post}$) ____________ ft^3

Total 100-year Volume (V_{100})

____________ ft^3

B. Determine Onsite Infiltration Requirement

Subtract the Pre-Development Bankfull from the Post-Development Bankfull volume

Total Post-Development Bankfull Volume ($V_{bf\text{-}post}$) ____________ ft^3

Pre-Development Bankfull Runoff Volume ($V_{bf\text{-}pre}$) ____________ ft^3

Bankfull Volume Difference ____________ ft^3

Compare the Bankfull Volume Difference with the First Flush Volume. The ***greater*** of the two is the Onsite Infiltration Requirement.

Onsite Infiltration Requirement (V_{inf}) ____________ ft^3

W10 Standard Method Runoff Volume Calculations

Detention/Retention Requirement

Detention

A. $Q_p = 238.6 T_c^{-0.82}$ $\qquad$ $Q_p = 238.6(\_\_\_\_)^{-0.82}$

Peak of the Unit Hydrograph $\qquad$ $Q_p = \_\_\_\_\_\_ cfs/in - mi^2$

B. *Total Site Area (ac) excluding "Self-Crediting" BMPs* $\qquad$ *Area = ________ ac*

C.

$Q_{100} = Q_{100\text{-per}} + Q_{100\text{-imp}}$ $\qquad$ $Q_{100} = \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_$

Note: $Q_{100\text{-per}}$ and $Q_{100\text{-imp}}$ from W6 and W7, respectively $\qquad$ $Q_{100} = \_\_\_\_\_\_\_\_\_\_$ *in*

D. *Peak Flow (PF)* = $\dfrac{Q_p\left(\frac{cfs}{in-mi^2}\right) Q_{100}(in)\, Area(ac)}{640}$ $\qquad$ $PF = \dfrac{(\_\_\_\_)(\_\_\_\_)(\_\_\_\_)}{640}$

PF = ________ *cfs*

E. Δ = PF (cfs) – 0.15 Area(ac) $\qquad$ Δ = (_______) -0.15 (_____)

Δ = __________ cfs

F. $V_{det} = \dfrac{\Delta\,(cfs)}{PF\,(cfs)} V_{100}\,(ft^3)$ $\qquad$ $V_{det} = \dfrac{(\_\_\_\_\_)}{(\_\_\_\_\_)}(\_\_\_\_\_\_\_)$

V_{det} = ___________ ft^3

V_{det} = Calculated Detention (ft^3), not including volume reduction credit for infiltration or penalty

Note: Projects/sites where the required infiltration volume cannot be achieved must increase the required detention volume by up to an additional 20%.

Retention

A. $V_{ret} = 2(V_{100})$ $\qquad$ V_{ret} = 2(___________)

V_{ret} = ___________ ft^3

W11 Standard Method Runoff Volume Calculations

Determine Applicable BMPs and Associated Volume Credits

Proposed BMP[A]	Area (ft^2)	Storage Volume[B] (ft^3) Surface	Storage Volume[B] (ft^3) Soil	Ave. Design Infiltration Rate (in/hr)	Infiltration Volume During Storm[C] (ft^3)	Total Volume Reduction[D] (ft^3)
Pervious Pavement w/Infiltration Bed						
Infiltration Basin						
Subsurface Infiltration Bed						
Infiltration Trench						
Bioretention Systems						
Rain Gardens						
Dry Well						
Bioswale						
Vegetated Filter Strip						
Green Roof						

Total Volume Reduction Credit by Proposed Structural BMPs (ft^3) __________

Runoff Volume Infiltration Requirement (V_{inf}) from Worksheet 9 - __________

Runoff Volume Credit (ft^3) = __________

[A] Complete checklist from Section VI for each Structural BMP type

[B] Storage volume as defined in individual BMP write-ups

[C] Approximated as the average design infiltration rate over 6 hours multiplied by the BMP area:
Infiltration Rate x 6 hours x BMP Area x Unit Conversions = Infiltration Volume (ft^3)

[D] Total Volume Reduction Credit is the sum of the Storage Volume and the Infiltration Volume During Storm

W12 Natural Features Inventory

1. Provide Natural Resources Map. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes and other natural features.

2. Summarize the existing extent of each natural resource in the Existing Natural Resources Table.

3. Summarize total proposed Protected/Undisturbed Area.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once (include as either floodplain or wetland, not both).

Existing Natural Resources	Mapped (yes, no, n/a)	Total Area (ac)	Protected/Undisturbed Area (ac)
Waterbodies			
Floodplains			
Riparian Areas			
Wetlands			
Woodlands			
Natural Drainage Area			
Steep Slopes, 15%-25%			
Steep Slopes, over 25%			
Special Habitat Areas			
Other			
TOTAL EXISTING (ac)			

W13 Summary

Site Summary of Infiltration & Detention

A. Stormwater Management Summary

Minimum Onsite Infiltration Requirement, V_{inf} ____________ ft^3

Designed/Provided Infiltration Volume ____________ ft^3

% Minimum Required Infiltration Provided ____________ %

Total Calculated Detention Volume, V_{det} ____________ ft^3

Net Required Detention Volume
(V_{det} - Designed/Provided Infiltration Volume) ____________ ft^3

B. Detention Volume Increase for sites where the required infiltration volume cannot be achieved

% Required Infiltration NOT provided
(*100% - % Minimum Required Infiltration Provided)* ____________ %

Net % Penalty
(*20% x % Required Infiltration NOT Provided)* ____________ %

Total Required Detention Volume, including penalty
[(100% + Net % Penalty) x Net Required Detention Volume)] ____________ ft^3

Section IV: Computational Requirements For Stormwater Management Systems

Acceptable Curve Numbers and Runoff Coefficients for Stormwater Calculations

Commonly Used Curve Numbers (from TR-55; AMC2)

Cover Description	Curve Numbers for Hydrologic Soil Group			
Cover Type and Hydrologic Condition	A	B	C	D
Fully developed urban areas (vegetation established) Open space (lawns, parks, golf course, cemeteries, etc.):				
Poor condition (grass cover <50%)	68	79	86	89
Fair conditions (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover >75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc. (excluding right-of-ways)	98	98	98	98
Streets and Roads:				
Paved; curbs and storm sewers (excluding right-of-way)	98	98	98	98
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Pasture, grassland or range - continuous forage for grazing				
Poor	68	79	86	89
Fair	49	69	79	84
Good	39	61	74	80
Meadow**- continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Brush - brush-weed-grass mixture with brush the major element				
Poor	48	67	77	83
Fair	35	56	70	77
Good	30	48	65	73
Woods - grass combination (orchard or tree farm)				
Poor	57	73	82	86
Fair	43	65	76	82
Good**	32	58	72	79
Woods				
Poor	45	66	77	83
Fair	36	60	73	79
Good	30	55	70	77
Farmsteads- buildings, lanes, driveways and surrounding lots	59	74	82	86
Wetlands				
No standing water that contributes to runoff	78	78	78	78
With standing water	98	98	98	98

**= Use Woods (good) or Meadow when estimating the pre-development bankfull runoff

Commonly Used Runoff Coefficients

Type of Surface	Runoff Coefficient		
Water Surfaces	1.00		
Roofs	0.95		
Asphalt or concrete pavements	0.95		
Gravel, brick or macadam surfaces	0.85		
Semi-pervious: lawns, parks, playgrounds	Slope <4%	Slope 4-8%	Slope >8%
Hydrologic Soil Group A	0.15	0.20	0.25
Hydrologic Soil Group B	0.25	0.30	0.35
Hydrologic Soil Group C	0.30	0.35	0.40
Hydrologic Soil Group D	0.45	0.50	0.55

Part F.

COMPUTATIONAL REQUIREMENTS – CONVEYANCE SYSTEMS

1. FLOW DETERMINATION

Acceptable methods of determining the flow rate required to size storm piping systems, open channels and culverts are listed below. The proprietor's engineer may use any of the methods listed or another if approved by the Water Resources Commissioner:

- Rational method (max drainage area of 120 acres)
- USDA NRCS Curve Number Method
- The Michigan Department of Environmental Quality (MDEQ) *Computing Flood Discharges at Small Ungaged Watersheds* method

The rational method of calculating stormwater runoff is generally acceptable for highly impervious sites less than 120 acres in size. However, it may not be considered an adequate design tool for sizing large drainage systems.
The Rational Formula is outlined as follows:

Where:
Q_p= peak runoff rate (cfs)
C= the runoff coefficient of the area
I = the average rainfall intensity (in/hr) for a storm with a duration equal to the time of concentration of the area
A = the size of the drainage area (acres)

All composite runoff coefficients must be based on the values shown in the Table 6 below. The slopes listed for the semi-pervious surfaces are the proposed finished slope of the tributary area.

Rainfall intensities for Washtenaw County are outlined as follows in Table 7.

Table 7. Intensity Formulas (24 hour storms)

Recurrence Interval	Rainfall Intensity
1 yr	72/(T+25)
5 yr	145/(T+25)
10 yr	175/(T+25)
25 yr	215/(T+25)
50 yr	245/(T+25)
100 yr	275/(T+25)

2. HYDRAULICS

Manning's formula shall be used to size the open channel or pipe system in most cases. In situations where a backwater condition exists, the Standard Backwater procedure or other method acceptable to the WCWRC must be used.

Manning's formula is outlined as follows:

EQUATION

$$Q = \frac{1.486}{n} A \cdot R^{2/3} \cdot S^{1/2}$$

A minimum "n" of 0.035 will be used for the roughness coefficient for open channels. See Table 8 for roughness coefficients, or contact WCWRC about unusual situations.

Table 6. Runoff Coefficients

Type of Surface	Runoff Coefficient		
Water Surfaces	1.00		
Roofs	0.95		
Asphalt or concrete pavements	0.95		
Gravel, brick or macadam surfaces	0.85		
Semi-pervious: lawns, parks, playgrounds	Slope <4%	Slope 4-8%	Slope >8%
Hydrologic Soil Group A	0.15	0.20	0.25
Hydrologic Soil Group B	0.25	0.30	0.35
Hydrologic Soil Group C	0.30	0.35	0.40
Hydrologic Soil Group D	0.45	0.50	0.55

3. OPEN CHANNELS

Streams, drains and other open channels will be expected to withstand all events (capacity and stability) up to the 10-year flow without increased erosion or deposition. Open channel velocities will neither be erosive nor cause siltation. Modifications to an Inland Lake or Stream, as defined by the MDEQ, will require a permit from the MDEQ and must be designed and constructed as per MDEQ requirements. Specific requirements for the sizing of created open channel conveyance systems (swales, ditches, drains) are as follows:

a. The minimum acceptable average channel velocity for the design storm will be 2.0 ft/sec, and the maximum acceptable velocity will be 6.0 ft/sec.
b. Sheer stress on the channel bed and banks shall be taken into account.
c. Vegetation establishment with locally adapted plants are required and native plants are preferred. Open channels shall be designed as per the FHWA's, Design of Roadside Channels with Flexible Linings (HEC No. 15) or per other methods approved by the Water Resources Commissioner.
d. Riprap shall be used where necessary and shall be designed to be stable for the 10-year flow rate. Computations must be provided to demonstrate riprap stability and be based on applicability to the specific situation. Riprap stability computational procedures are provided in the FHWA publications HEC No. 15 (Design of Roadside Channels with Flexible Linings), HEC No. 14 (Hydraulic Design of Energy Dissipators for Culverts and Channels) and HEC No. 11 (Design of a Riprap Revetment) and the NRCS National Engineering Handbook, Part 654.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.

4. ENCLOSED DRAINS & PIPING SYSTEMS

Enclosed drains and piping systems shall be designed for the 10-year flow. Specific requirements for the sizing of enclosed systems are as follows:

a. Enclosed storm drains and piping systems will be sized to accommodate the 10-year flow, with the hydraulic gradient maintained below the top of the pipe.
b. In a situation where a piping system outlets to a detention or retention facility, the 2-year recurrence interval pond water surface elevation must be used for the starting water surface elevation in the 10-year recurrence interval pipe capacity computations.
c. Catch basin or inlet covers must be designed to accept the 10-year design storm while maintaining spread to the curb gutter section, or as required by the agency regulating the roadway (MDOT, WCRC, etc.) All private sump and/or roof drainage lines must connect to a catch basin structure to further prevent surface ponding of water during storm events.
d. Pipe full flowing velocity will be greater than 3 ft/sec and less than 10 ft/sec.
e. Pipe inverts will be such that all selections drain completely during dry weather.
f. All structure rims must be above the 100-year storm elevation.
g. Minimum pipe diameter of 12 inches.
h. There should be a minimum of 42 inches from the

Table 8. Manning Roughness Coefficients for Various Surfaces

Boundary Material	n value	Boundary Material	n value
HDPE pipe, smooth lined	0.011	Brick	0.016
Concrete pipe	0.013	Riveted steel	0.018
Vitrified clay pipe	0.014	Rubble	0.025
Cast iron pipe	0.015	Gravel	0.029
HDPE pipe, unlined	0.018	Riprap	0.033
Finished concrete	0.012	Natural channels with stones & weeds	0.035
Planed wood	0.012	Natural channels in poor condition	0.060
Unplaned wood	0.013	Natural channels with heavy brush	0.100
Unfinished concrete	0.014		

proposed ground surface elevation to the spring line of all pipes within the pipe network.

i. A drop of a minimum of 0.1 feet should be incorporated where inflow and outflow pipes of the same diameter meet at a manhole structure.
j. When inflow and outflow pipes of different diameters meet at a manhole structure, the invert of the smaller pipe must be raised to maintain the energy gradient line such that the $8/10^{ths}$ depth point of both pipes are at the same elevation.

5. CULVERT SIZING

Under Michigan State Law, Part 31, Water Resources Protection of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, crossroad culverts draining areas of two square miles or greater must be reviewed and approved by the MDEQ.

Culverts draining an area of two (2) square miles or greater of upstream watershed will be sized by the proprietor's engineer and approved by the MDEQ, Washtenaw County Road Commission (if applicable) and Washtenaw County Water Resources Commissioner.

Specific requirements for the sizing of culverts are as follows:

a. At a minimum, culverts will be designed to convey the peak 10-year storm flow with the velocity not exceeding 8 ft/sec.
b. The 100-year recurrence interval storm must pass the embankment with no adverse increase in water elevation occurring off of the site or flooding of structures within the proposed development. A minimum of one foot of freeboard is required.
c. The discharge velocity from culverts should consider the effect of high velocities, eddies, or other turbulence on the natural channel, downstream property and roadway embankment.
d. The culvert exit velocity shall not cause downstream channel erosion or scour.
e. Sizing of culvert crossings will consider entrance and exit losses as well as tailwater conditions on the culvert. Once the design flow is determined, the required size of the culvert will be determined by one of the following methods, as applicable to the situation:
    - "Mannings" formula
    - Inlet headwater control/outlet tailwater control nomographs (FHWA, Hydraulic Design of Highway Culverts (Hydraulic Design Series No. 5))
    - FHWA's HY-8 computer program
    - ACOE's HEC-RAS computer program
    - Other methods approved by the Water Resources Commissioner
f. The maintenance plan for the stormwater system shall include inspection and maintenance of culverts, wingwalls, headwalls, and other appurtenances along with vegetation management and erosion management (including scour) within 20 feet of the inlet and outlet. No tree growth shall be permitted in these areas.

6. REQUIREMENTS – MDEQ

For sites that impact streams with upstream watersheds equal to or greater than two (2) square miles, approval by the MDEQ is required, pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The MDEQ may compute the runoff rate at no charge. The MDEQ requires applicants to use the UD-21 method by NRCS in lieu of the rational method. This method was developed for small watersheds by NRCS, and can be used for watersheds up to 10 square miles.