# ENGINEERING DESIGN MANUAL

**City of Novi Oakland County, Michigan**

# CITY OF NOVI
# ENGINEERING DESIGN MANUAL
# UPDATED JANUARY 31, 2024

CITY OF NOVI-ENGINEERING DIVISION

**REVIEWED and APPROVED:**

BY: Ben Croy Digitally signed by Ben Croy Date: 2024.02.05 13:20:40 -05'00'

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# RESOLUTION OF AUTHORITY

# ENGINEERING DESIGN MANUAL

**WHEREAS,** the City of Novi's Code of Ordinances contains numerous technical details and specifications relating to construction; and,

**WHEREAS,** standards in the construction industry change frequently as technologies, materials and equipment improve; and,

**WHEREAS,** the City and its development community would benefit from a streamlined, single document that contains construction details and specifications.

**NOW, THEREFORE, BE IT RESOLVED** that the Mayor and Council of the City of Novi authorize the City Engineer to prepare, maintain and approve the contents of an Engineering Design Manual for purposes of clearly conveying technical details and specifications related to construction within the City of Novi.

## CERTIFICATION

I, Maryanne Cornelius, duly appointed Clerk of the City of Novi, do hereby certify that the foregoing is a true and complete copy of a resolution adopted by the City Council of the City of Novi at a regular meeting held this 24th day of September, 2007.

Maryanne Cornelius
City Clerk

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# CHAPTER 5
# STORMWATER MANAGEMENT

This document sets forth specific performance, design, construction and maintenance standards that will be used by the city in review of proposed stormwater management systems in accordance with the objectives of addressing stormwater quality, volume, and flood control.

It is difficult to develop one (1) set of uniform standards that can accommodate all variables and unique site circumstances. Waivers or variances from specific provisions of these standards can be requested, and alternatives consistent with the overall intent of stormwater quantity and quality management can be proposed. Any variation to the Design Standards are subject to the approval of the City in accordance with the procedure and standards in the City's Code of Ordinances.

## PART ONE - PERFORMANCE CRITERIA FOR STORMWATER MANAGEMENT SYSTEMS

This Part One sets forth performance standards that the City has adopted to comply with the National Pollutant Discharge Elimination System (NPDES) Phase II Municipal Separate Storm Sewer System (MS4) permit requirements. The City is required to implement and enforce a Stormwater Management Program to address post-construction storm water runoff from new development and redevelopment projects that disturb one or more acres, or that are part of a common plan of development or redevelopment activity that disturbs one or more acres and that discharge into the permittee's MS4.

To meet the objectives of managing the quantity and quality of stormwater runoff, designers may select any combination of stormwater management elements which meet the performance standards provided the selections: (1) comply with the requirements identified in this document and the City's Code of Ordinances; (2) comply with other local, county, state or federal requirements; (3) do not conflict with the existing local stormwater management and watershed plans; and/or (4) qualify and be approved for a payment-in-lieu option at the discretion of the City.

The performance standards described in this Section pertain to permanent stormwater management systems.

## SECTION5.1 LOW-IMPACT DEVELOPMENT

There are several additional methods of controlling the quantity of and improving the quality of stormwater runoff from the site. The designer should incorporate low impact design principles into the site design as a method of improving the stormwater quality and reducing peak flows. The goal of low impact design is to more closely mimic the watershed's natural hydrologic functions and:

- Prevent negative stormwater impacts rather than having to mitigate them.

- Manage stormwater quantity and quality as close to the source as possible and minimize the use of large or regional collection and conveyance.

- Preserve natural areas, native vegetation, and reduce the impact on the watershed hydrology.

- Use natural drainage pathways as a framework for site design.

- Utilize simple, non-structural methods for stormwater management that are lower cost and lower maintenance than structural controls, if they perform similarly.

- Create a multifunctional landscape.

Low impact design practices and techniques for site design include the following:

A. Preservation of Natural Features and Conservation Design
    1. Preservation of undisturbed areas
    2. Preservation of buffers
    3. Reduction of clearing and grading
    4. Locating sites in less sensitive areas
    5. Open space design

B. Reduction of Impervious Cover
    1. Roadway reduction
    2. Sidewalk reduction
    3. Driveway reduction
    4. Cul-de-sac reduction
    5. Building footprint reduction
    6. Parking reduction

C. Utilization of Natural Features and Source Control for Stormwater Management
    1. Vegetated buffer/filter strips
    2. Open vegetated channels
    3. Bioretention, rain gardens, and bioswales
    4. Infiltration
    5. Rooftop runoff mitigation
    6. Stream daylighting for redevelopment projects
    7. Tree planting

Additionally, the following techniques can improve the stormwater management plan for a site:

- Minimization of impervious surfaces
- Reduced slopes and increased roughness of flow paths
- Avoid channelizing of stormwater flow

## SECTION 5.2 STORMWATER QUANTITY CONTROL

The design of a stormwater management system must incorporate elements for protecting against the effects of flooding. Stormwater quantity control shall be implemented to manage the ***100-year peak runoff rate***. The City has adopted the following minimum performance standards for controlling the volume of stormwater runoff from development/redevelopment projects:

A. Stormwater quantity control facilities must accommodate the 100-year peak runoff rate ($Q_{100P}$), which shall be approved by the City on a case-by-case basis. This rate can be calculated using the Variable Release Rate (see equations below).

The Variable Release Rate and corresponding post-development peak flow rate are calculated as follows:

$$Q_{VRR} = 1.1055 - 0.206 \ln(A)$$

*where*: $Q_{VRR}$ = allowable release rate in cfs/acre
A = contributing area in acres

The variable release rate (cfs/acre) is capped at 1.0 cfs/acre for developments 2 acres or less. For all developments greater than 100 acres, the variable release rate is 0.15 cfs/acre.

$$Q_{100P} = Q_{VRR} \, x \, A$$

*where*: $Q_{100P}$ = allowable 100yr, post development peak flow rate in cfs
A = contributing area in acres

B. Stormwater management facilities shall, in every way feasible, conform to the natural and historic drainage patterns within and adjacent to the site and stormwater discharge shall remain within the watershed where flows originate. Off-site runoff shall pass through the proposed site's stormwater system. If this cannot be achieved, detailed hydrologic and hydraulic calculations shall be provided to the City to demonstrate no adverse impacts downstream for the 10-year and 100-year storms.

a. When calculating the required detention volume, all on-site contributing drainage areas shall be used in the calculation. Volume stored within the forebay and extended detention area may be applied towards the required detention volume.

The required 100-year detention volume ($V_{100D}$ ) is calculated as follows:

1. Calculate the total 100-year runoff volume ($V_{100R}$) under post-development conditions:

$$V_{100R} = 18{,}985\ x\ C\ x\ A$$

*where*: C = post development runoff coefficient
A = contributing area in acres
$V_{100R}$ = post development, 100 year runoff volume in cubic feet

2. Calculate the 100-year peak inflow rate, $Q_{100in}$, into the detention basin; this is the post development peak instantaneous flow prior to (upstream of) the detention basin:

$$Q_{100IN} = C\ x\ I_{100}\ x\ A$$

*where*: $Q_{100IN}$ = 100 year, post development peak inflow rate in cfs
C = post development runoff coefficient
$I_{100}$ = 100 year peak rainfall intensity in inches/hour
A = contributing area in acres

3. Calculate the Storage Curve Factor for the 100-year detention volume ®:

$$R = [0.206 - 0.15\ln(Q_{100P}/Q_{100IN})]$$

*where*: $Q_{100IN}$ = 100 year, post development peak inflow rate in cfs
$Q_{100P}$ = 100 year, post development peak flow rate in cfs
R = storage curve factor (dimensionless)

4. Finally, calculate the 100-year detention basin size, identifying any credits to the detention basin volume to reflect the provided Channel Protection Volume (VCP-P):

$$V_{100D} = (V_{100R}\ x\ R) - V_{CP-P}$$

*where*: $V_{100D}$ = required 100 year detention volume in cubic feet
$V_{100R}$ = 100 year runoff volume in cubic feet
R = storage curve factor (dimensionless)
$V_{CP-P}$ = **provided** CVPC volume in cubic feet
**KEY RULE**: $\mathbf{V_{100D} \geq V_{ED}}$

5. Check to verify the adjusted 100-year detention basin volume is equal to or greater than the Extended Detention Volume ($V_{ED}$). Under no circumstances shall the adjusted detention basin volume be less than ($V_{ED}$).

C. Stormwater management facilities shall not be constructed within the 100-year floodplain unless specifically approved by the Michigan Department of Environment, Great Lakes, and Energy, and the City.

D. The designer may consider the following stormwater management technologies for meeting these performance standard's:

1. Detention Basins
2. Retention Basins
3. Infiltration Trenches or Ponds
4. Underground Detention Systems are typically discouraged unless the criteria outlined in **Section 5.7** have been met.
5. Use of Existing Wetlands for stormwater management is typically discouraged unless the criteria outlined in **Section 5.2.5** have been met.
6. If downstream capacity is insufficient for the proposed development, the developer can make improvements that may include construction of additional off-site conveyance capacity, improvements to the existing drain, acquisition of easements from downstream property owners, etc. The developer is responsible for securing all necessary easement(s) from downstream property owners and is responsible for all improvement costs.

Additional design requirements for the above-mentioned technologies are detailed in Part Two of this Chapter Five.

### 5.2.1 Allowable Discharge Rate

In no event shall the maximum design rate or volume of discharge exceed the maximum capacity of the downstream land, channel, pipe, or watercourse to accommodate the flow and conform with all public and private rights. It is the applicant's obligation to meet this standard. Should a stormwater system, as built, fail to comply, it is the applicant's responsibility to design and construct, or to have constructed at their own expense, any necessary additional and/or alternative stormwater management facilities. Such additional facilities shall be subject to the City's review and approval.

The stormwater discharge from the site shall be directed to a defined watercourse, channel, or storm sewer. The stormwater discharge from the site shall not exceed the calculated variable release rate for the site as outlined in Section 5.2, provided sufficient capacity exists within the downstream watercourse, channel, or storm sewer. For 100-year storm events, the variable release rate will be capped at 1.0 cfs/acre for developments of 2 acres or less. For all developments equal to or greater than 100 acres, the variable release rate is 0.15 cfs/acre. The applicant is required to identify the ultimate stormwater outlet for the site (surface water body, established country drain, etc.) and provide documentation that sufficient conveyance capacity exists within the downstream watercourse between the site and the ultimate outlet for the discharge from the site.

If sufficient capacity does not exist within the downstream watercourse, channel, or storm sewer to effectively handle a concentrated flow of water from the proposed development, allowable discharge rates shall be further reduced. If an open channel is used to convey storm water discharge to an off-site storm water basin for quantity control, then bank full detention must be provided on the site prior to discharge into the open channel.

Discharge should outlet within the drainage basin where flows originate, and generally shall not be diverted to another basin.

### 5.2.2 Determination of Required Detention Storage Volume

Stormwater detention facilities must provide enough storage volume so as not to exceed the maximum allowable runoff rate for the site during a 100-year, 24-hour design storm event. Detention volume must be provided for all on-site and off-site acreage contributing to the detention basin. Alternatively, off-site drainage may be routed around the detention basin. The method for determining required detention volume is provided in Section 5.5.2. Additional requirements for detention facilities are identified in Section 5.6 or Section 5.7.

### 5.2.3 Determination of Required Retention Storage Volume

Retention of stormwater within a “no outlet” retention basin is discouraged and will only be considered when the designer can demonstrate that no possible stormwater outlet exists for the site. A retention basin is permissible only under specific site conditions that are outlined in **Section 5.8.1**.

The method for determining required retention volume is provided in **Section 5.5.3**. The City reserves the right to require additional storage up to that required by two consecutive 100-year storm events from the entire contributing tributary area including any off-site drainage and based on the results of soils data or the overflow assessment. Additional requirements for retention facilities are identified in **Section 5.8**.

### 5.2.4 Determination of Required Infiltration Storage Volume

Where infiltration facilities are installed to meet the performance standards for quantity control, the minimum design volume shall be calculated in a manner similar to the method used for determining required detention volume outlined above. The infiltration facility shall be sized to accommodate the runoff from a 100-year, 24-hour design storm. The "outlet" rate shall be determined based on the infiltration rate of the in-situ soils. Additional requirements for infiltration facilities are identified in **Section 5.9**.

### 5.2.5 Use of Existing Wetlands

The City discourages the use of existing wetlands for the purposes of providing stormwater quantity control. The City will only consider approval of use of an existing wetland for stormwater quantity control if all of the following requirements are satisfied:

A. The wetland must already be highly altered by watershed development and meet certain benchmarks for isolation, high water level fluctuation, low wetland plant richness, dominance of invasive or aggressive plants, and altered hydrology.

B. It must be shown that the wetland site does not contain any unique wetland features.

C. The wetland must be characterized as an emergent, submergent aquatic, or open water wetland. In some cases, scrub-shrub, or forested wetlands may be considered if it is clearly demonstrated that the additional storage would not jeopardize the health of the wetland community.

D. An analysis of the pre-developed and post developed water balance for the wetland shows no negative impacts to the existing wetland or adjacent properties. The designer is required to provide the water balance documentation for review. The water balance shall include runoff from irrigation.

E. A stormwater management easement shall be provided for the entire wetland. Where portions of the wetland are located on adjacent properties, the developer shall secure all of the required easements. See **Section 5.14** of this chapter for additional easement requirements.

F. Sufficient pretreatment of the stormwater is provided prior to its discharge to the wetland. Pretreatment shall be designed in accordance with the requirements of **Section 5.2** and **Section 5.3**.

G. A wetland enhancement plan shall be provided for all wetlands that are dominated by invasive species. The enhancement plan shall include some or all of the following: removal of all or some of the invasive species and restoration with native species as permitted by the City; planting of additional trees and shrubs; and creation of open water areas.

H. For wetlands regulated by the Michigan Department of Environment, Great Lakes, and Energy, a permit from MDEGLE has been obtained as well as all proposed stormwater discharges and use of the existing wetland for stormwater quantity control.

I. For wetlands regulated by the City, a permit from the City has been obtained for all proposed stormwater discharges and use of the existing wetland for stormwater quantity control.

## SECTION 5.3 STORMWATER QUALITY CONTROL

The design of a stormwater management system must incorporate elements for providing stormwater quality improvements. The goal is to limit the concentration of Total Suspended Solids (TSS) in post-development runoff to either of the following water quality standards: 80 mg/L, or 80% TSS reduction. To protect water resources from stormwater pollutants, the City has adopted the following minimum performance standards for controlling the quality of stormwater runoff from development projects.

A. Infiltration (i.e., runoff volume-reducing) or water reuse BMPs that achieve the required Channel Protection Volume ($V_{CP-R}$) (see **Section 5.2**) meet the TSS requirements for only areas tributary to an infiltration BMP. If any areas of a site plan bypass infiltration BMPs, those areas must receive alternative TSS treatment (see below for other options).

B. Volume based stormwater quantity control facilities (sediment forebay, bioretention, etc.), when combined with downstream Extended Detention, the proposed system shall be designed with a volume equal to 15% of the Water Quality Volume (0.15 x $V_{WQ}$) and capture heavy sediment at inlet pipe locations where access is provided to accommodate sediment removal equipment. The required sediment forebay volume, $V_F$, can be calculated with the following equation:

$$V_F = 0.15V_{WQ} = 545\ x\ C\ x\ A$$

*where*: $\mathrm{C} =$ post development runoff coefficient
$\mathrm{A} =$ contributing area in acres
$\mathrm{V_{WQ}} =$ required water quality volume in cubic feet

C. Flow based stormwater quality control facilities (manufactured treatment systems) must provide required TSS removal at the peak flow associated with a 1-year storm event ($Q_{WC}$). The calculations are as follows:

$$Q_{WQ} = C\ x\ I_1\ x\ A$$

*where*: $\mathrm{Q_{WQ}} =$ peak flow rate for mechanical separator design in cfs
$\mathrm{C} =$ post development runoff coefficient
$\mathrm{A} =$ contributing area in acres
$\mathrm{I_1} =$ rainfall intensity in inches/hour

$$I_1 = \frac{30.20}{(T_c + 9.17)^{0.81}}$$

*where*: $\mathrm{T_c} =$ time of concentration (minutes)

Maximum Peak Intensity $(\mathrm{I_{1-Max}}) = 2.0\frac{\text{inches}}{\text{hour}}$ for smaller sites with time of concentation equal to or less than 15 minutes

Minimum Peak Intensity $(\mathrm{I_{1-Min}}) = 1.0\frac{\text{inches}}{\text{hour}}$ for larger sites with time of concentation equal to or greater than 1 hour

D. The designer may consider the following stormwater management technologies for meeting these performance standards:

1. Bioretention BMPs (infiltration), discharging to a conventional detention basin* (wet or dry)
2. Mechanical separator(s), discharging to a conventional detention basin* (wet or dry)
3. Sediment forebay(s), discharging to a conventional detention basin* (wet or dry)

*Conventional detention basins include hydraulic controls for both $V_{ED}$ and $V_{100D}$ as defined in **Sections 5.3.2 and Section 5.2**.

Additional design requirements for the above-mentioned technologies are detailed in Part Two of this Chapter Five.

### 5.3.1 Channel Protection Volume Control

Channel Protection Volume Control (CPVC) is necessary to protect natural watercourses from increased erosion and sedimentation, as a result of increased imperviousness and runoff volume from development occurs. CPVC also promotes groundwater recharge, stabilizes flow rates and baseflow in our natural watercourses, and addresses water quality control criteria (Total Suspended Solids).

CPVC shall be implemented to the Maximum Extent Practicable (MEP). The required Channel Protection Volume ($V_{CP-R}$) is the post-development site runoff volume from a 1.3-inch rainfall event.

A. Implement land use practices that limit the increase in runoff volume, such as LID practices including (but not limited to) a design emphasis on naturalized areas (i.e., meadow or wooded areas vs turf grass), reduced impervious coverage, etc.

B. Calculate the required Channel Protection Volume using the following equation:

$$V_{CP-R} = 4{,}719\ x\ C\ x\ A$$

*where*:

$V_{CP-R}$ = required CPVC volume in cubic feet
C = post development runoff coefficient
A = contributing area in acres

C. Provide adequate infiltration and/or storage/reuse BMPs, to the MEP, to provide the calculated CPVC volume. This may include (but is not limited to) bioretention, rain gardens, bio-swales, pervious pavement, cisterns, green roofs, and infiltration trenches. For water reuse BMPs (i.e., cisterns), water demand (such as gray water or irrigation water) must be established and documented to show adequate drawdown times.

1. When the measured in-situ infiltration rate is above 0.5 in/hr., supplemental measures, such as subsoil amendments and/or a perforated underdrain system, are not required.

2. When the measured in-situ infiltration rate is between 0.24 in/hr. and 0.5 in/hr., soils are marginally suitable for infiltration BMPs, and supplemental measures are required. Supplemental measures may include subsoil amendment, or an underdrain located at the top of the storage bed layer to maximize infiltration.

3. When the measured in-situ infiltration rate is less than 0.24 in/hr., infiltration is deemed impractical, and the use of this BMP is therefore waived. When infiltration is waived, other volume-reducing LID practices must be implemented to the MEP.

4. Infiltration BMPs shall completely dewater in less than 72 hours, consisting of 24-hour dewatering for the surface volume, and 48-hour dewatering of the void space (soil storage) volume. water storage/reuse BMPs shall also be designed to fully dewater within 72 hours.

D. Pretreatment is required for all BMPs to remove fine sediment, trash, and debris to preserve the longevity and function of the BMPs.

   1. Common methods of BMP pretreatment include mechanical separators, sediment forebays, vegetated filter strips, vegetated swales, constructed filters, and curb cuts with sediment traps.

E. To incentivize and encourage stormwater infiltration on all sites, the provided Channel Protection Volume, (VCP-P) can be subtracted from the required 100-year detention volume, V100D (see equations in **Section 5.2**). Upon subtracting the provided Channel Protection Volume from the required 100-year detention volume, the resulting volume cannot be less than the Extended Detention Volume (VED, see **Section 5.3.2** below).

   For underground infiltration BMPs that are not easily accessible for inspection and maintenance, such as underground detention system infiltration, this Channel Protection Volume is generally not credited and will be evaluated on a case-by-case basis.

Infiltration BMPs are prohibited in areas containing contaminated soils/groundwater, wellhead protection areas, high seasonal groundwater (less than 2 feet from the bottom of the stone storage layer of the infiltration BMP to the seasonally high groundwater table) and in areas with hotspot activities and setback restrictions (foundations, property lines, drinking wells, septic fields, pavement, etc.) as defined in the standards. When any of the above adverse conditions are demonstrated, other volume-reducing LID practices must be implemented to the MEP.

### 5.3.2 Channel Protection Rate Control: Extended Detention

Channel Protection Rate Control (CPRC) is necessary to protect natural watercourses from increased erosion and sedimentation as a result of increased imperviousness and runoff rates as development occurs. Channel protection rate control is based on a 2-year / 24-hour storm event. The CPRC shall be implemented to the MEP as outlined below.

D. Extended Detention is required for the site's post-development runoff volume from a 1.9-inch rainfall event. This Extended Detention Volume (VED) shall be dewatered in not less than 48 hours.
E. Calculate the required Extended Detention Volume using the following equation:

$$V_{ED} = 6{,}897 \; x \; C \; x \; A$$

$where:$ $V_{ED}$ = required extended detiontion volume in cubic feet
C = post development runoff coefficient
A = contributing area in acres

F. The Extended Detention requirement effectively maintains the 2-year pre-settlement peak flow rates, to the MEP, for new developments and reduces the existing 2-year peak flow rates for redevelopments.

## SECTION 5.4 STORMWATER CONVEYANCE

The design of the site shall include sufficient provisions for stormwater conveyance. Stormwater management facilities may use open channels or closed conduits or both for means of conveying stormwater runoff. To ensure adequate stormwater conveyance, the City has adopted the following minimum performance standards.

A. Stormwater conveyance facilities shall have capacity to convey stormwater runoff from the 10-year storm event. Increased capacity requirements may be required by other governing agencies. Acceptable methods for determining the runoff associated with a 10-year storm event are included in **Section 5.5.1**.

B. Open channels are generally preferred to closed conduits as a method for stormwater conveyance. Specifically, natural water courses, vegetated swales and channels, and bioswales are preferred.

Additional design requirements for stormwater conveyance technologies are detailed in **Section 5.13**.

### PART TWO - DESIGN CRITERIA FOR STORMWATER MANAGEMENT SYSTEMS

This Part Two sets forth specific design and construction standards that will be used by the City in review of proposed stormwater management systems in accordance with the objectives of meeting the performance standards.

The standards and design criteria set forth herein are intended to guide designers to develop a stormwater management system that controls the quantity and quality of stormwater discharge from a site. The internal drainage for a site as well as the downstream conditions will be reviewed. Every site is part of an overall watershed and the system shall be designed with this in mind. The system shall conform to natural drainage patterns both on and off-site. These standards are the minimum requirements of the City and shall not be construed as all-inclusive. The design engineer shall consider many factors when planning the stormwater management system. In particular, Federal, State and County standards may be stricter than these standards. In most cases where conflicting standards arise, the more stringent requirements will govern. Exceptions will be considered when conformance with a local community master plan, stormwater management plan or watershed plan is required.

## SECTION 5.5 DETERMINATION OF SURFACE RUNOFF

The Rational Method of calculating stormwater runoff is generally acceptable for calculating peak flow rates at any particular location within a stormwater management system for sites less than 150 acres in size. More precise methodologies for predicting runoff such as runoff hydrographs are widely available and may be required by the City for sizing drainage systems on large sites and/or smaller sites that are deemed potentially problematic. Acceptable alternative methods will include:

A. Corps of Engineers HEC-1
B. Soil Conservation Service UD-21, TR-20 and TR-55
C. U.S. EPA's SWMM
D. Continuous simulation (e.g. HSPF)

Unless a continuous simulation approach to drainage system hydrology is used, all design rainfall events will be based on the SCS Type II distribution.

Computations of runoff hydrographs that do not rely on a continuous accounting of antecedent moisture conditions will assume a conservative wet antecedent moisture condition.

### 5.5.1 The Rational Method

For all stormwater management systems that are designed using the Rational Method, the following formula must be used for calculating peak flow rate:

$$Q = C\ x\ i\ x\ A$$

*where*:
$\mathrm{Q} = $ peak runoff (cfs)
$\mathrm{C} = $ composite runoff coefficient
$\mathrm{I} = $ design rainfall intensity (inches/hour),
$\mathrm{A} = $ drainage area in acres

A. Runoff Coefficient

A realistic runoff coefficient will be used based upon the imperviousness of the tributary area. The range of this coefficient shall vary from 0.15 for completely grassed areas to 0.95 for impervious areas and 1.0 for open water.

Certain calculations require use of a composite runoff coefficient value. The composite runoff coefficient is calculated as follows:

$$C = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i}$$

*where*:
$\mathrm{C} = $ composite runoff coefficient for drainage are
$\mathrm{n} = $ total number of subareas
$\mathrm{C_i} = $ runoff coefficient for each subarea
$A_i = $ drainage area for each subarea in acres

Minimum runoff coefficients for various surface types are provided in the table below:

| **Type of Surface** | **Runoff Coefficient (c)** |
|---|---|
| Water surfaces | 1.0 |
| Roofs | 0.95 |
| Asphalt or concrete pavements | 0.95 |
| Gravel or brick | 0.85 |
| Pervious Pavement | 0.4 to 0.7[1] |
| Turf grass lawn (minimum) | 0.35 |

| Semi-pervious[2]: | Slope: <4% | Slope: 4-8% | Slope: >4% |
|---|---|---|---|
| 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 |

Notes:
1. Design engineer to provide supporting data for selected C-factor
2. Semi-pervious surfaces include meadow, forest, landscaped areas, etc.

Soil compaction reduces soil volume and increases runoff rates and volumes. Construction activity causes significant compaction of soils. Grading for new sites shall include a final de-compaction tillage to reduce soil bulk density and improve infiltration. Alternatively, when de-compaction is not done, the Hydrologic Soil Group for post-construction conditions shall be increased by one letter. That is, what used to be Group A becomes Group B due to compaction. Group C becomes D.

The runoff coefficient calculation must be included with plan submittal.

B. Design Rainfall Intensity

Formulas for determining rainfall intensities for various storm events are as follows:

| Design Storm | Intensity (in/hr) |
|---|---|
| 1-year | $72/(t_c+25)$ |
| 10-year | $175/(t_c+25)$ |
| 100-year | $275/(t_c+25)$ |

*where:* $t_c$ = Time of Concentration (min)

C. Time of Concentration

An initial time of concentration of 20 minutes will be used on residential subdivisions. The time of concentration must also be calculated for commercial and industrial subdivisions.

The design engineer may also use a calculated time of concentration if desired. The methodology and computations must be submitted for review. The time of concentration for unimproved, pre-development lands will be checked using the following formulas:

Small Tributary $$T_c(\text{min}) = \frac{L'}{2.1\sqrt{S_o} * 60}$$

Waterway $$T_c(\text{min}) = \frac{L'}{1.2\sqrt{S_o} * 60}$$

Sheet Flow $$T_c(\text{min}) = \frac{L'}{0.48\sqrt{S_o} * 60}$$

*Where:* $L' = \text{length, in feet}$
$S_o = \text{slope, in \%}$

When more than one type of flow exists, the individual flows shall be summed up to find the total time of concentration.

D. Determination of Runoff from Green Roofs, Porous Pavers, Cisterns and other LID Techniques

The design of green roofs, porous pavers, cisterns and other LID techniques varies greatly from site to site. The City recognizes that these technologies will provide a reduction in the peak flow rate and volume of runoff. The design engineer should work with the City to identify how use of these technologies and fit into the overall stormwater management plan for a site. In general, the following information should be considered when these LID techniques are proposed:

1. The storage capacity (volume) of the system.
    a. For green roofs and porous pavers: a porous material is often provided for the base materials and the capacity within the void space should be identified.
    b. For cisterns: the total volume of the vessel.

2. The anticipated time for complete drainage of the system.
   a. For green roofs: a summary of how long it takes for the base material and underdrain system to drain following a rain event.
   b. For porous pavements: if infiltration is the only mechanism for drainage from the base material, the time for complete drainage will be based on the infiltration rate of the in-situ soil. Sufficient documentation (similar to the requirements for infiltration facilities outlined in **Section 5.9**) shall be provided to support the assumed infiltration rate. If an underdrain is proposed, the time to drain will be a function of the base material and pipe capacity.
   c. For cisterns: if water is to be used as grey water for a building or for irrigation purposes, an annual water balance calculation shall be provided.
3. An analysis of the overflow, including prediction of when overflow will occur (i.e. storm events larger than 1-year, etc.) and identification of where water will be directed.

### 5.5.2 Determination of Required Detention Storage Volume

The following equations can be used to determine the required storage volume for a 100-year, 24-hour storm event. Also refer to **Section 5.2** for additional equations.

$$Q_o = \frac{Q_a}{A\ x\ c}$$

*where:*

$Q_o$ = alloawable outflow per acre imperviousness (cfs/ac)
$Q_a$ = alloawable outflow as defined in **Section 5.2.1**
$c$ = runoff coefficient
$A$ = tributary area (acre)

$$T = -25 + \sqrt{\frac{10312.5}{Q_o}}$$

*where:*

$Q_o$ = alloawable outflow per acre imperviousness (cfs/ac)
$T$ = time of maximum storage (min)

$$V_s = \frac{16500T}{T + 25} - 40Q_oT$$

$$\begin{aligned} where: \quad & V_s = \text{storage volumer per acre imperviousness (cf/ac)} \\ & Q_o = \text{alloawable outflow per acre imperviousness (cfs/ac)} \\ & T = \text{time of maximum storae (min)} \end{aligned}$$

$$V_t = V_s \; x \; A \; x \; c$$

$$\begin{aligned} where: \quad & V_t = \text{required detention volume (cf)} \\ & V_s = \text{storage volumer per acre imperviousness (cf/ac)} \\ & c = \text{runoff coefficient} \\ & A = \text{tributary area (acre)} \end{aligned}$$

### 5.5.3 Determination of Required Retention Storage Volume

Retention of stormwater within a "no outlet" retention basin is discouraged and will only be considered when the designer can demonstrate that specific site conditions, including but not limited to those outlined in **Section 5.8.1** can be met.

The following formula can be used to determine the required retention volume.

$$V_{RB} = (18{,}985 \; x \; C \; x \; A \; x \; 2) - V_c$$

$$\begin{aligned} where: \quad & V_{RB} = \text{total retention basin volume in cubic feet} \\ & V_c = \text{volumer or 100\% BMP credit in cubic feet} \\ & C = \text{composite runoff coefficient} \\ & A = \text{contributing area in acres} \end{aligned}$$

## SECTION 5.6 DETENTION BASINS

Stormwater detention may be provided as part of a stormwater management system to satisfy the quantity control performance standards described in **Section 5.2**. Stormwater detention basins are generally acceptable for most sites. Detention ponds should be designed to be ecologically sustainable. Mosquito populations can proliferate in environments that are ecologically unbalanced. A detention pond environment rich with diverse vegetation, including wetland plantings and riparian buffer plantings supplemented with trees and shrubs in appropriate areas promotes a diverse wildlife population. Wildlife will include birds, butterflies, insects and various aquatic species. This combination creates a sustainable and ecologically balanced environment.

The following standards shall be adhered to when designing stormwater detention basins.

A. Pretreatment shall be provided for the stormwater prior to discharge into the detention basin. Acceptable methods and performance standards for pretreatment of stormwater are outlined in **Section 5.3**.

B. The volume of detention provided must be equal to or in excess of the volume of stormwater runoff generated from a 100-year storm event. The method for determining this volume is outlined in **Section 5.5.2**.

C. Detention basins must have a positive method for draining. If a permanent pool is proposed, the basin must completely dewater to the elevation of the permanent pool. The outlet shall restrict the flow so that the flow does not exceed the maximum allowed outflow defined in **Section 5.2.1**.

D. In general, wet ponds and stormwater marsh systems will be preferred to dry ponds. Dry ponds providing extended storage will be accepted when the development site's physical characteristics or other local circumstances make the use of a wet pond infeasible.

E. Shade plantings on the west and south sides of facilities are encouraged unless such plantings would not thrive or are not otherwise in the public interest.

F. Public safety will be a paramount consideration in stormwater system and pond design. Providing safe detention is the applicant's responsibility. Pond designs will incorporate gradual side slopes, vegetative and barrier plantings, and safety shelves. Where further safety measures are required, the applicant is expected to include them within the proposed development plans.

G. Subdivision stormwater holding facilities and pretreatment systems shall be located in parks or out-lots and not on a subdivision lot. During the plat approval process, City Council may, at their discretion, allow the use of a lot for holding facilities and pretreatment systems when the lot has been oversized for this use or when construction on the lot is prohibited until elimination of the holding facilities and pretreatment system. Holding facilities and pretreatment systems within proposed septic field areas will not be permitted.

H. The ground water elevation shall be at least 3 feet below the bottom of the pond or permanent pool elevation.

### 5.6.1 Detention Basin Types

Detention basins may be designed in a number of ways. The following are examples of types of ponds:

A. Wet detention basins

A wet detention basin is a small man-made surface water vessel designed to treat stormwater runoff. Incoming stormwater runoff displaces "old water" out of the basin and is then stored until the next storm. By retaining the water for long periods of time, pollutants are effectively removed. The basin also deters re-suspension of deposited materials. Wetland vegetation shall be used around the banks to help removed dissolved contaminants and algae. In addition to the general requirements for all detention basins outlined in this Manual, wet detention basins shall meet the following requirements:

1. A minimum permanent pool depth of 3 feet shall be provided. Where a permanent pool is provided for meeting the quality performance standards, the volume of the permanent pool shall be equal to or greater than the first flush volume.

2. A safety shelf of fringe wetland (minimum 4-foot wide and 1-foot deep) should be provided along the perimeter of the pond to establish aquatic vegetation and for safety concerns. The total area of the shelf should be 25-50% of the water surface area.

3. Vegetation should be used to control erosion and enhance sediment entrapment.

4. Where feasible, a drain for completely dewatering the pond should be installed for maintenance purposes.

B. Constructed wetlands

Constructed wetlands are characterized as a man-made basin with over 50% of its surface area covered by wetland vegetation. Permanent wetland pool depths should vary between 0.5 and 3.0 feet depending on vegetation type. Wetlands should be constructed to mitigate stormwater quality and quantity impacts associated with development projects and should not serve to mitigate the loss of natural wetlands or encroach on natural delineated wetland areas. Wet ponds and constructed marsh/wetland systems are an effective BMP for controlling both stormwater quantity and quality. In addition to the general requirements for all detention basins outlined in this Manual, constructed wetlands should meet the following requirements:

1. Basins should be designed to maximize sheet flow across the wetland. In general, a rectangular configuration should be used with a length to width ratio of 3 to 1 placing the inlet and outlet pipes at the opposite ends. Baffles may be used to increase the flow path and maintain the topography.

2. A diversity of depth zones throughout the basin should be used to meet the unique growing requirements of divergent wetland plants.

C. Dry detention basins

Dry detention basins are designed so to drain completely following a storm event. Dry ponds are generally not preferred except where thermal impacts to the receiving waters are a concern.

### 5.6.2 Pond Geometry

A. Ponds (basins) shall be designed as an integral part of the overall site plan and shall be considered a natural landscape feature having an irregular shape.

B. The basin shape should be such that flow entering the basin is evenly distributed and no stagnant zones can develop. An irregularly shaped basin is best. The inlet and the outlet shall be at opposite ends with the maximum distance possible between them. For dry basins, use of swales or berms on the bottom of the basin to maximize travel distance during periods of low flow is encouraged.

C. A minimum length to width ratio of 3 to 1 should be provided.

D. When there is no permanent pool of water, the bottom of all detention basins shall be graded in such a manner as to provide positive flow to the outlet.

E. Detention basin side slopes shall generally not be flatter than 1 foot vertical to 20 feet horizontal and shall not exceed 1 foot vertical to 4 feet horizontal.

F. One foot of freeboard shall be provided above the 100-year storm storage elevation.

G. An emergency (secondary) overflow shall be provided at an elevation 6-inches above the 100-year storm storage elevation. Standards for the emergency overflow are provided in **Section 5.6.4**.

H. Anti-seep collars should be installed on any piping passing though the sides or bottom of the basin to prevent leakage through the embankment.

### 5.6.3 Determination of Storage Volume Provided

A. Storage volume shall be considered to be the volume above the invert elevation of the outflow device. Any storage within storm sewer shall not be considered as storage volume.

### 5.6.4 Basin Inlets & Outlets

Velocity dissipation measures shall be incorporated into basin designs to minimize erosion at inlets and outlets, and to minimize the resuspension of pollutants.

A. *Basin Inlets*. All inlets to the detention basin shall meet the following requirements:

1. The velocity of the storm water entering the storage facility should be a non-erosive velocity. This velocity is generally between 2.5 fps and 5 fps.

2. Oil and gas separators, designed to separate pollutants from stormwater within an enclosed storm drainage system shall be provided at the last structure prior to discharge to the detention system.

3. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance, via an easement, prior to release off-site or into a sedimentation or stormwater holding facility.

B. *Restricted Outlet*. All detention basin outlets shall meet the following requirements

1. The outlet for storm water detention facilities shall be designed to meet the following requirements:
   a. The maximum outlet rate at the design high water level shall not exceed the maximum allowable outflow rate as defined in Section 5.2.1.

   b. Unless otherwise treated by a bioretention facility or sediment forebay, the first flush volume shall be retained for a minimum of 24 hours. The first flush volume is generally considered to be the first 1.0-inch of runoff from the site and can be determined by the following equation:

$$V_{ff} = 3630 \text{ x acreage x the relative imperviousness factor C}$$

c. The bankfull flood volume shall be retained in the detention facility for a minimum of 24 hours and no more than 40 hours. The bankfull flood is generally defined as the total rain from a 1.5-year, 24-hour design storm, which can be determined by the following equation:

$$V_{bf} = 5160 \text{ x acreage x the relative imperviousness factor C}$$

2. V-notch weirs, dual outlets, riser pipe or other designs shall be utilized to assure an appropriate detention time and maximum outlet rate for the 100-year flood and bankfull flood volumes as required above. Where orifice holes or restrictor pipes are provided to restrict the flow and the required size is less than 4-inches, maintenance provisions for preventing clogging of the restrictor hole should be provided.

3. The outlet will be well protected from clogging.

4. All outlets will be designed to be easily accessible for heavy equipment required for maintenance purposes.

5. Riser pipe designs shall meet the following requirements:

   a. Flow restrictive devices shall be located inside a standpipe. One (1) inch holes, spaced a minimum of 4-inches apart shall be provided around the perimeter of the riser between the elevation of the permanent water and the 100-year storm event. The riser will not function to restrict flow but will prevent clogging of the internal restrictive device.
   b. Hoods or trash racks shall be installed on the riser to prevent clogging.
   c. The riser shall be placed near or within the embankment, to provide for ready maintenance access. Where the outlet structure is not located near enough to the bank to facilitate visual inspection of the structure, a stone bridge with a minimum top width of five (5) feet shall be provided.
   d. The riser pipe shall be a minimum of three (3) feet in diameter and constructed of materials that will reduce future maintenance requirements.

6. Backwater on the outlet structure from the downstream drainage system will be evaluated when designing the outlet.

7. Pumped outlets are not permitted absent a variance from City Council, which shall require demonstration that it is in the public interest and no feasible alternative exists. IF City Council grants a variance to allow a pumped outlet, the following documentation shall apply:

a. The pump(s) shall be designed to meet the maximum discharge rate and time requirements for the 100-year and bankfull flood events. Minimum and maximum system head curves and pump curves shall be provided to verify the operating duty points of the pump(s).
b. Pump(s) shall be of appropriate construction for conveying storm water.
c. A redundant pump shall be provided.
d. A generator shall be provided for the pump station. A permanent on-site generator shall be provided or a generator receptacle in combination with a portable generator shall be provided.
e. A mechanism for determining failure of the pumps (alarm lights, water depth indicator, tele-dialer, etc.) shall be provided. The mechanism shall be of a nature that ensures the current property owner (filed with the Register of Deeds) will easily be able to identify a pump failure.
f. An operation and maintenance plan shall be provided, and a maintenance agreement shall be in place with the current property owner (filed with the Register of Deeds).

C. Overflow

1. An emergency spillway with a defined downstream drainage path or a secondary standpipe must be provided at an elevation 6-inches above the 100-year elevation to allow discharge from the basin when the flows exceed the capacity of the outlet structure. Provisions for preventing erosion of the spillway shall be provided. The emergency spillway or secondary standpipe shall have sufficient capacity to convey the peak flow associated with a 100-year design storm. Methods for determining the 100-year storm peak flows are outlined in **Section 5.5.1**.

### 5.6.5 Additional Requirements

A. Fencing or retaining walls around or partially around detention basins shall not be permitted to allow for steeper side slopes unless specifically approved by the City Engineer.

B. A permanent buffer strip of natural vegetation with a minimum width of 25 feet shall be provided and maintained around the entire perimeter of the basin. The buffer strip should be planted with native vegetation. Chemical lawn care applications and mowing are prohibited in the buffer. Buffers shall be provided as follows:
   a. In residential developments, buffers should be provided around the perimeter of the basin.

b. In commercial and industrial developments, buffers shall be provided in areas where impervious surface is directed to the basin via surface flow.
c. Where elevations allow, a buffer shall be provided at the outlets to the detention basin.

C. All detention basins must be permanently stabilized to prevent erosion. Basins must be stabilized prior to directing stormwater flow to them.

D. Construction of pretreatment systems is required prior to commencement of any construction activities on site except clearing and grubbing operations. Sump manhole construction must be completed as soon as is practical during construction of the storm sewer system. Removal of collected sediment from the pretreatment systems is required at regular intervals during the construction process or at the direction of the City such that the basins are maintained in working order at all times.

E. Landscaping shall be provided as required by the City's Landscape Design manual and as directed by the City's Landscape Architect.

F. Detention basins constructed by building up on existing grade must have berms with a clay core keyed into native ground.

G. Easement requirements for detention basins are outlined in Part Three of this Chapter Five.

H. Adequate maintenance access from a public or private right-of-way to the basin shall be provided via an access easement granted to the City.. The access shall be a minimum of 15-feet wide, have a maximum running slope of 1-foot vertical to 5 feet horizontal, have a maximum cross-slope of three percent, and be stabilized to withstand the passage of heavy equipment. Additional maintenance requirements for detention basins are outlined in Part Three of this Chapter Five.

## SECTION 5.7 UNDERGROUND DETENTION

Above ground detention systems are preferred over underground detention systems. However, underground detention may be considered for sites that meet at least one of the following criteria, as determined by City Engineer:

- The site is an existing developed site that is proposed to be redeveloped.
- The site has topographical constraints that would limit the effectiveness of a traditional basin.
- The site has size constraints (buildable area is 5 acres or less).
- Traditional stormwater management measures are not feasible.

The following will be required for underground detention facilities:

A. Pretreatment shall be provided for the storm water prior to discharge into the underground detention facility. Acceptable methods and performance standards for pretreatment of storm water are outlined in **Section 5.3**.

B. The volume of detention provided must be equal to or in excess of the volume of storm water runoff generated from a 100-year storm event. The method for determining this volume is outlined in **Section 5.2.2**.

C. Oil and gas separators, designed to separate pollutants from stormwater within an enclosed storm drainage system shall be provided at the last structure prior to discharge to the detention system.

D. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance prior to release off-site or into a sedimentation or stormwater holding facility.

E. Underground detention systems shall be designed, installed and maintained per the manufacturer's recommendations.

F. Underground detention systems must have a positive method for draining. The outlet shall restrict the flow so that it does not exceed the maximum allowed outflow defined in **Section 5.2.1**.

G. Perforated or open bottom systems will be permitted if a suitable outlet is provided for the total storage volume. Due to the difficulty of removing silt and sediment from the aggregate, the void space of the aggregate bedding and backfill around the underground detention facilities will not be considered as detention volume.

H. Soil borings must be obtained within the location of the proposed detention system and extend to a depth of 25 below the existing ground or 20 feet below the proposed underground detention facility bottom elevation, whichever is greater. Additional boring depth may be appropriate for large detention systems. A minimum of one soil boring shall be obtained for every 1,000 square feet of detention area, with a minimum of two borings for any detention system. The soil borings shall be provided for review. The soil borings shall indicate the ground water elevation. The ground water elevation shall be at least 3 feet below the bottom of the storage volume.
   1. Sufficient design provisions shall be made to facilitate cleaning of the system without disruption to the surrounding stone.

I. Permanent inspection and maintenance practices shall be considered when designing an underground detention facility. The final design shall minimize the effort required for regular inspection and maintenance of the facility by the future property owner (filed with the Register of Deeds). The City Engineer may require inspection ports or manholes depending on the design and configuration of the system. The designer will need to provide documentation indicating the procedures and required frequency for inspection and maintenance of the facility. Ease of inspection and maintenance will be considered in review of the underground detention system. A maintenance plan must be provided and a maintenance agreement must be in place with the ultimate property owner (filed with the Register of Deeds). Additional requirements for maintenance are identified in Part Three of this Chapter Five.

### 5.7.1 Restricted Outlet

A. The outlet for underground detention facilities shall be designed to meet the following requirements:

   1. The maximum outlet rate at the design high water level shall not exceed the maximum allowable outflow rate as required in **Section 5.2.1**.

   2. The bankfull flood volume shall be retained in the facility for a minimum of 24 hours and no more than 40 hours. The bankfull flood is generally defined as the total rain from a 1.5-year storm, which can be determined by the following equation:

$$V_{bf} = 5160 \text{ x acreage x the relative imperviousness factor C}$$

B. V-notch weirs, orifice plates or other designs shall be utilized to assure an appropriate detention time for the 100-year flood and bankfull flood volumes as required above.

C. The outlet will be well protected from clogging.

D. All outlets will be designed to be easily accessible for heavy equipment required for maintenance purposes.

E. The restricted outlet shall be located in a catch basin, manhole or other structure that will allow for regular inspection and maintenance.

F. The standard orifice equation shall be used in determining the outflow from orifice holes used in the detention basin outlet. The minimum restrictor size is one inch diameter.

G. Pumped outlets are not permitted for underground detention facilities.

H. An emergency overflow with a defined drainage path shall be provided.

# SECTION 5.8 RETENTION BASINS

## 5.8.1 Minimum Site Requirements

Stormwater retention may be approved on sites where all of the following can be documented.

A. There is no other available positive outlet for the stormwater runoff from the property. Every effort should be made to provide a means to de-water the basin, including a pump outlet and possible downstream improvements.

B. The volume is consistent with the calculations found in **Section 5.5.3**.

C. The permeability of the soils shall follow all requirements set forth for large BMPs with the exception of the following:

   a. The Basin shall be able to dewater a 100-year storm ($V_{100R}$) within 72 hours based on the infiltration rates.

   b. When calculating the volume of storage, no credit will be given for infiltration volume within the basin. However, infiltration volume from upstream BMPs may be credited towards the total retention volume required.

D. An infiltration trench is not considered an acceptable substitution for permeable soils.

E. The general requirements for retention basins shall follow the requirements for detention basins.

F. An overflow route from the retention basin must be provided. Elevations of surrounding buildings, development or other features that would be impacted by a basin overflow must be indicated. The overflow route may not endanger any existing structures or features. Downstream drainage easements may be required for the overflow route.

G. The proprietor must submit a soil boring log taken within the basin bottom area to a depth of 25 feet below existing ground or 20 feet below proposed basin bottom elevation. Additional boring depth may be appropriate for large basins. A minimum of one soil boring shall be obtained for every 500 square feet of basin area, with a minimum of two borings for any basin, or as directed by the City Engineer.

H. The City reserves the right to require additional storage up to that required by two consecutive 100- year storm events based on the results of soils data or the overflow assessment.

I. The ground water elevation shall be at least 3 feet below the bottom of the storage volume.

### 5.8.2 Additional Requirements

A. Pretreatment shall be provided for the storm water prior to discharge into the detention basin. Acceptable methods and performance standards for pretreatment of storm water are outlined in **Section 5.3**.

B. The retention basin shall have sufficient capacity to store the runoff from two consecutive 100-year storm events. The method for determining this volume is provided in **Section 5.2.3**. The City will consider approval of modified storage volumes based on the recommendation from a licensed hydrogeological engineer.

C. Underground retention shall not be permitted.

D. The side slopes of the proposed retention basin shall be no steeper than 1-foot vertical to 4-foot horizontal.

E. One foot of freeboard shall be provided above the proposed high water level.

F. A permanent buffer strip of natural vegetation with a minimum width of 25 feet shall be provided and maintained around the entire perimeter of the basin. The buffer strip should be planted with native vegetation. Chemical lawn care applications and mowing are prohibited in the buffer.
    1. In residential developments, buffers should be provided around the perimeter of the basin.
    2. In commercial and industrial developments, buffers shall be provided in areas where impervious surface is directed to the basin via surface flow.
    3. Where elevations allow, a buffer shall be provided at the outlets to the detention basin.

G. Oil and gas separators, designed to separate pollutants from stormwater within an enclosed storm drainage system shall be provided at the last structure prior to discharge to the basin.

H. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance prior to release off-site or into a sedimentation or stormwater holding facility.

I. An overflow structure shall be provided and an overflow assessment shall be provided to the City for review. Elevations of the surrounding buildings, structures and other facilities that would be impacted by a basin overflow must be indicated. If an overflow structure cannot be constructed, a defined overflow routed must be indicated. The overflow route shall not endanger and existing structures. Downstream drainage easements shall be required for the overflow route.

J. Subdivision stormwater holding facilities and pretreatment systems shall be located in parks or outlots and not on a subdivision lot. During the plat approval process, the council may, at their discretion, allow the use of a lot for holding facilities and pretreatment systems when the lot has been oversized for this use or when construction on the lot is prohibited until elimination of the holding facilities and pretreatment system. Holding facilities and pretreatment systems within proposed septic field areas will not be permitted.

K. All retention basins must be permanently stabilized to prevent erosion. Basins must be stabilized prior to directing stormwater flow to them.

L. Landscaping shall be provided as required by the City's Landscape Design Manual and as directed by the City's Landscape Architect.

M. Adequate maintenance access from a public or private right-of-way to the basin shall be reserved. The access shall have a maximum slope of 1-foot vertical to 5 feet horizontal and stabilized to withstand the passage of heavy equipment. Additional maintenance requirements for retention basins are provided in Part Three of this Chapter Five.

## SECTION 5.9 INFILTRATION FACILITIES

Stormwater infiltration systems are generally described as natural or constructed depressions located in permeable soils that capture, store and infiltrate stormwater runoff with a certain period of time. Stormwater infiltration may be provided through the use of infiltration trenches, infiltration basins or other mechanisms. While infiltration practices may not be practical as a sole method for meeting the performance standard of this manual, they can be incorporated as one component of an overall stormwater management system.

### 5.9.1 Minimum Site Requirements

Stormwater infiltration may be approved on sites where the following can be documented. Soil borings must be obtained within the location of the proposed infiltration facility and extend to a depth of 20 feet below the proposed bottom elevation. Additional boring depth may be appropriate for large basins. A minimum of one soil boring shall be obtained for every 500 square feet of basin area, with a minimum of two borings for any basin, or as directed by the City Engineer. The soil borings shall be provided for review.

A. Infiltration facilities will be permitted only on sites with undrained hydrologic soil group classifications of A or B. Where infiltration facilities are proposed, a sufficient number of soil borings will be provided in each location to evaluate the soil suitability.

B. The infiltration rate of the existing soils must be such that percolation of the retained stormwater is possible within a reasonable time. Calculations performed by a professional geotechnical engineer shall be submitted to support this. The calculations shall be based on the percolation rates for the soils encountered in the soil borings. Pre and post construction percolation tests shall be performed to confirm the actual infiltration rate of the soil.

C. The seasonal high ground water elevation or bedrock must be a minimum of 4 feet below the bottom of the infiltration facility.

D. Infiltration facilities are not suitable for land uses or activities with potential for high sediment or pollutant loads.

E. It is recommended that drainage areas for infiltration trenches not exceed 5 acres and drainage areas for infiltration basins be between 5 and 50 acres.

F. Slopes in the tributary area shall not exceed 5% unless proper energy dissipation devices are installed.

### 5.9.2 Design Requirements

A. Pretreatment shall be provided for the storm water prior to discharge into the infiltration facility. Acceptable methods and performance standards for pretreatment of storm water are outlined in **Section 5.3**. Special care shall be taken to ensure that coarse sediments and oil that would clog infiltration facilities are sufficiently removed from the storm water upstream of the infiltration facility.
   1. The use of pretreatment systems that provide some degree of storage is encouraged.
   2. For infiltration facilities designed to meet the water quality performance standard, a vegetated filter strip with a minimum width of 25 feet is required.
   3. For discharges from an enclosed storm sewer, an oil/grit separator or other pretreatment mechanism that will remove oil and grease in addition to coarse soils shall be provided in the structure upstream of the infiltration facility.
   4. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance prior to release off-site or into a sedimentation or stormwater holding facility.

B. Where infiltration facilities are installed to meet the performance standards for quantity control, the facility shall be sized to accommodate the runoff from a 100-year, 24-hour design storm event as outlined in **Section 5.2** and pretreatment shall be provided to meet the stormwater quality performance standards. Sufficient documentation shall be provided to support the infiltration rate of the in-situ soils.

C. Infiltration facilities shall be designed to hold water for a minimum of 6 hours and a maximum of 72 hours.

D. It is recommended that flows entering the infiltration facility (and exiting the pretreatment facility) have non-erosive velocities (less than 3 fps) and are evenly distributed across the width of the infiltration facility.

E. The bottom of the infiltration facility should be generally flat to enable even distribution and infiltration of storm water. Additionally, the bottom of the facility will be placed two (2) feet below the frost line to ensure proper operation during the winter.

F. Where an overflow pipe is provided, the pipe will be placed near the surface of the trench and outlet to an acceptable point of discharge.

### 5.9.3 Additional Requirements

A. It is recommended that infiltration facilities not be hydraulically connected to structure foundations or pavement to avoid seepage and frost heave concerns. A minimum separation of 100 feet shall be provided between infiltration facilities and building foundations.

B. Infiltration facilities shall not be located with 100 feet of a water supply well.

C. Uniform, washed stone. 1.5 inches to 3 inches in diameter will be used within the facility.

D. Filter fabric shall be used to line the sides of the trench and either filter fabric or six 6 inches of sand shall be used on the bottom of the infiltration facility. Filter fabric placed six (6) to twelve (12) inches below the surface of the infiltration facility can prevent the need for major rehabilitation.

E. An observation well, consisting of a perforated vertical pipe within the trench will be installed in every infiltration facility to monitor performance.

F. Trenches and underground components shall be readily accessible for maintenance purposes.

G. Infiltration facilities should not be built down slope of new construction until the entire development area has been permanently stabilized.

H. Care shall be taken during construction to avoid compaction of the existing in-situ soils. The bottom of the infiltration facility shall be scarified or roto-tilled to a depth of 6 inches or more to reduce the possibility of initial soil compaction caused by excavation with heavy equipment. All methods for avoiding soil compaction shall be provided on the site plan.

I. A legally enforceable and binding maintenance agreement shall be provided. All systems shall require annual inspection and maintenance.

J. Subdivision stormwater holding facilities and pretreatment systems shall be located in parks or out-lots and not on a subdivision lot. During the plat approval process, the City Council may, at their discretion, allow the use of a lot for holding facilities and pretreatment systems when the lot has been oversized for this use or when construction on the lot is prohibited until elimination of the holding facilities and pretreatment system. Holding facilities and pretreatment systems within proposed septic field areas will not be permitted.

## SECTION 5.10 SEDIMENT FOREBAYS

A sediment forebay is generally very compatible with an above ground detention or retention basin. However, it could also be used in combination with an underground detention system or infiltration system. Sediment forebays shall meet the following requirements:

A. The sediment forebay shall be sized to accommodate the first flush volume. The first flush volume is the first 1.0-inch of runoff from the site and can be determined by the following equation:

$$V_{ff} = 3630 \text{ x acreage x the relative imperviousness factor C}$$

The volume of storage provided in the forebay shall not be included as a part of the total provided storage volume required for storm water quantity control, above any permanent pool of water.

B. Oil and gas separators, designed to separate pollutants from stormwater within an enclosed storm drainage system shall be provided at the last structure prior to discharge to the forebay.

C. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance prior to release off-site or into a sedimentation or stormwater holding facility.

D. When used in combination with an above ground detention or retention basin, the sediment forebay shall be a separate cell, which can be formed by gabions or an earthen berm. For small sites, where the size of the forebay would not provide sufficient settling time, alternative methods of providing quality control should be considered.

E. Forebay side slopes shall not exceed 1-foot vertical to 4 feet horizontal.

F. The forebay should have a sump with a minimum of 2 feet deep to capture sediment and prevent resuspension of sediment. The bottom of the basin should slope toward the sump area to capture the sediment. The surface area of the sump should be approximately 1/3 of the total bottom area of the sediment forebay. The sump should be located near the inlet(s) to the forebay.

G. The outlet shall be designed to capture the first flush volume and dewater the basin after 24 hours or longer. An outlet structure with restricted discharge is recommended. Guidelines for designing restricted outlets are provided in **Section 5.6.4**.

H. An outlet (overflow) spillway shall be constructed in a manner that allows water to exit the forebay at non-erosive velocities (less than 3 fps). Overflow from the sediment forebay shall be directed into the storm water quantity control facility.

I. All forebays must be permanently stabilized to prevent erosion. Basins must be stabilized prior to directing stormwater flow to them.

J. Direct maintenance access to the forebay for heavy equipment shall be provided.

K. An adequate disposal area should be provided for accumulated sediment.

L. The forebay should also have a fixed vertical sediment depth marker to measure the amount of sediment that has accumulated. The depth marker shall have a marking showing the depth where sediment removal is required. The sediment should be removed when half of the sediment storage capacity has filled in. The marker shall be constructed of a material that will not rust.

M. Subdivision stormwater holding facilities and pretreatment systems shall be located in parks or outlots and not on a subdivision lot. During the plat approval process, the City Council may, at their discretion, allow the use of a lot for holding facilities and pretreatment systems when the lot has been oversized for this use or when construction on the lot is prohibited until elimination of the holding facilities and pretreatment system. Holding facilities and pretreatment systems within proposed septic field areas will not be permitted.

## SECTION 5.11 MANUFACTURED TREATMENT SYSTEMS

Manufactured treatment systems include underground swirl concentrators, which are "treatment systems" used to remove sediment and other particulate matter from stormwater runoff. Manufactured treatment systems are the least preferred method for meeting the stormwater quality performance standard and will only be allowed for sites that meet at least one of the following criteria:

- The site is an existing developed site that is proposed to be redeveloped.
- The site has topographical constraints that would limit the effectiveness of a traditional sediment forebay or bioretention facility.
- The site has size constraints (typically two acres or smaller).

For sites where a forebay would be relatively small, a swirl concentrator device may be an acceptable substitute because of the reduced effectiveness and inadequate detention time of small forebays.

### 5.11.1 General Performance and Design Specifications

A. The system may be used to meet the storm water quality performance standards outlined in **Section 5.3** as approved by the City Engineer. Only manufactured treatment systems approved by the City Engineer shall be used.

B. Systems that have demonstrated 80% removal of the annual total suspended solids load based on third party independent testing are required.

C. The system must treat 100% of the runoff from the 1-year, 24-hour storm event and remove a minimum of 80% of the Total Suspended Solids (TSS) load based on a 110-micron particle size. The peak runoff from a 1-year, 24-hour storm event can be calculated as provided in **Section 5.5.1**.

D. Rain events larger than the 1-year, 24-hour event shall bypass the system without causing any re-suspension of trapped sediments and without causing re-entrainment of floatable contaminants.

E. The system shall not create any backwater in the upstream pipe network during any dry weather conditions.

F. The treatment system must prevent oil and floatable contaminants from entering downstream piping during routine maintenance and during rain events.

G. Direct access must be provided to the sediment and floatable chambers to facilitate maintenance. There shall be no appurtenances or restrictions within these chambers.

H. Systems that require confined space entry for inspections or maintenance are not approved for use as a treatment system.

I. If the system is proposed in traffic areas, then it must be designed to handle H20 loading capability.

J. A maintenance plan must be provided and a maintenance agreement must be in place with the current property owner (filed with the Register of Deeds). An inspection and maintenance manual must be provided for review, specific to the model.

K. All treatment systems shall be cleaned of accumulated sediment and other materials prior to inspection of the system by the City.

L. Additional requirements for maintenance are identified in Part Three, of this Chapter Five.

## SECTION 5.12 BIORETENTION/RAIN GARDENS

Bioretention basins (sometimes referred to as rain gardens) can generally be described as shallow, landscaped depressions that receive runoff and are deigned to use soil and plant material to mimic the natural water cycle by storing, filtering and infiltrating stormwater into the ground. Bioretention areas may be used anywhere to meet the stormwater quality performance standards. Bioretention areas are the preferred method of meeting the stormwater quality performance standards of this Manual.

Some key components of bioretention facilities are defined below:

- *Pretreatment* – mechanism(s) for removing coarse sediments.
- *Ponding Area* – created by a "bowl-shaped" topography that allows for surface storage of runoff and promotes evaporation.
- *Plant Material* – takes up some of the nutrients and other pollutants from stormwater through natural processes. The use of native plant material is recommended for this component wherever possible.
- *Organic or Mulch Layer* – placed on top of the planting soil/filter media, this layer provides an environment for plant growth by maintaining moisture, providing micro-organisms, decomposing incoming organic matter and acts as a filter for finer particles.
- *Filter Media/Planting Soil* – is generally the thickest layer of the facility that provides the environment for water and nutrients to be made available to the vegetation. The soil particles can absorb some additional pollutants through cation exchange and voids within the filter media/planting soil can store some of the first flush volume. A minimum infiltration rate (permeability) of 0.5 inches per hour is desired.
- *Sand Bed* – provided to keep finer particles from washing out through the underdrain system.
- *Gravel Underdrain System* – used to collect and distribute the treated runoff where in-situ soils do not allow for sufficient infiltration of the runoff.
- *Overflow System* – allows for bypass of larger storm flow volumes to the downstream stormwater quantity treatment system.

### 5.12.1 Site Suitability

Bioretention basins are generally suitable for all land uses, provided the tributary area is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot setback areas, open spaces and streetscapes.

### 5.12.2 Design Guidelines

A. The bioretention basin shall be sized to accommodate the first flush volume. The first flush volume is the first 1.0-inch of runoff from the site and can be determined by the following equation:

$V_{ff}$ = 3630 x acreage x the relative imperviousness factor C

Storage provided within the bioretention facility (including above-grade ponding and storage within the subsurface porous medium) and/or calculated infiltration will count toward the detention/retention storage requirements.

B. The surface area of the bioretention basin shall generally be sized based on the principle's of Darcy's Law, as follows:

$$A_f = \frac{V_{ff} d_f}{k(h_f + d_f)t_f}$$

*where*:

$A_f$ = surface area of facility (sf)
$d_f$ = depth of filter media or planting soil (ft)e
generally 18inches or as recommended by the Landscape Archiect
k = coefficient of permeability of filter media or planting soil (ft/day),
minimumof 1 ft/day
$h_f$ = average height of water above filter media or planting soil (ft)
$t_f$ = design filter media bed drain time (days)

Notes: Where an underdrain is *not* provided, the lesser of the k value for the in-situ soils and filter media or planting soil shall be used.

Additionally, the designer must demonstrate that the volume provided within the bioretention facility is equal to or greater than the first flush elevation. Where the designer intends to consider storage volume provided within the planting media and stone base, documentation needs to be provided to support the assumed void space. Further, the designer shall assume that 15% of the void space is unavailable for storage. This will account for accumulation of sediment within the medias. The City may require a field test for verification of the assumed void space.

C. A separation distance of 3 feet shall be provided between the bottom of the bioretention facility and the ground water elevation.

D. The tributary area to a bioretention facility should be smaller than 5 acres and preferably less than one acre. For larger sites, multiple bioretention areas can be used.

E. The maximum recommended ponding depth is 6 inches. A maximum ponding depth of 3 to 4 inches is preferred for areas that receive high hydraulic loading or have soils with low infiltration rates. The ponding depth may exceed 6 inches in cases where sandy soils and underdrain systems are being used to increase infiltration.

F. An overflow structure shall be provided. Generally, a catch basin with a raised rim installed in the bioretention facility is appropriate. The rim of the overflow structure shall be located to allow for the design ponding depth and prevent water from overflowing the bioretention facility. The overflow structure and storm sewer outlet pipe shall be sized to convey the 10-year storm event and shall convey water into the storm water quantity treatment facility.

G. An emergency overflow spillway shall be provided a minimum of 6 inches above the rim elevation of the overflow structure. The spillway shall be constructed in a manner that allows water to exit the bioretention facility at non-erosive velocities. Overflow from the bioretention facility shall be directed into the storm water quantity control facility.

H. Bioretention areas should be designed as off-line treatment systems wherever possible. This is to prevent erosive flow of water within the facility.

I. Adequate pretreatment shall be provided to capture and remove coarse sediment particles from storm water prior to entering the bioretention facility. Pretreatment may be accomplished with the following methods:

    1. Grass filter strip
    2. Gravel diaphragm
    3. Mulch layer
    4. Forebay

J. Oil and gas separators, designed to separate pollutants from stormwater within an enclosed storm drainage system shall be provided at the last structure prior to discharge to the forebay.

K. For all developments, regardless of size, a permanent four (4) foot deep sump is required to be constructed in the last stormwater structure that is readily accessible for maintenance prior to release off-site or into a sedimentation or stormwater holding facility.

L. Bioretention facilities must be permanently stabilized to prevent erosion. Facilities must be stabilized prior to directing stormwater flow to them.

M. Bioretention areas shall not be hydraulically connected to structure foundations or pavement to avoid seepage and frost heave concerns. It is recommended that a minimum separation of 10 feet be provided between bioretention facilities and buildings or other structures.

N. Sloped areas exceeding 20% shall not be used for bioretention. It is recommended that the slope of the surface of the bioretention facility not exceed 1% to promote even flow distribution.

O. Bioretention facilities should be located away from traveled areas such as public pathways to avoid compaction.

P. In parking lot applications, bumper blocks or gapped curbing should be used to prevent entry of vehicles into the bioretention area.

Q. Underdrains should be installed for all facilities placed in residential areas and in areas where the slow infiltration rate of in-situ soils may cause excess surface ponding or other drainage problems. When in-situ soils are being used without an underdrain system, a soil investigation will be required to document the in-situ soil suitability. Additionally, a raised "underdrain" (located near the top of the stone subbase layer) is recommended for all systems to provide a mechanism for a subsurface "overflow".
   1. Underdrains shall have a hydraulic capacity greater than the planting soil infiltration rate.
   2. The underdrain shall be perforated. The locations of the perforations (invert of pipe or elsewhere) depends on the design of the facility. Typically, the perforations are placed closest to the invert of the pipe to achieve maximum potential for draining the facility. The perforations can be placed near the top of the pipe if an anaerobic zone is intended. Water below the perforated portion of the underdrain will have a tendency to accumulate during periods of saturation. Otherwise, water will have a tendency to infiltrate into the surrounding in-situ soils.

3. Underdrains shall connect to a storm sewer or watercourse to achieve positive flow.
4. A gravel bed of 34R Pea Stone is recommended to protect underdrain pipes and reduce clogging. Placement of 6 inches of gravel bedding is recommended beneath the discharge points.
5. A mechanism for cleaning the underdrain system shall be provided.

R. Geotextile filter fabric shall be provided to separate the planting material from the underdrain/base material or in-situ soils.

S. The planting soil should have sufficient depth to provide adequate moisture capacity and create space for root systems. Soil for bioretention facilities should have a sandy loam, loamy sand, or loam texture per USDA textural triangle. Maximum clay content is <5%; soil mixture shall be 50-60% sand; 20-30% leaf compost; and 20-30% topsoil. Leaf compost is essentially composed of aged leaf mulch and provides added organic matter to improve the health of the soil and ensure adequate soil structure. The soil must be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the bioretention that may be harmful to plant growth or prove a hindrance to the planting or maintenance operations. The planting soil must be free of plant or seed material of non-native, invasive species, or noxious weeds.

### 5.12.3 Additional Requirements

A. In residential properties, bioretention facilities provided to meet the stormwater management performance standards must be located within common areas and be protected from changes to grading and landscaping by the Master Deed or other appropriate document.

B. Subdivision stormwater holding facilities and pretreatment systems shall be located in parks or out-lots and not on a subdivision lot. During the plat approval process, the council may, at their discretion, allow the use of a lot for holding facilities and pretreatment systems when the lot has been oversized for this use or when construction on the lot is prohibited until elimination of the holding facilities and pretreatment system. Holding facilities and pretreatment systems within proposed septic field areas will not be permitted.

C. Landscaping shall be provided as approved by the City's Landscape Architect. Plantings for bioretention facilities should be appropriate for the anticipated hydrologic and nutrient loading conditions. A list of suitable plantings for bioretention facilities is provided in Appendix 5-A. The list is not inclusive of all appropriate plant materials and the designer may choose to propose alternate plant materials.

D. Maintenance requirements for bioretention facilities are provided in Part Three, of this Chapter Five.

## SECTION 5.13 STORMWATER CONVEYANCE

Stormwater management facilities may use open channels or closed conduits or both for means of conveying stormwater runoff. Sufficient stormwater conveyance of a 10-year storm event is required. Methods for determining the 10-year design flow for a tributary area is outlined in **Section 5.5.1**. Generally, open channels are preferred to closed conduits and naturally vegetated of grassed lined channels or swales are preferred.

All stormwater conveyance structures shall be constructed in accordance with governing specifications that may include Michigan Department of Transportation, Oakland County Road Commission and/or the City. In the event of no other governing specifications, the latest edition of the Michigan Department of Transportation Standards will be observed.

### 5.13.1 Storm Sewer

Detailed requirements for storm sewer are provided in Chapter 11 of the City's Ordinance.

### 5.13.2 Open Channels

Detailed requirements for storm sewer are provided in Chapter 11 of the City's Ordinance.

### 5.13.3 Vegetated Swales

A. Vegetated swales shall follow natural, pre-development drainage paths insofar as possible and be well vegetated, wide and shallow.

B. Flow velocities within the swale shall neither be siltative nor erosive. In general, the minimum acceptable velocity should be two (2.0) feet per second and the maximum acceptable velocity will be six (6.0) feet per second.

C. Swale slopes shall be appropriate for the swale cross section, capacity, existing soils and proposed vegetation. Wherever possible, the slope shall be greater than 1.5 percent. For slopes less than 1.5 percent, additional inspection will be necessary to ensure proper, positive drainage. In no case shall slopes be less than one (1.0) percent, unless other techniques such as infiltration are implemented. Maintenance for these devices must be detailed in the overall maintenance plan.

D. Side slopes of swales shall be no steeper than 1-foot vertical to 3-foot horizontal. Soil conditions, vegetative cover and access for maintenance will be the governing factors in determining side slope requirements.

E. The sides and bottom of swales shall be temporarily and permanently stabilized to prevent erosion.

F. A minimum swale length of 200 feet is recommended to increase the contact time of stormwater.

G. A series of check dams or drop structures across swales should be provided to enhance water quality and reduce velocities.

H. Bioswales are encouraged to enhance water quality. Bioswales shall generally be designed in accordance with the above noted requirements for vegetated swales and as follows:

1. The longitudinal slope of the bioswale shall be steep enough to prevent ponding and shallow enough to slow water velocity. Recommended slopes range between one and a half percent (1.5%) and four percent (4%).
2. Flow velocity should be sufficiently low to provide adequate residence time within the channel.
3. Channel bottom width should be maximized. A wider channel allows for maximum filtering surface and slower water velocities within the channel.
4. Flow depth should not be taller than the proposed vegetation. A maximum depth of four (4) inches is recommended.
5. The channel length shall be long enough to provide approximately 10 minutes of residence time.
6. Plantings for bioswales shall be appropriate for the anticipated hydrologic and nutrient loading conditions as approved by the City's Landscape Architect. A list of suitable plantings for bioretention facilities is provided in Appendix 5-A. The list is not inclusive of all appropriate plant materials and the designer may choose to propose alternate plant materials.

### 5.13.4 Natural Streams and Channels

A. Natural streams are to be preserved. Modifications to existing natural streams, where unavoidable shall be designed and constructed according to governing regulations including, but not limited to, the Michigan Department of Environment, Great Lakes, and Energy, the U.S. Army Corps of Engineers and the Federal Emergency Response Agency.

B. Natural swales and channels shall be preserved whenever possible.

C. If channel modifications must occur, the physical characteristics of the modified channel will meet the existing channel in length, cross section, slope, sinuosity and carrying capacity. For unstable existing channels, a geomorphologic analysis should be completed to determine the most stable channel geometry and capacity.

D. Streams and channels are expected to withstand all events up to the one-hundred year storm without increased erosion. Floodplains should be constructed where necessary. Armoring the banks with rip rap and other manufactured materials will only be accepted where erosion cannot be prevented in any other way.

# PART THREE – EASEMENT AND MAINTENANCE REQUIREMENTS

## SECTION 5.14 EASEMENTS FOR STORMWATER MANAGEMENT FACILITIES

Permanent easements shall be provided for all stormwater management facilities. If a facility is to be located within the right-of-way or any existing public utility easement, it shall be located such that it will not significantly increase the expense of maintaining the drainage facility. Easement requirements for legally established County Drains are detailed in the Oakland County Drain Commissioner's Standards. The following pertain to private storm water management facilities:

### 5.14.1 Easement Width

Minimum easements widths for facilities that are not part of a legally established County Drain are as follows:

A. Open Drains and Watercourses – The minimum easement width shall be equal to the extreme width of the drain or watercourse plus fifteen (15) feet from the top of bank on both sides of the channel. Additional width may be required in some cases, including, but not limited to: water courses with floodplains delineated by FEMA, sandy soils, steep slopes and at access points from road crossings. Public easements shall be provided to the City for natural water courses that are not under the jurisdiction of the Oakland County Drain Commission, Michigan Department of Environment, Great Lakes, and Energy or other regulatory agency.

B. Enclosed Drains – The easement width shall be equal to twice the depth of the sewer plus the size of the outside diameter of the pipe. Certain soil conditions may require larger easements. In no cases shall the easement width be smaller than twenty (20) feet. The easement shall be centered on the centerline of the pipe.

C. Rear Yard Swales - The minimum easement width shall be twenty (20) feet centered on the centerline of the swale.

D. Detention/Retention & Other Storm Water Management Facilities - Sufficient easement area to allow for operation and maintenance of the entire facility, including freeboard area, the banks and any berms at the top of the banks. Easements shall be 15-feet wide or greater and located to accommodate access and operation of equipment, spoils deposition and other activities identified in the maintenance plan. An access easement from the right-of-way shall be granted to the City as part of the maintenance agreement.

### 5.14.2 Additional Requirements

A. Easement information shall be included on preliminary and final site plans.

B. In cases where storm water is discharged to a drain or watercourse on adjoining private property, an improvement to the drain and agreement with the property owner (filed with the Register of Deeds) may be necessary. An off-site drainage easement will be required if:
   1. The watercourse is not depicted as a solid blue line on a USGS map.
   2. It is not indicated on the MIRIS map.
   3. The watercourse is not considered wetlands by the governing municipality.

C. In cases where storm water is discharged to a wetland located on the development property, the developer may be required to obtain an easement from the adjacent property owners, approved by the City, and filed with the Register of Deeds. An off-site drainage easement will be required if all of the following conditions are met:
   1. The wetland extends onto adjacent properties
   2. The development would cause a change in the natural flow of storm water from the development by diverting (or concentrating) additional storm water flow from the property into wetlands, which extend onto the adjacent property.
   3. The development would cause the amount of water on the adjacent property to increase and/or changes the velocity of the water moving across the adjacent property

## SECTION 5.15 MAINTENANCE REQUIREMENTS FOR STORM WATER MANAGEMENT FACILITIES

A. All sites shall have a stormwater drainage facility maintenance easement agreement (SDFMEA) for the on-site storm water management facilities. A SDFMEA shall be submitted with all construction plans and included in the bylaws of all developments and site condominiums. Additional requirements for maintenance plans are provided in **Section 5.15.1**.

B. The applicant may fulfill his or her obligation to ensure that a governmental entity will be responsible for drainage system maintenance by establishing a county drainage district, or other similar mechanism approved by the City to provide for the permanent maintenance of stormwater management facilities and necessary funding. If a county drain is not established, the applicant will submit evidence of a legally binding agreement with another governmental agency responsible for maintenance oversight.

C. A legally binding private stormwater drainage facility maintenance easement agreement will be executed before final project approval is granted. The agreement shall be referenced on the property deed (or condominium master deed document) so that it is binding on all subsequent property owners.

D. Stormwater management facilities shall be designed to minimize and facilitate maintenance, including, but not limited to:

1. Riser pipes placed near or within pond embankments
2. Easily accessible trash racks
3. Alternative outflows for wet detention basins that can be used to completely drain the pool for sediment removal (pumping shall be considered if drainage by gravity is not feasible)
4. Access for heavy equipment
5. On-site area for spoil deposition, wherever possible

### 5.15.1 Maintenance Plan Requirements

The stormwater drainage facility maintenance easement agreement shall outline the tasks associated with maintenance of the storm water management facilities during the construction process and once the property owner (filed with the Register of Deeds) has assumed responsibility of the storm water management facilities. Where underground detention facilities, manufactured treatment systems and/or storm water pumps are proposed, the maintenance plan for the site shall be developed in accordance with the recommendations of the manufacturer.

The following information shall be included in the stormwater drainage facility maintenance easement agreement:

A. A copy of the final approved drainage plan that delineates the facilities, easements, maintenance access and buffer areas.

B. An estimated annual maintenance budget, itemized in detail by task and a description of the financing mechanism.

C. A listing of appropriate maintenance tasks and a schedule for their implementation, including:
    1. Regular inspections
    2. Sediment/pollution removal
    3. Vegetation management
    4. Debris and litter control
    5. Embankment and outlet stabilization

D. Identification of the party responsible for performing each of the inspection and maintenance described.

E. Detailed descriptions of the procedure(s) for preventative and corrective maintenance activities. Preventative activities shall include:
    1. Periodic inspections, adjustments and replacements
    2. Record keeping of operations and expenditures

F. Provisions for the routine and non-routine inspection(s) of all components within the system, including:
    1. Wet weather inspections of structural elements (including inspection for sediment accumulation in detention basins) should be conducted annually with as-built plans in hand. These inspections should be carried out by a professional engineer reporting to a responsible agency or owner.
    2. Housekeeping inspections, such as checking for trash removal, should be conducted at least annually.
    3. Emergency inspections on an as-needed basis, upon identification of severe problems, should be carried out by a professional engineer.

G. A description of on-going landscape maintenance needs. The viability of plantings will be monitored by the applicant and for at least one (1) year after establishment and plantings will be replaced as needed. After one (1) year, the responsibility of monitoring and replacing plantings shall be the responsibility of the property owner. The City is not responsible for landscape maintenance.

H. Provisions for the maintenance of vegetative buffers by homeowner's associations, conservation groups or a public agency. Buffers will be inspected annually for evidence of erosion or concentrated flows through or around the buffer.

### 5.15.2 Maintenance Guidelines

Specific minimum guidelines for maintenance of various storm water management facilities are as follows:

A. Detention Basins
   1. Check outlets regularly for clogging and clean when necessary, especially after large storm events. Replace stone around standpipe as needed.
   2. Inspect entire system at least annually including inlet/outlet pipes, animal grates and filters.
   3. Inspect for and remove floatables and debris at least annually.
   4. Regularly check banks and bottom for erosion (at least annually) and correct as necessary.
   5. Reseed banks near inlet/outlet and stabilize eroded banks as necessary.
   6. Add additional plantings as necessary.
   7. Remove dead vegetation (in early spring) that obstructs flow.
   8. Inspect for sediment accumulation. Remove sediment when accumulation reaches six inches or resuspension is observed.

B. Underground Detention Systems
   1. Maintenance of underground detention systems shall performed be in accordance with the manufacturer's recommendations.
   2. Underground detention systems should be inspected regularly in accordance with the manufacturer's recommendations and site conditions. At a minimum, the system should be inspected every six months.
   3. Check outlets regularly for clogging and clean when necessary, especially after large storm events.
   4. Accumulated sediment should be removed from the underground detention system on a regular basis.

C. Retention Basins
   1. Regularly check banks and bottom for erosion (at least annually) and correct as necessary.
   2. Inspect for and remove floatables and debris at least annually.

3. Reseed banks near inlets and stabilize eroded banks as necessary.
4. Add additional plantings as necessary.
5. Remove dead vegetation (in early spring) that obstructs flow.
6. Inspect for sediment accumulation. Remove sediment when accumulation reaches six inches or resuspension is observed.

D. Infiltration Facilities, including Porous Pavement
1. Infiltration systems, including porous pavement must be aggressively maintained and protected from clogging by sediment, including maintenance of vegetative buffer strips.
2. In the event of clogging by accumulated sediments, partial or total reconstruction of the infiltration facility shall be required.
3. Porous pavement shall be vacuum swept and jet hosed at least four (4) times per year to remove any grit or sediment trapped in the pores of the open-graded asphalt. Evidence of a regular service contract for performing this activity will be required.

E. Sediment Forebays
1. Check outlets regularly for clogging and clean when necessary, especially after large storm events. Replace stone around standpipe as needed.
2. Inspect entire system at least annually including inlet/outlet pipes, animal grates and filters.
3. Inspect for and remove floatables and debris at least annually.
4. Regularly check banks and bottom for erosion (at least annually) and correct as necessary.
5. Reseed banks near inlet/outlet and stabilize eroded banks as necessary.
6. Add additional plantings as necessary.
7. Remove dead vegetation (in early spring) that obstructs flow.
8. Remove sediment when accumulation reaches six inches or resuspension is observed.

F. Manufactured Treatment Systems
1. Treatment systems shall be maintained according to the manufacturer's recommendations.
2. At a minimum, the system must be inspected and cleaned every 6 months, or more frequently if recommended by the manufacturer or directed in the reasonable exercise or discretion by the City Engineer.

G. Bioretention Facilities
1. Mulch should be re-applied uniformly with 2 to 3 inches of depth every six months. The mulch layer should be removed and replaced every two (2) years.

2. Soils should be tested regularly and replaced when soil fertility (ability to filter pollutants) is lost.
3. Regular weeding should be performed to remove unwanted and/or invasive plants.
4. Take appropriate actions to correct clogging that causes long-term pooling water. This shall include:
    a. Clean the underdrain system.
    b. Remove the mulch layer and rake the surface to eliminate surface blockages.
    c. Use small lengths of reinforcing bar (e.g. 2-3 feet or #4 rebar) to puncture the filter fabric with holes to correct blocked filter fabric.
    d. Punch holes in the soil to eliminate blockages within the soil layer.
5. Water plantings if wilted plants do not recover in the evening or if soils are dry at depths below 4 inches.
6. Replace dead or diseased plants.
7. Trash and debris should be removed from the bioretention facility regularly.

APPENDIX 5-A
Short List of Suitable Plants for Bioretention Facilities

| **Bioretention Basin/Rain Garden Side Slopes** | |
|---|---|
| **Scientific Name** | **Common Name** |
| ***Trees and Shrubs*** | |
| *Acer saccharinum* | silver maple |
| *Aronia melancocarpa* | black chokeberry |
| *Celtis occidentalis* | hackberry |
| *Cornus racemosa* | gray dogwood |
| *Cornus sericea* | red-osier dogwood |
| *Ilex verticillata* | winterberry |
| *Physocarpus opulifolius* | ninebark |
| *Quercus bicolor* | swamp white oak |
| *Salix nigra* | black willow |
| *Spiraea alba* | meadowsweet |
| *Viburnum lentago* | nannyberry |
| *Viburnum trilobum* | high bush cranberry |
| ***Forbs and Ferns*** | |
| *Anemone canadensis* | Canada anemone |
| *Asclepias tuberosa* | butterfly milkweed |
| *Aster laevis* | smooth aster |
| *Aster lanceoloatus* | panicle aster |
| *Aster macrophyllus* | big-leaved aster |
| *Aster novae-angliae* | New England aster |
| *Aster pilosus* | hairy aster |
| *Boltonia asteroides* | false aster |
| *Eryngium yuccifolium* | rattlesnake master |
| *Euthanmia graminifolia* | grass-leaved goldenrod |
| *Helianthus grosseserratus* | sawtooth sunflower |
| *Heuchera richardsonii* | prairie alumroot |
| *Matteuccia struthiopteris* | ostrich fern |
| *Monarda fistulosa* | wild bergamot |
| *Osmunda regalis* | royal fern |
| *Physosotegia virginianum* | mountain mint |
| *Smilacina racemosa* | false solomon's seal |
| *solidago flexicaulis* | broad-leaved goldenrod |
| *solidago riddellii* | Riddell's goldenrod |
| *solidago rigida* | stiff goldenrod |

| | |
|---|---|
| *tradescantia ohiensis* | common spiderwort |
| *Zizia aurea* | golden alexanders |

| ***Grasses, Sedges and Rushes*** | |
|---|---|
| *Andropogan gerardii* | big bluestem |
| *Bromus ciliatus* | fringed brome |
| *Panicum virgatum* | switchgrass |
| *schizachyrium scoparium* | little bluestem |
| *sorghastrum nutans* | indian grass |

| **Bioretention Basin/Rain Garden Basin Bottom** | |
|---|---|
| **Scientific Name** | **Common Name** |
| ***Trees and Shrubs*** | |
| *Aronia melancocarpa* | black chokeberry |
| *Cornus sericea* | red-osier dogwood |
| *Ilex verticillata* | winterberry |
| *Viburnum trilobum* | high bush cranberry |
| ***Forbs and Ferns*** | |
| *Anemone canadensis* | Canada anemone |
| *Asclepias incarnata* | swamp milkweed |
| *Aster novae-angliae* | New England aster |
| *Aster puniceus* | swamp aster |
| *Boltonia asteroides* | false aster |
| *Chelone glabra* | turtlehead |
| *Eupatorium maculatum* | joe-pye weed |
| *Eupatorium perfoliatum* | boneset |
| *Gentiana andrewsii* | bottle gentian |
| *Helenium autumnale* | sneezeweed |
| *Iris versicolor* | blue flag iris |
| *Lobelia cardinalis* | cardinal flower |
| *Lobelia siphilitica* | blue lobelia |
| *Lysimachia thrysiflora* | tufted loosestrife |
| *Onoclea sensibilis* | sensitive fern |
| *Osmunda regalis* | royal fern |
| *Physosotegia virginianum* | mountain mint |
| *rudbeckia subtomentosa* | brown-eyed susan |
| *Silphium perfoliatum* | cup plant |
| *Solidago rigida* | stiff goldenrod |
| *Thalictrum dasycarpum* | purple meadow rue |
| *Verbena hastata* | blue vervain |

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|---|---|
| *Vernonia fasciculata* | ironweed |
| *Veronicastrum virginicum* | Culver's root |

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| ***Grasses, Sedges and Rushes*** | |
| *Bromus ciliatus* | fringed brome |
| *Carex comosa* | bottlebrush sedge |
| *Carex crinita* | caterpillar sedge |
| *Carex hystericina* | porcupine sedge |
| *Carex vulpinoidea* | fox sedge |
| *Glyceria striata* | fowl manna grass |
| *Juncus effusus* | soft rush |
| *Panicum virgatum* | switchgrass |
| *Scirpus cyperinus* | woolgrass |
| *Spartina pectinata* | prairie cord grass |

| **Bioswale** | |
|---|---|
| **Scientific Name** | **Common Name** |
| ***Trees and Shrubs*** | |
| *Acer saccharinum* | silver maple |
| *Aronia melanocarpa* | black chokeberry |
| *Celtis occidentalis* | hackberry |
| *cornus racemosa* | gray dogwood |
| *Physocarpus opulifolius* | ninebark |
| *Quercus bicolor* | swamp white oak |
| *Salix nigra* | black willow |
| *Spiraea alba* | meadowsweet |
| *Viburnum lentago* | nannyberry |
| *Viburnum trilobum* | high bush cranberry |
| ***Forbs and Ferns*** | |
| *Anemone canadensis* | Canada anemone |
| *Asclepias tuberosa* | butterfly milkweed |
| *Aster laevis* | smooth aster |
| *Aster lanceoloatus* | panicle aster |
| *Aster macrophyllus* | big-leaved aster |
| *Aster novae-angliae* | New England aster |
| *Aster pilosus* | hairy aster |

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|---|---|
| *Boltonia asteroides* | false aster |
| *Eryngium yuccifolium* | rattlesnake master |
| *Euthanmia graminifolia* | grass-leaved goldenrod |
| *Helianthus grosseserratus* | sawtooth sunflower |
| *Heuchera richardsonii* | prairie alumroot |
| *Matteuccia struthiopteris* | ostrich fern |
| *Monarda fistulosa* | wild bergamot |
| *Osmunda regalis* | royal fern |
| *Physosotegia virginianum* | mountain mint |
| *Smilacina racemosa* | false solomon's seal |
| *solidago flexicaulis* | broad-leaved goldenrod |
| *solidago riddellii* | Riddell's goldenrod |
| *solidago rigida* | stiff goldenrod |
| *tradescantia ohiensis* | common spiderwort |
| *Zizia aurea* | golden alexanders |
| ***Grasses, Sedges and Rushes*** | |
| *Andropogan gerardii* | big bluestem |
| *Bromus ciliatus* | fringed brome |
| *Carex vulpinoidea* | fox sedge |
| *Elymus canadensis* | Canada wild rye |
| *Panicum virgatum* | switchgrass |
| *schizachyrium scoparium* | little bluestem |
| *sorghastrum nutans* | indian grass |
| *Sporobolis heterolepis* | prairie dropseed |