Section 3
Stormwater Controls

This section provides criteria and guidance for the successful design of facilities that control stormwater discharges from development and redevelopment projects to prevent flooding, streambank erosion, and water quality impairment in downstream areas. Separate design criteria are provided for stormwater quantity and quality control facilities; however, in many cases quantity and quality controls are integrated into a single facility. This section provides criteria in five major sections:

3.1 General Criteria
3.2 Stormwater Quantity Controls
3.3 Post-Construction Stormwater Quality Controls
3.4 As-Built Surveys
3.5 Construction Stormwater Quality Controls

3.1 General Criteria

Stormwater runoff generated from onsite areas shall be controlled before it is released from the development site. Stormwater management reports or construction plans will not be approved until it is demonstrated that the onsite runoff will be controlled in a manner that is consistent with the criteria in this section. At a minimum, the following criteria shall apply to all stormwater controls described in Sections 3.2 and 3.3.

1) Stormwater control facilities shall not be located within the Stream Corridor Protection Zone defined using criteria in Section 1.3 of the Manual.

2) Stormwater control facilities shall not be located within designated Federal Emergency Management Agency (FEMA) floodplain boundaries

3) Discharges from stormwater control facilities shall be directed into an approved Tier I or Tier II stream, either directly as sheet flow from a level spreader, or via a storm sewer or open channel conveyance system, according to criteria in Section 2.1 of the Manual.

4) Stormwater runoff shall not be diverted from an existing naturally occurring wetland that is preserved according to City criteria in Section 1.5 and that is not approved for filling and/or removing (as necessary) via an approved Section 404 permit issued by the U.S. Army Corps of Engineers. Wetland hydrology shall be sustained to the extent possible. The quantity and quality of this runoff shall be controlled prior to its release to the wetland system according to criteria in Section 3.2 and 3.3 of the Manual.

3.2 Stormwater Quantity Controls

Stormwater quantity control facilities shall be designed to control runoff from small, moderate, and large storm events before it is discharged offsite. The design criteria provided in this section are intended to minimize flooding downstream of the development site and to reduce streambank erosion. The stormwater management report for the project, prepared according to

the guidelines and criteria in Section 6, shall show the location of the stormwater quantity control facilities and calculations defining how they were sized.

3.2.1 Stormwater Quantity Control Exemptions

Stormwater quantity controls will not be required in the following instances:

1) The construction, enlargement, or location, on a permanent foundation, of one single-family residence, one two-family residence, one three-family residence or an accessory structure appurtenant to either a single-family or two-family residence, on a single lot that is not part of a larger common plan of development.

2) Single-family residential development sites that are less than one (1) acre in size and not part of a larger common plan of development.

3) Runoff from a development is controlled by a regional stormwater facility in place at the time of development and adequately sized to serve the development area.

See Section 3.3.1.1 to determine if the development is exempt from stormwater quality controls.

3.2.2 Hydrologic Requirements

The volume and distribution of rainfall for the storm events to be used for quantity control calculations shall be developed using the 24-hour rainfall intensity from Figure 2-1. This intensity shall be converted into a rainfall volume by multiplying it times 24 hours. The design rainfall hyetograph shall be developed by distributing this volume over the 24-hour period with the SCS Type II distribution (Table 2-3), as described in Section 2.2.2.1. Stormwater quantity control facilities shall be designed using one of the hydrograph methods defined in Section 2.2.4.

Unless otherwise exempted under the criteria in Section 3.1, onsite facilities to control post-development stormwater runoff from residential, commercial, and industrial development sites shall be designed according to the methodology presented below, which is derived from the critical storm method.[1] Under this methodology the percent increase in post-development runoff volume from a site during a 1-year storm event shall be calculated in the following manner to determine the critical storm event:

1) Determine the total volume of runoff from a 1-year, 24-hour storm, occurring over each of the site's drainage areas before and after development, using the methodology in Section 2.2.4.

2) Determine the percent of increase in runoff volume due to development. Using this percentage, select the critical storm from **Table 3-1**.

[1] Mid-Ohio Regional Planning Commission, "Stormwater Design Manual", June 1977.

Table 3-1

Critical Storm Determination

If the percent of increase in runoff volume is		The critical storm runoff rate will be limited to:
Equal to or greater than	**And less than**	
--	10	1-year
10	20	2-year
20	50	5-year
50	100	10-year
100	250	25-year
250	500	50-year
500	--	100-year

Runoff from storm events less than or equal to the critical storm event shall be released from the site at a rate no greater than the peak runoff during a 1-year storm event under pre-developed conditions[2]. Additionally, the peak runoff rate during the 100-year storm event shall be released at a rate less than or equal to the peak runoff rate during the 10-year storm event under pre-developed conditions (where the critical storm is more frequent than a 100-year storm).

The Administrator, or the Administrator's designee, reserves the right to require more stringent stormwater controls if it is determined that flood control benefits can be achieved in downstream portions of the watershed where flooding problems have been identified as existing prior to the proposed development. To encourage the redevelopment of existing developed parcels within the City, the Division of Sewerage and Drainage will consider less stringent stormwater quantity controls than those required in this section so long as the volume of stormwater generated from the site after redevelopment is not increased. The SWMS will work with Applicants on a case-by-case basis to identify opportunities where a reduction in stormwater flow can be achieved on redevelopment projects while allowing the parcel to be utilized for its intended purpose.

[2] For development sites discharging into a field tile system, the release rate for any storm up to and including the critical storm event shall be the equal to the development's fair-share of the field tile's full-flow capacity. Refer to Section 2.1.4 for more information. In no instance shall the release rate for any storm, up to and including the critical storm event, exceed the 1-year storm event under pre-developed conditions.

3.2.3 Acceptable Methods and Criteria

Stormwater quantity controls provide temporary onsite storage to detain runoff and control downstream flooding. The City allows the following stormwater quantity control facilities:

1) Dry Detention Basins (those that drain completely dry after a precipitation event),

2) Wet Detention Basins (i.e., those with a permanent pool),

3) Parking Lot Storage,

4) Underground Tank Storage, and

5) Green Roof Technologies.

The general criteria presented in Section 3.1 apply to all of these types of controls. In addition, the following specific criteria apply to each type of facility. Where a single facility is designed to provide stormwater quantity and quality control, appropriate criteria from this section and Section 3.3 shall apply. The Division of Sewerage and Drainage may give consideration to the use of other stormwater quantity control technologies provided they meet the requirements of this section.

3.2.4 Dry and Wet Detention Basins

Detention basins are one method used to meet the peak flow control (allowable post-development runoff rate) requirements for a site. Their design may also include features to control water quality, as defined in Section 3.3.4. In instances where detention basins are utilized to provide water quantity and water quality controls, peak flow rate and drawdown time criteria for both water quantity and water quality shall be met.

3.2.4.1 General Requirements for All Detention Basins

All proposed dry and wet detention basins shall be designed according to the general criteria in this section, as well as the specific criteria for stormwater quantity basins (in Sections 3.2.4.2 and 3.2.4.3), stormwater quality basins (in Section 3.3.4), or both.

Layout and Geometry Requirements

The following criteria shall be used to define the layout and geometry of all stormwater quantity and quality detention basins in the City:

1) Detention basins shall not be located on uncompacted fill, on slopes 2 (H) to 1 (V) or greater, or where infiltrating groundwater could adversely impact slope stability.

2) Detention basins shall be designed such that they readily accommodate flow from a site's major flood routing path(s) (see Section 2.4). Overland flow from a site shall be directed to a site's detention basin(s), to ensure that site runoff is controlled.

3) The basin shall be designed with an emergency spillway for storms that exceed the 100-year, 24-hour storm event. The emergency spillway shall be designed to direct the flow to a suitable downstream flood routing path without erosion, scouring, or soil undermining, and to meet other pertinent Ohio Dam Safety requirements.

4) The basin shall be designed so that the peak water surface elevation in the basin does not overtop the basin embankment or flood structures around the basin. **Table 3-2** provides the peak water surface requirements for basins with different design intent.

5) Side slopes within and adjacent to the basin shall be 4 (H) to 1 (V) or flatter to prevent bank erosion and minimize safety risks when the basin is full. The maximum cross slope for the vehicle access way shall be 10 (H) to 1 (V).

6) Detention basins shall be designed to limit the migration of groundwater from the basin towards sanitary sewers and building basements. In these cases, the City may require that a geotechnical analysis of the area be performed where the basin is proposed so that groundwater controls may be properly incorporated into the design. If the geotechnical analysis determines that exfiltration from the basin may increase infiltration into sanitary sewers or basements, then the facility design shall include compacted clay or a synthetic liner.

7) The Applicant shall submit preliminary design information to ODNR as necessary to determine the regulatory classification (Class I through Class IV) of any impoundment structures (e.g., dams, berms, embankments, levies) under Ohio dam safety regulations, and shall provide the City with documentation of ODNR's determination of the

Table 3-2

Peak Basin Water Surface Elevation Requirements

Basin Design Criteria	Peak Water Surface Elevation(1)
Water Quality Only – Larger Storms Bypassed	Peak water surface elevation during WQ_v must be 1 foot below the basin embankment elevation and the first floor elevations of structures near the basin.
Water Quantity – No Dam Safety Requirements (2)	Peak water surface elevation during the 100-year design event must be 1 foot below the basin embankment elevation and the first floor elevations of structures near the basin.
Basins Subject to Dam Safety Requirements (2)	Peak water surface elevation must satisfy Ohio dam safety requirements and be 1 foot below the floor elevation of structures during the 100-year design event. Refer to ODNR requirements.

Note:

(1) Requirements for a 1-foot freeboard will be waived if the detention basin is to outlet directly to a Tier I or Tier II stream. In such instances, the first floor elevations of structures near the basin must be at least 1 foot above the top of the basin embankment.

(2) Section 1521.06 of the Ohio Revised Code lists those dams and embankments that are exempt from dam safety requirements.

structure's classification All impoundment structures that require a dam safety permit from ODNR (Class I through III impoundment structures) shall provide sufficient design information in the Stormwater Management Report to demonstrate that dam safety permit requirements will be satisfied, including a description of the fill materials, required compaction, and other features provided to satisfy ODNR dam safety requirements, limit seepage through the impoundment structure, and protect the integrity of the structure. An as-built certification of the fill compaction shall be provided when construction is complete.

8) All inflow pipes to the detention basin that are not entirely submerged below the permanent pool elevation shall be designed with headwalls or endwalls according to criteria in Section 2.3.4. Rock channel protection designed according to criteria in Section 2.3.5 shall be used to minimize erosion around the headwall or endwall, as well as along the side slopes of the basin under each inflow pipe or open channel.

9) If inflow to the facility is conveyed through an open watercourse, including a major storm routing path (Section 2.4), the open channel conveyance system shall be designed in accordance with Sections 2.3.5 and 2.3.7. Channel protection shall be provided along any reaches within 20 feet of the 100-year high-water mark of the basin, or to the edge of the easement (for publicly maintained basins) surrounding the basin, whichever is wider. Channel protection shall be designed according to criteria in Section 2.3.5 and shall be used where the peak flow velocity during the 10-year, 24-hour design storm exceeds the criteria for grass watercourses as presented in Section 2.3.7. Such protection shall extend to the basin's bottom or 2 feet below the normal water elevation of any permanent pool.

10) Woody vegetation may not be planted or allowed to grow on the embankment, within 15 feet of the toe of the embankment, and within 25 feet from the principal spillway structure. The establishment of woody vegetation in other areas around the basin is encouraged to provide shade and moderate surface water temperatures.

11) Permanent stormwater quantity control basins, as defined herein, may be used as temporary sedimentation basins designed to control sedimentation during construction as long as collected sediments are removed, the design grade of the facility is restored, permanent vegetation is established, the temporary outlet is removed, and permanent outlet structure is constructed as designed. In instances where vegetation is not established, additional measures shall be taken to ensure that the area stabilized, including providing additional topsoil, additional seeding and mulching, or providing sodding in the areas where sparse ground cover occurs.

Debris Control Requirements

Debris control structures (trash racks) for both wet and dry basins may be required at the basin outlet if the potential exists for large debris to enter the detention basin through an open watercourse or large diameter inlet pipe. Debris control structures shall be designed using Hydraulic Engineering Circular No. 9, available from the U.S. Department of Transportation, Federal Highway Administration.

Outlet Facility and Outfall Protection Requirements

1) The detention basin shall be designed with an outlet control structure sized to meet the stormwater quantity control requirements presented in Section 3.2.2, the stormwater quality control requirements presented in Section 3.3, or both.

2) Seepage along any structure that extends through the embankment to the downstream slope shall be controlled using an anti-seep collar or drainage diaphragm. The collar/diaphragm shall be aligned approximately parallel to the centerline of the stormwater basin or approximately perpendicular to the direction of seepage flow, extending horizontally and vertically into the adjacent embankment and foundation to intercept potential cracks, poorly compacted soil zones or other discontinuities associated with the structure or its installation. Appropriate criteria for establishing the minimum horizontal and vertical distances from the surface of the conduit may be obtained from NRCS Technical Release 60, Amendment 1 pg 6-7, dated January 1991, or NRCS Technical Note 709 – Dimensioning of Filter-Drainage Diaphragms for Conduits According to TR-60, dated April 1985.

3) Open channels receiving discharges from the facility shall be protected with rock channel protection designed according to criteria in Section 2.3.5 of the Manual.

4) The outlet structure shall be sized to achieve the release rates required under Section 3.2.2 and 3.3.4. This outlet shall be designed to resist plugging by meeting the following criteria. The City shall not allow a single orifice outlet to be used for a dry detention basin that is less than 4 inches in diameter. Alternative outlet designs (e.g., V-notch weir, perforated) of smaller orifice diameter shall be permitted upon City approval if acceptable design practice is proven for site conditions. For basins that do not have micropools or permanent pools, single orifices shall be adequately protected from clogging by an acceptable external trash rack.

5) The detention basin outlet structure shall be designed to retain floatables, such as debris, oil, and grease within the basin up through and including the 100-year design storm event. Acceptable floatables control devices are illustrated in Section 3.3.4, including perforated pipes (Figure 3-3), skimmers, baffles, inverted pipes (Figure 3-5) and other devices that the City determines to be suitable.

It is recommended that detention basins be provided with an emergency drain, where practicable, so that the basin may be emptied if the primary outlet becomes clogged and/or to drain the permanent pool to facilitate maintenance. If an emergency drain is used, the emergency drain should be designed to drain by gravity where possible. Where used, gravity pipes shall be made of approved materials as specified in Item 901 of the CMSC. If site conditions prevent gravity flow, the basin may be designed to drain by pumping. Basins requiring pumping may be provided with an emergency drain made of ductile iron pipe with mechanical joints and a quick connect coupling extended to the bottom of the basin at a point near the outlet structure. It is suggested that emergency drains have an elbow within the basin to prevent sediment deposition, and a diameter capable of draining the basin within 24 hours.

The emergency drain should include an operable gate, plug valve, mud valve, ball valve, or sluice gate, which should be set and locked in the closed position. Valves or gates should be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.

3.2.4.2 Additional Layout Requirements for Dry Detention Basins

In addition to the requirements in Sections 3.2.2 and 3.2.4.1, the following shall apply to the design of dry detention basins for stormwater quantity control:

1) Dry detention basins shall be designed to drain toward the outlet or micropool in order to minimize standing water and saturated soil conditions that impede maintenance and mowing of the facility.

2) Dry detention basins that will be publicly maintained shall include a paved low flow channel from each inlet pipe or open channel to the basin's outfall. Paved low flow channels are recommended for privately maintained detention facilities. The maintenance plan for dry basins that do not include a paved low flow channel shall describe how the basin will be maintained and drain efficiently. Low flow channels shall be designed per the following requirements:

   a. ***Bottom width*** – minimum width shall be 6 feet (to allow access for maintenance equipment such as a Bobcat),

   b. ***Side slopes*** – shall not be steeper than 4 (H) to 1 (V),

   c. ***Channel slope*** – minimum slope toward the basin outlet shall be 0.5 percent for channels with paved bottoms, and

   d. ***Channel depth*** – minimum depth of channel shall be 1 foot

   The bottom and side slopes of the channel shall be 6 inch minimum thickness, concrete reinforced with steel mesh (per CMSC Section 509) to accommodate temperature stresses, and composed of air-entrained Class C concrete (per CMSC Section 499); weep holes shall be designed in the concrete side walls.

3) The minimum bottom width for dry detention basins, other than the low flow channel, shall be 12 feet to allow for vehicular access for maintenance. The detention basin bottom shall be sloped to drain, and such slopes shall be sufficient to mitigate against "flat spots" developing due to construction errors and soil conditions. The minimum transverse slope for the bottoms of such facilities shall be 2.0 percent.

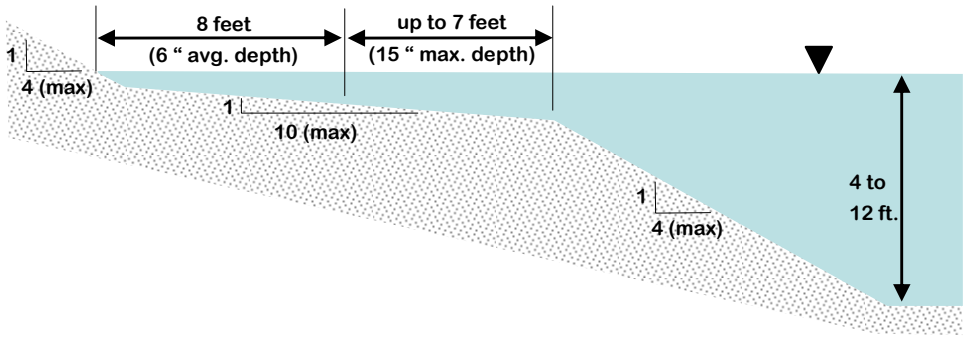
4) Dry detention basins shall be provided with topsoil, and shall be seeded and mulched to prevent erosion (per CMSC Sections 653 and 659). Grasses seeded within the basin should be able to survive 48 hours under water. Jute and Excelsior matting shall be used as required to stabilize slopes and prevent erosion.

3.2.4.3 Additional Layout Requirements for Wet Detention Basins

In addition to the requirements in Sections 3.2.2 and 3.2.4.1, the following shall apply to the design of wet detention basins.

1) The depth of wet detention basins shall be no more than 12 feet below the basin's normal water elevation. The City may approve deeper ponds that are to be privately owned and operated where practices (e.g. aeration) are proposed to prevent thermal stratification. The minimum bottom width of wet basins shall be 12 feet.

2) The perimeter of all permanent pool areas deeper than 4 feet shall be surrounded by an aquatic bench that extends at least 8 feet and no more than 15 feet outward from the normal water edge, as illustrated in the following figure. The portion of the aquatic bench within 8 feet of the shoreline shall have an average depth of 6 inches below the permanent pool to promote the growth of aquatic vegetation. The remainder of the aquatic bench shall be no more than 15 inches below the permanent pool to enhance public safety, and to limit growth of dense vegetation in a manner that allows waves and mosquito predators to pass through the vegetation. The maximum slope of the aquatic bench shall be 10 (H) to 1 (V).



3) The designer shall prepare a landscaping plan for the aquatic bench. Plantings along the aquatic bench shall be selected from the shallow water-emergent species in the list of Native Plant Species for Central Ohio is provided in Appendix B. These plants must be able to withstand prolonged inundation and be tolerant to road salts if receiving runoff from areas that are expected to be treated with salt-based deicing materials.

4) Side slopes for wet basins shall be 4 (H) to 1 (V) from the maintenance berm (see maintenance access requirements Section 4.1.1) down to the aquatic bench, and from the aquatic bench to the bottom of the basin.

5) At a minimum, wet detention basins shall be provided with topsoil, seeded and mulched (per CMSC Sections 653 and 659), in all areas that are above the basin's permanent pool. Appropriate species listed in Appendix B shall be specified in areas along the perimeter of the basin at elevations higher than the permanent pool that are periodically inundated after storms.

6) The City recommends that wet detention basins and stormwater wetlands not be constructed any closer than 10,000 feet from the aircraft movement areas, loading ramps, or aircraft parking areas of a public-use airport (i.e., a publicly or privately owned airport open to public use) serving turbine-powered aircraft, or 5,000 feet from these areas of a public-use airport serving piston-powered aircraft as recommended by the Federal Aviation Administration (FAA), Advisory Circular Number 150/5200-33. As an alternative, dry detention facilities and green roofs are stormwater best management practices that do not maintain a permanent pool of water and are not as likely to attract large numbers of waterfowl

3.2.5 Parking Lot Storage

Parking lot storage is a stormwater quantity control method allowing shallow ponding within paved portions of the parking lot during the design storm event. Parking lot storage is a convenient multi-use structural control method where impervious parking lots are planned. The following criteria shall apply to parking lot storage facilities:

1) Ponding in parking or traffic areas shall be designed for a maximum ponding depth of twelve (12) inches for all storms up to and including the 100-year event. Flood routing or overflow to a designed conveyance system must occur after the maximum depth is reached.

2) Runoff from specific graded areas within a parking lot shall be controlled by orifices. The release rate of the flow from a parking lot storage facility shall meet the allowable post-development runoff criteria presented in Section 3.2.2. The minimum size outlet device shall be a 4-inch single orifice for water quantity control. Alternative outlet designs (e.g., V-notch weir, perforated) of smaller diameter shall be permitted upon City approval.

3) A site with a parking lot storage facility shall employ a separate water quality treatment BMP that meets the water quality treatment criteria presented in Section 3.3. This BMP may be located either downstream of the parking lot or integrated into the medians, landscaping, or other pervious areas of the parking lot.

3.2.6 Tank Storage

Tank storage is a stormwater quantity control method that employs an underground tank or chamber, either prefabricated or constructed in place, and has a designed release feature to control stormwater discharge. This method is most applicable where land is valuable or the site is constrained, such as in industrial, commercial, and redevelopment areas. Construction costs and operation costs, which may include pumps, make this method relatively expensive.

1) Tank storage facilities shall not be used in instances where the City is to own or operate the facility.

2) If storage tanks are to be used for a site, a plan for long term maintenance of the facility shall be provided to the City, including a health and safety plan for confined space entry.

3) The release rate of the flow from a tank storage facility shall meet the allowable post-development runoff criteria presented in Section 3.2.2.

4) A site with a tank storage facility shall employ a separate water quality BMP that meets the water quality treatment criteria presented in Section 3.3.

5) The minimum size outlet device shall be a 4-inch single orifice for water quantity control. Alternative outlet designs (e.g., V-notch weir, perforated) of smaller diameter shall be permitted upon City approval.

6) Air-tight lids shall be used on all access structures, and traps shall be provided on inlet and outlet pipes to limit mosquito access to standing water.

3.2.7 Green Roof Technologies

Green roofs are systems used to control runoff volume, improve air and water quality, and promote energy conservation. They typically include layers of drainage material and planting media on a high-quality membrane to minimize leakage. These systems use foliage and lightweight soil mixtures to potentially absorb, filter, and detain rainfall. There are two types of green roofs:

1) Extensive green roofs, illustrated in **Figure 3-1**, typically use drought tolerant roof covers of succulents, grasses and mosses which require little to no maintenance. These roofs are not intended for recreation, are generally less expensive than intensive green roofs, and are typically not designed for public access.

2) Intensive green roofs are typically more elaborately designed roof landscapes, such as roof gardens, that are intended for human interaction and need to be engineered to conform to the additional load requirements for such activities. Alternative or intensive green roofs will only be approved upon City review and must be justified by the Applicant.

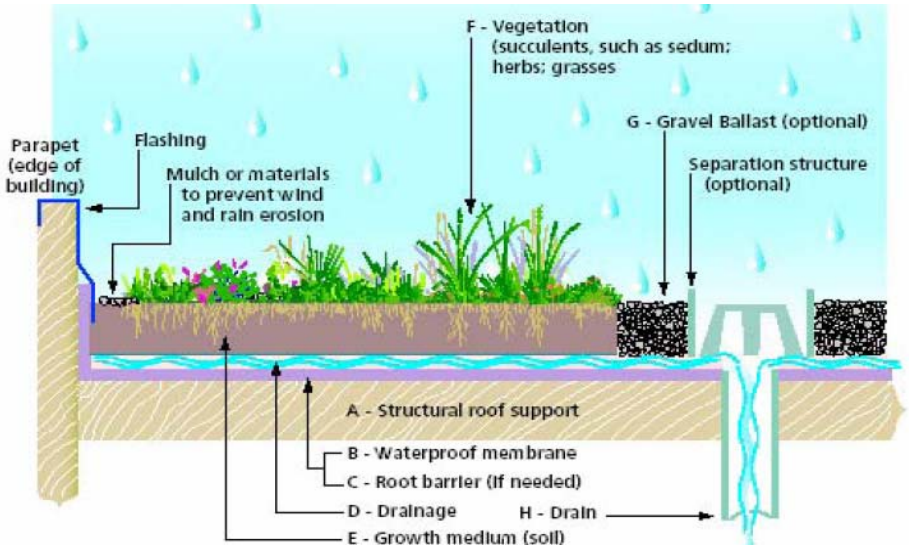


Figure 3-1. Schematic of Typical Extensive Green Roof

3.2.7.1 Design Guidelines and Performance Standards

Developers may use green roof technology on new development and redevelopment projects as a best management practice (BMP) to assist in satisfying the City's stormwater quantity and quality control requirements. The City will accept submittals with green roof components if they are designed to retain at least 50 percent of the average annual precipitation in the Columbus area (approximately 19 inches per year) and satisfy the design criteria and monitoring requirements defined in this section. **Table 3-3**[3] presents general guidelines and performance standards that shall be used to design green roofs for redevelopment projects in Columbus. These criteria are based on a review of recent literature about green roof installations in North America and Europe and may be revised as industry-wide design and material standards develop. More guidance on the design of green roof systems is available in the Guidelines for the Planning, Execution, and Upkeep of Green-Roof Sites, 2002.

3.2.7.2 Maintenance Requirements

While green roofs should be designed to minimize maintenance requirements, some maintenance is necessary to ensure its continued stormwater management performance. **Table 3-4**[4] presents the minimum maintenance requirements that shall be provided for green roof installations. The developer shall include specific requirements in a maintenance plan, as defined in Section 4.

3.2.7.3 Monitoring Requirements

Currently, field data documenting the effectiveness of green roofs at reducing stormwater quantity and quality are under development. Since green roofs are an emerging technology, they may be used on new development and redevelopment projects as a best management practice to assist in satisfying the City's stormwater quantity and quality control requirements, if the developer agrees to monitor their performance for three years after the project is complete. Monitoring is required to gain a better understanding of a number of highly-variable factors that control the stormwater benefits of green roofs, namely:

1) The antecedent moisture content of the growing media,

2) Criteria for establishment of the vegetation layer,

3) Species of plants and soil which make up the vegetation layer,

4) How control levels vary with the intensity of the rainfall,

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[3] Adapted from *Stormwater Management Manual, pgs. 2-37:24,* City of Portland – Clean River Works, Environmental Services, September 2004. General information also from the *Introductory Manual for Greening Roofs*, Public Works and Government Services of Canada, December 2002.
[4] Adapted from *Stormwater Management Manual, pgs. 3-11,* City of Portland – Clean River Works, Environmental Services, September 2004.

Table 3-3

Extensive Green Roof System Components

Major Green Roof Component	Design Requirement
Structural roof support (for both existing and new construction)	Adequate to hold an additional 10 – 25 psf (pounds per square foot) of saturated soil weight (in addition to snow load requirements)
Waterproof Membrane (Impermeable Material)	Acceptable material includes modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC
Protection Boards or Materials	Composed of soft fibrous materials; used to protect the waterproof membrane
Root Barrier (as needed)	Typically required for roofs with modified asphalt waterproof membranes while not required for EPDM and PVC membranes. (Check with waterproof membrane manufacturer to determine if required)
Drainage Layer	Range of acceptable manufactured products from plastic to gravel layers; minimum recommended thickness is 20mm
Growth Medium (Soil)	3– 6 inches of well-draining material weighing 10 – 25 psf when saturated
Vegetation	▪ Drought and extreme-weather (heat, cold, high winds) tolerant ▪ Mature plant growth patterns which cover at least 90% of the overall surface within 2 years ▪ Self-sustaining, low-maintenance, fire resistant perennials or self-sowing species ▪ Four methods recommended to install the vegetation: vegetation mats, plugs/potted plants, sprigs, & seeds ▪ Acceptable vegetation includes mosses, succulents, or grasses which are shown to thrive in plant hardiness Zone 5[5].
Gravel Ballast (as needed)	Dependent upon operational and structural design issues
Drain	Must safely drain runoff from the roof to an appropriate stormwater conveyance system
Leak Detection	Some companies recommend the incorporation of an electronic leak detection system between or underneath the waterproof membrane to pinpoint the exact location of water leaks. [6]
Minimum Roof Slope	Chapter 15 of the Ohio Building Code provides minimum roof slope criteria for various roof materials. Minimum slopes shall also comply with recommendations provided by the green roof manufacturer.
Maximum Roof Slope	25%

[5] Zone 5, as defined by the U.S. Department of Agriculture falls within most of Ohio and includes areas with average annual minimum temperature ranges between -10 and -20 degrees Fahrenheit.
[6] *Design Guidelines for Green Roofs*, Peck, S., Kuhn, M., and Arch, B – Ontario Association of Architects.

Table 3-4

Green Roof Maintenance Requirements

Major Green Roof Component	Maintenance Requirements
Soil Substrate/Growing Medium	Inspected annually for evidence of erosion from wind or water
Structural Components	Operated & maintained in accordance with manufacturer's requirements; drain inlets kept unrestricted
Debris & Litter	Remove after major storms to prevent clogging of inlet drains and interference with plant growth
Vegetation	Maintain as needed to provide 90% plant cover
Irrigation	Regularly irrigate during first two years of installation until 90 percent plant cover is achieved. Irrigate as necessary to maintain 90 % plant cover through hand watering or automatic sprinklers
Spill Prevention	Use preventative measures for mechanical systems when handling substances that could potentially contaminate stormwater
Training and/or Written Guidance Information	Provide to all Property Owners and tenants
Aesthetics	Maintained as an asset to the Property Owner/community
Insects	Prevent infestation that prevent maintenance of 90 percent plant cover criteria.
Inspections	Recommended twice annually

5) How control levels vary by season, and

6) Limits on roof pitch

The maintenance plan for the project shall define a monitoring program consisting of visual inspections, rainfall monitoring, flow monitoring, pollutant sampling, and reliability testing to demonstrate that the City's performance standards are achieved. The City will work with the Applicant to define an acceptable monitoring program for the project. The City plans to use the data collected, along with data from similar climatic regions, to contribute toward establishing design criteria for green roofs in future editions of the Manual.

3.3 Post-Construction Stormwater Quality Controls

Stormwater quality control facilities shall be designed to control runoff from small storm events before discharged offsite. The design criteria provided in this section, or alternative criteria approved by the City, are intended to reduce pollutants contained in stormwater runoff and to reduce streambank erosion during frequent storm events. The Stormwater Management Report for the project, prepared according to the guidelines and criteria in Section 6, shall include the rationale for selecting appropriate stormwater quality controls, a master drainage plan (if applicable) showing their location, and calculations defining how they were sized.

3.3.1 General Requirements

3.3.1.1 Stormwater Runoff Quality Control

Unless otherwise exempted, all runoff from development sites shall be directed to one or more stormwater quality controls designed according to:

1) Ohio EPA's Authorization for Stormwater Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System (Construction General Permit), latest version (http://www.epa.state.oh.us/dsw/permits/CGP_renewal_final_s.pdf),

2) Ohio EPA's Post-Construction Q&A Document, latest version (http://www.epa.state.oh.us/dsw/storm/CGP-PC-Q&A.html), and

3) Criteria provided in this section, as well as Section 3.1.

Additional criteria are presented in this section to assist Applicants in:

1) determining the size of stormwater quality control facilities,

2) laying out stormwater quality controls within the site, and

3) specifying features of stormwater facilities that will ensure proper function and maintenance in a manner that is acceptable to the City.

As they apply to post-construction water quality controls, the definitions, exemptions, variances, and stormwater quality criteria applicable to new development, redevelopment, small construction sites, and large construction sites, as referenced in the Construction General Permit and attending Q&A document, shall apply unless otherwise noted in the Manual. In instances where conflicts exist between OEPA criteria and the criteria presented in this section, the more stringent standards shall apply.

All stormwater quality control facilities shall be sized to completely capture and treat the WQ_v determined for the entire contributing drainage area, according to the criteria contained in Section 3.3.2. Stormwater quality control facilities may be integrated with the stormwater quantity controls addressed under Section 3.2. If not integrated, flows exceeding the capacity of the stormwater quality control shall be conveyed to a stormwater quantity control facility before being discharged offsite.

3.3.1.2 Illicit Discharge and Illegal Dumping Control

An illicit discharge is any discharge into the storm drainage system that is not composed entirely of stormwater[7]. It is the policy of the City that no person shall:

1) Construct, maintain, operate, and/or utilize any illicit connection,

2) Cause or allow any prohibited discharge, and

3) Act, cause, or permit any agent, employee, or independent contractor to construct, maintain, operate or utilize any illicit connection, or cause, allow or facilitate any prohibited discharge.

All development in the City shall be constructed in a manner that does not result in an illicit discharge into the City's stormwater system. Discharges allowable under the terms of an NPDES permit are not considered illicit discharges.

3.3.2 Water Quality Volume (WQ_v) Determination

The following formula shall be used to determine the design water quality volume (WQ_v)[8]:

$$WQ_v = C * P * (A/12)$$

where:

WQ_v = water quality volume in acre-feet
C = runoff coefficient appropriate for storms less than 1 inch
P = precipitation depth = 0.75 inch, and
A = drainage area in acres

3.3.2.1 Runoff Coefficients for Water Quality

Runoff coefficients appropriate for the various single family residential and Traditional Neighborhood Development (TND) types in Columbus are presented in **Table 3-5**. Runoff coefficients for non-single family residential and non-TND type developments shall be determined using the following equation[9]:

$$C=0.858i^3 - 0.78i^2 + 0.774i+0.04.$$

---

[7] U.S. EPA and Ohio EPA regulations allow certain non-stormwater discharges to enter the storm drainage system that are commonly not a source of pollution. Applicants should refer to the latest Ohio Environmental Protection Agency (OEPA) NPDES permit issued to the City of Columbus to determine authorized non-stormwater discharges.
[8] Ohio Environmental Protection Agency, Authorization for Stormwater Discharges Associated with Construction Activity Under the National Pollutant Discharge Elimination System. OEPA Permit No. OHC000002
[9] ASCE/WEF, "Urban Runoff Quality Management", 1997.

where:

i = fraction of the drainage area that is impervious

Per OEPA criteria[10], the minimum runoff coefficient for commercial (non-TND) and industrial developments shall be 0.8. A minimum runoff coefficient of 0.5 for non-TND multi-family developments shall be used. Detailed criteria for using the WQ_v to design each accepted type of stormwater quality control facility is found in subsequent sections of the Manual.

3.3.2.2 Minimum Drawdown Requirements

With the exception of swales and proprietary flow-through devices, stormwater quality controls proposed for new development and redevelopment projects that disturb one (1) acre or more, shall meet the minimum drawdown times specified in Sections 3.3.4 and 3.3.5. The minimum drawdown times provided in Section 3.3.6.3 are applicable where vegetated swales are proposed to provide runoff treatment for projects that disturb five (5) acres or more. For vegetated swales, filter strips, or proprietary flow-through devices intended to serve project sites that disturb less than five (5) acres, the water quality flow (WQ_f) criteria as presented in Section 3.3.6.1 may be used to size these facilities.

Table 3-5
Runoff Coefficients for Determining WQv

Land Use	Runoff Coefficient for WQv
Commercial/Business (TND-TC) and Industrial	0.8
Multi-family (TND-NC)	0.6
1/12 – 1/8 acre lots (TND-NG)	0.6
1/8 acre lots (TND-NE)	0.5
1/4 acre lots	0.4
1/2 acre lots	0.3
Undeveloped	0.2

3.3.3 Stormwater Quality Control – Acceptable Methods and Criteria

Four general categories of stormwater quality control facilities have been approved for use in the City:

1) Group 1 – Stormwater Basins

2) Group 2 – Media Filters

3) Group 3 – Vegetated Swales and Filter Strips

4) Group 4 – Controls for Commercial Activity Areas and Redevelopment

Table 3-6 presents guidance information that may be used to select appropriate control facilities for the site. The designer shall present written documentation in their Plan supporting selection of appropriate control measures based upon site conditions.

[10] Ohio Environmental Protection Agency, Authorization for Stormwater Discharges Associated with Construction Activity Under the National Pollutant Discharge Elimination System. OEPA Permit No. OHC000002

Table 3-6

Major Selection Criteria for Stormwater Quality Controls

Criteria	Group 1: Stormwater Basins	Group 2: Media Filters	Group 3: Vegetated Swales and Filter Strips	Group 4: Controls for Commercial Activity Areas
Drainage Area	> 10 ac	<5 ac	<5 ac	<5 ac
Land Required	2-3%	> 5%	> 5%	Varies
Cold Weather Issues	▪ Impacts of Pavement Deicers	▪ Impacts of Pavement Deicers ▪ Clogging from Icing	▪ Impacts of Pavement Deicers	▪ Clogging from Icing
Locational Conflicts	▪ Separation from buildings and sanitary sewers	▪ Separation from buildings and sanitary sewers ▪ Minimum elevation difference across filter	▪ Requires mild slopes	▪ Varies
Mosquito and Vector Control Issues	▪ Excessive aquatic vegetation ▪ Habitat for mosquito predator species	▪ Media clogging causes stagnant water	▪ Zero slopes, rutting, impermeable soils causing standing water	▪ Sediment debris buildup causes stagnant water
Pollutant Removal	▪ Meets Ohio EPA Criteria for New Development	▪ Meets Ohio EPA Criteria for New Development	▪ Meets Ohio EPA Criteria for New Development	▪ Pretreatment for Commercial Activity Areas

Within each group, detailed design criteria are presented in subsequent sections that govern feasibility, conveyance, pretreatment, treatment, environmental/landscaping and maintenance requirements. The following major design considerations shall be addressed during design and documented in the Plan:

1) ***Drainage Area*** **—** The drainage area sizes provided in Table 3-6 are based on literature review of demonstrated design criteria, and are provided for guidance purposes only. Significant departures from this guidance may require that the designer provide additional information, upon request, to demonstrate that the facility will function properly if the actual drainage area varies significantly from this guidance. Designers should keep in mind, however, that stormwater basins serving areas smaller than 10 acres may require extremely small outlets that are prone to clogging. Wet basins and stormwater wetlands typically require larger drainage areas or alternative water sources to sustain a permanent pool and maintain aquatic vegetation. An acceptable alternative to treating runoff from the entire site using a single BMP is to divide the development into smaller catchment areas where treatment can be provided by several smaller BMPs located throughout the development site.

2) ***Hydraulics*** —Design the facility with an outlet to control release rates and prevent clogging, provide storage for intense rain events, and install an observable high-flow bypass.

3) ***Sediment Management*** — Design the facility with pre-treatment for coarse sediments and a sediment storage volume for finer sediments.

4) ***Health & Safety*** — Design facilities containing a permanent pool with a healthy aquatic habitat for mosquito control and an aquatic bench with a maximum slope of 10 (H) to 1 (V) to increase public safety.

5) ***Aesthetics*** — Provide features that "hide" accumulated silt & debris and integrate the facility with overall site design.

6) ***Maintainability*** — Design the facility to minimize the amount and frequency of maintenance, to ease required maintenance activities, and to eliminate emergency / extraordinary maintenance requirements. Design criteria in the Manual are intended to facilitate maintenance, are required for facilities that will be maintained by the City, and are recommended for other facilities. If a design is proposed that does not include some or all of these features, the maintenance plan shall explain how maintenance activities shall be performed.

7) ***Accessibility*** — Design the facility to eliminate physical barriers (e.g., curbs and steep slopes) to entry for maintenance or emergency access, use strong, lightweight, noncorroding materials at access points (e.g., manhole covers and doors) to underground facilities, and provide legal right of entry for publicly maintained basins.

8) ***Durability*** — Design the facility to include strong, light-weight materials for "removable" features, reinforced concrete structures for "permanent" features, and hardy, disease-resistant vegetation.

9) ***Separation from buildings and sanitary sewers*** — Keep water quality controls that allow infiltration of runoff into the ground away from buildings, sanitary sewers, and building laterals to minimize infiltration/inflow into sanitary sewers.

10) ***Cold Weather Issues*** — Stormwater quality control facilities shall be designed to operate effectively under cold weather conditions. Design considerations include use of outlets that will not clog when frozen, additional pre-treatment and/or sediment storage/disposal in areas where sand or other solids are used for pavement deicing, and salt-tolerant plants in controls that incorporate vegetation.

11) ***Mosquito and Vector Control*** — Design criteria are included in the Manual that minimize conditions causing mosquito breeding without significantly compromising the effectiveness of controls that rely upon permanent pools of water and vegetation. The following guiding principals apply:

a. Areas of facilities outside the permanent pool shall be designed to drain completely toward the outlet or permanent pool within 72 hours of a precipitation event. Small depressions in paved, rip-rap, and/or vegetated areas shall not be allowed, and shall be eliminated if they form.

b. Wet detention basins and wetlands shall be designed to maximize habitats that promote colonization of the facility by mosquito predators (i.e., dragonflies, diving beetles, and mosquito fish). These facilities shall also incorporate large areas of open water to allow waves to propagate through vegetated areas, drowning mosquito larvae.

c. Underground and enclosed vaults containing certain stormwater quality controls are particularly susceptible to mosquito breeding. Facilities not intended to include a permanent pool of water shall be designed to drain without allowing standing water to remain, and shall not permit any trapped debris or sediment to create standing water. Air-tight lids shall be used on all access structures, and traps shall be provided on inlet and outlet pipes to limit mosquito access to standing water.

d. The maintenance plan for the facility shall address mosquito monitoring and control activities, including periodic harvesting of aquatic vegetation, removal of invasive/exotic and/or emigrant vegetation, removal of trash, debris sediment accumulation, and cleaning/rejuvenation of media filters.

3.3.4 Group 1 – Stormwater Basins

Stormwater basins typically provide a combination of a permanent pool and/or extended detention to treat the entire WQ_v. Acceptable design variants include:

1) Extended dry detention basin,

2) Extended wet detention basin, and

3) Constructed stormwater wetland.

Stormwater quality design features can be readily incorporated into stormwater basins that are designed to function as quantity control facilities, making them an attractive choice for stormwater controls. Stormwater basins that are intended to provide stormwater quantity as well as stormwater quality control shall be designed in accordance with the criteria presented in both this section and Section 3.2.

At a minimum, all stormwater basins shall be designed according to the general criteria in Sections 3.1 and 3.2.4.1. Additional design requirements are specified in the following sections. **Table 3-7** summarizes the major design criteria for the three types of stormwater basins. Major differences in design criteria are the required facility size, the use of permanent pools, and the required drawdown time for a basin at design capacity. If a dam or spillway is part of the basin's design, the design and construction of the basin are required to follow Ohio law

Table 3-7

Major Design Criteria for Stormwater Basins

Type of Basin	Permanent Pool Volume[1]	Extended Detention Volume	
		Volume	Drawdown
Extended Dry Detention	Micropool[2]	WQv	48 hrs
Extended Wet Detention	0.75*WQv	0.75*WQv	24 hrs
Wetland	Wetland[3]	WQv	24 hrs

[1]Facility volumes should be increased 20 percent for sediment storage
[2]Equals 0.20(WQv)
[3]Equals twice the 30-day summertime evaporation rate or 0.75 WQv, whichever is greater

pertaining to dam design (Section 1521 of the Ohio Revised Code and Chapter 1501:21 of the Ohio Administrative Code) and safety requirements.

3.3.4.1 Extended Dry Detention Basins

Extended dry detention basins are designed to capture stormwater during small to moderate rain events and slowly release the captured volume over a specified period of time. **Figure 3-2** provides schematic drawings of two types of extended dry detention basins: one incorporating a micropool near the outlet, and one that does not. The following criteria shall be used to design extended dry detention basins intended to serve as water quality BMPs.

General Criteria
All extended dry detention basins shall be designed according to the following criteria:

1) The general criteria for stormwater controls in Section 3.1,

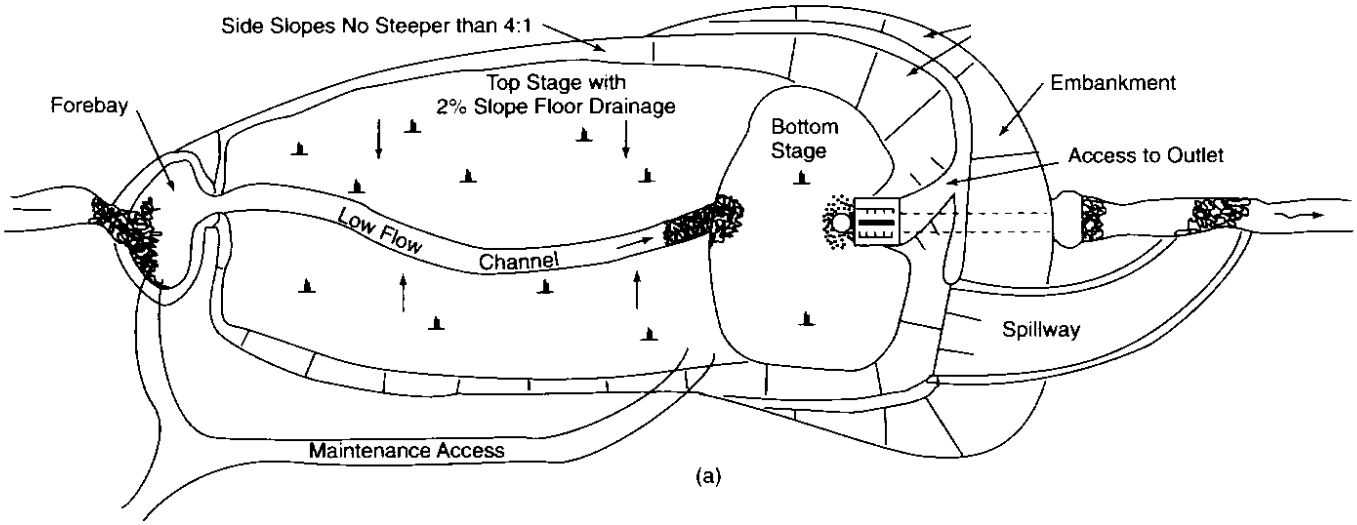
2) The general criteria for stormwater detention basins in Section 3.2.4.1,

3) The criteria for dry stormwater quantity control detention basins in Section 3.2.4.2, and

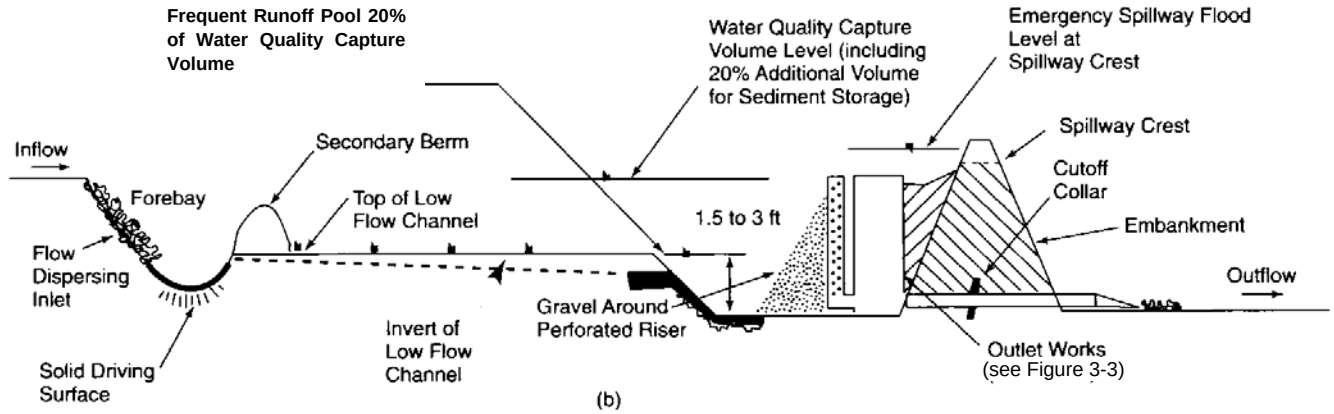
4) Specific criteria in this section.

Hydrology Requirements
The extended dry detention basin shall be sized to capture the WQ_v calculated according to the methodology in Section 3.3.2. A minimum drawdown time of 48 hours shall be used to size the facility outlet, as described under the Outlet Facility and Outfall Protection Requirements later in this section. If a stormwater quality control basin is incorporated within a stormwater quantity control basin, the entire stormwater quantity design storm, as defined in Section 3.2, shall be routed through the stormwater quality portion of the basin when sizing the facility.

Type 1. No Micropool at Outlet.



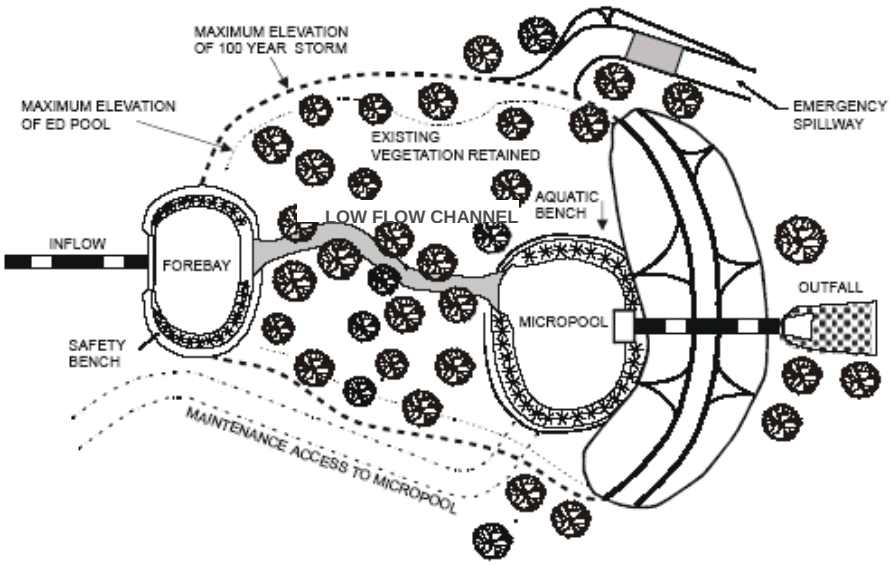
a) Plan View



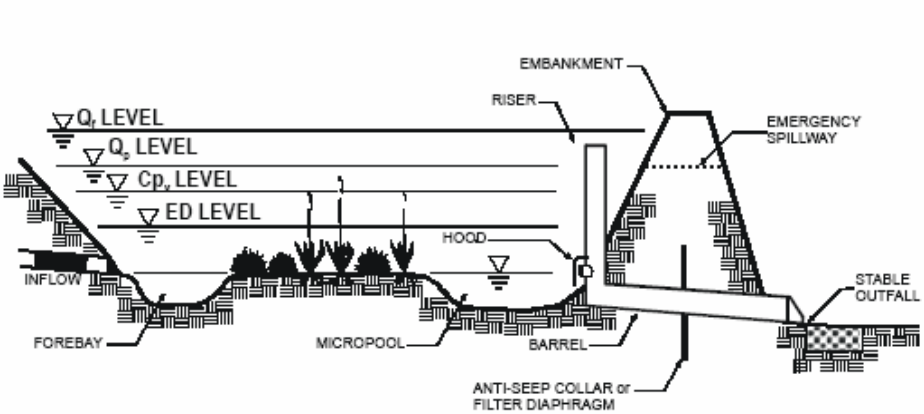
b) Profile View

Figure 3-2. Schematics of Extended Dry Detention Basins

Type 2. Micropool at Outlet



a) Plan View



b) Profile View

Figure 3-2 (continued). Schematics of Extended Dry Detention Basins

Layout and Geometry Requirements
The layout and general requirements of extended dry detention basins shall meet the minimum requirements stipulated in this section:

1) The recommended minimum drainage area of 10 acres is proposed to avoid outlets with extremely small orifices prone to clogging. Alternative stormwater quality control facilities specified in the Manual are generally preferred for drainage areas smaller than 10 acres.

2) Additional storage equal to at least 20 percent of the WQ_v shall be provided within the basin to account for sediment deposition. This sediment storage volume shall be placed at a lower stage surrounding the outlet control structure of the basin. This area shall be designed to minimize aesthetic and other impacts associated with sediment and debris accumulation and saturated soils in this portion of the basin. Design features to address these concerns include a micropool, rock landscaping, or other treatments that obscure sediments and debris accumulation. If a micropool is incorporated into the basin, its size shall be at least equal to the sediment storage volume.

3) The minimum length-to-width ratio for extended dry detention basins shall be 2:1. Where site conditions allow, basins should be wedge-shaped, narrowest at the inlet and widest at the outlet to achieve the required length-to-width ratio. Where site conditions do not allow this configuration, the length-to-width ratio shall be increased by relocating the basin inlet or outlet where possible, or by installing berms or baffles within the basin to the full depth of the WQ_v to avoid short-circuiting and to increase travel time to the outlet.

4) If water quantity control is provided by parking lot storage, the WQ_v shall not extend onto paved surfaces.

Pretreatment Requirements
A forebay or other pretreatment feature shall be provided at all inlets of basins that are to be publicly maintained and are recommended for basin inlets that are to be privately owned and operated. Basin forebays provided on publicly maintained basins shall meet the following minimum requirements:

1) Basin forebays shall provide at least 10 percent of the WQ_v . The storage volume provided within the forebay will count toward the total WQ_v requirement.

2) The forebay shall consist of a separate cell, formed by an acceptable barrier such as a rock and/or vegetated weir.

3) Direct maintenance access shall be provided to the forebay at a slope no steeper than 10 (H) to 1 (V).

4) Forebay side-slopes shall not exceed 4 (H) to 1 (V).

5) To make sediment removal easier, the bottom and side slopes of the forebay shall be lined

with Class C concrete (per CMSC Section 499) having a minimum thickness of 6 inches. The concrete shall be reinforced with steel mesh (per CMSC Section 509) to accommodate temperature stresses.

6) A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time.

7) Forebays of basins that are privately owned and operated may be constructed upon the City's approval with alternative bottom material, provided that an access point of sufficiently compacted material is available to support equipment necessary to perform the necessary routine maintenance for cleaning the structure.

Outlet Facility and Outfall Protection Requirements
Outlet designs shall provide the necessary drawdown time, route flood flows, resist clogging, and facilitate maintenance. **Figure 3-3** illustrates the accepted outlet for extended dry detention basins without micropools. For extended dry detention basins with micropools, the outlet designs for extended wet detention basins may be used (see Section 3.3.4.2 and Figure 3-5 for design criteria). The following criteria shall be used to design outlet facilities and outfall protection:

1) The outlet shall be designed to release 50 percent of the WQ_v in 18 to 24 hours, and 100 percent of the WQ_v in 48 hours.

2) If a single orifice outlet is used, it shall be designed with the following equation:

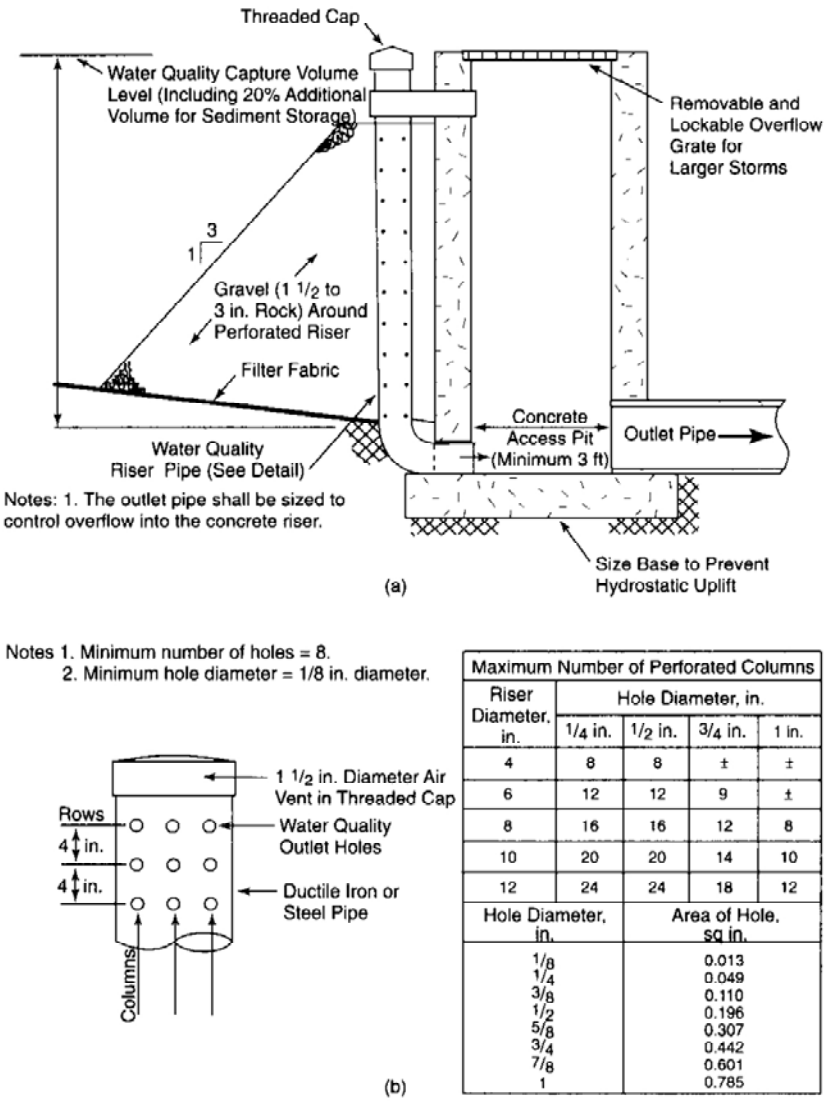
$$Q = A*C*(64.4*H)^{1/2}$$

where:

Q = orifice discharge rate, cfs
A = area of the orifice, ft^2
C = orifice coefficient
= 0.66 for material thicknesses less than the orifice diameter
= 0.80 for material thicknesses thicker than the orifice diameter
H = head, measured from the centerline of the orifice, ft

3) Single orifice outlets with diameters of at least 4 inches shall be used as the water quality outlet for extended dry detention basins without a micropool. An external trash rack and hood that protects against clogging shall be provided. Alternative outlet designs (e.g., V-notch weir, perforated riser) shall be permitted upon City approval.

4) If a perforated riser is used as the water quality outlet control facility for the basin, then the perforations shall be designed according to criteria shown on Figure 1116-13 of the



Maximum Number of Perforated Columns				
Riser Diameter, in.	Hole Diameter, in.			
	1/4 in.	1/2 in.	3/4 in.	1 in.
4	8	8	±	±
6	12	12	9	±
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter, in.	Area of Hole, sq in.
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

Figure 3-3. Perforated Riser Design for Extended Dry Detention Basins without Micropools

Ohio Department of Transportation's (ODOT's) Location and Design (L&D) Manual[11].

5) The principal spillway for flows in excess of the WQ_v shall be designed according to criteria in Section 3.2 and equipped with a removable trash rack.

6) Extended dry detention basins that are intended to serve as a stormwater quality control only, must be designed to safely bypass all storms larger than the WQ_v, up to and including the 100-year storm event (Section 2.2) to an appropriately sized stormwater quantity control facility.

[11] Ohio Department of Transportation, "Location and Design Manual, Volume Two, Drainage Design".

3.3.4.2 Extended Wet Detention Basins

Extended wet detention basins provide a permanent pool of water overlain with an extended detention volume that drains following rainfall events. Basins designed according to the criteria in this section will provide settling for suspended solids entrained in the stormwater. **Figure 3-4** provides a schematic drawing of an extended wet detention basin. The following criteria shall be used to design extended wet detention basins.

General Criteria

Extended wet detention basins shall be designed according to the following criteria:

1) The general criteria for stormwater controls in Section 3.1,

2) The general criteria for stormwater detention basins in Section 3.2.4.1,

3) The criteria for wet stormwater quantity control detention basins in Section 3.2.4.3, and

4) Specific criteria in this section.

Hydrology Requirements

The volume of the extended wet detention basin shall be 150 percent of the WQ_v, calculated according to the methodology in Section 3.3.2.

1) This volume shall be split, with approximately 75 percent of the WQ_v placed in the permanent pool, and 75 percent of the WQ_v placed in the extended detention volume overlaying the permanent pool.

2) If a stormwater quality control basin is incorporated within a stormwater quantity control basin, the entire stormwater quantity design storm, as defined in Section 3.2, shall be routed through the stormwater quality portion of the basin when sizing the facility.

Layout and Geometry Requirements

The layout and general requirements of extended wet detention basins shall meet the minimum requirements stipulated in this section:

1) The recommended minimum drainage area of 20 acres is proposed to avoid basins where the permanent pool partially or completely evaporates during dry weather conditions. Alternative facilities specified in the Manual are generally preferred for drainage areas smaller than 20 acres.

2) Extended wet detention basins shall only be allowed under the following conditions:

    a. Where existing soils are categorized as hydrologic soil group C (HSG-C) or hydrologic soil group D (HSG-D),

    b. Where gravelly sands or fractured bedrock are not present, or

c. Where a liner is installed to sustain the permanent pool of water thereby avoiding basins where the permanent pool partially or completely infiltrates into the ground.

3) The minimum length-to-width ratio for extended wet detention basins shall be 2 (L) to 1 (W). Where site conditions allow, basins should be wedge-shaped, narrowest at the inlet and widest at the outlet to achieve the required length-to-width ratio. Where site conditions do not allow this configuration, the length-to-width ratio shall be increased by

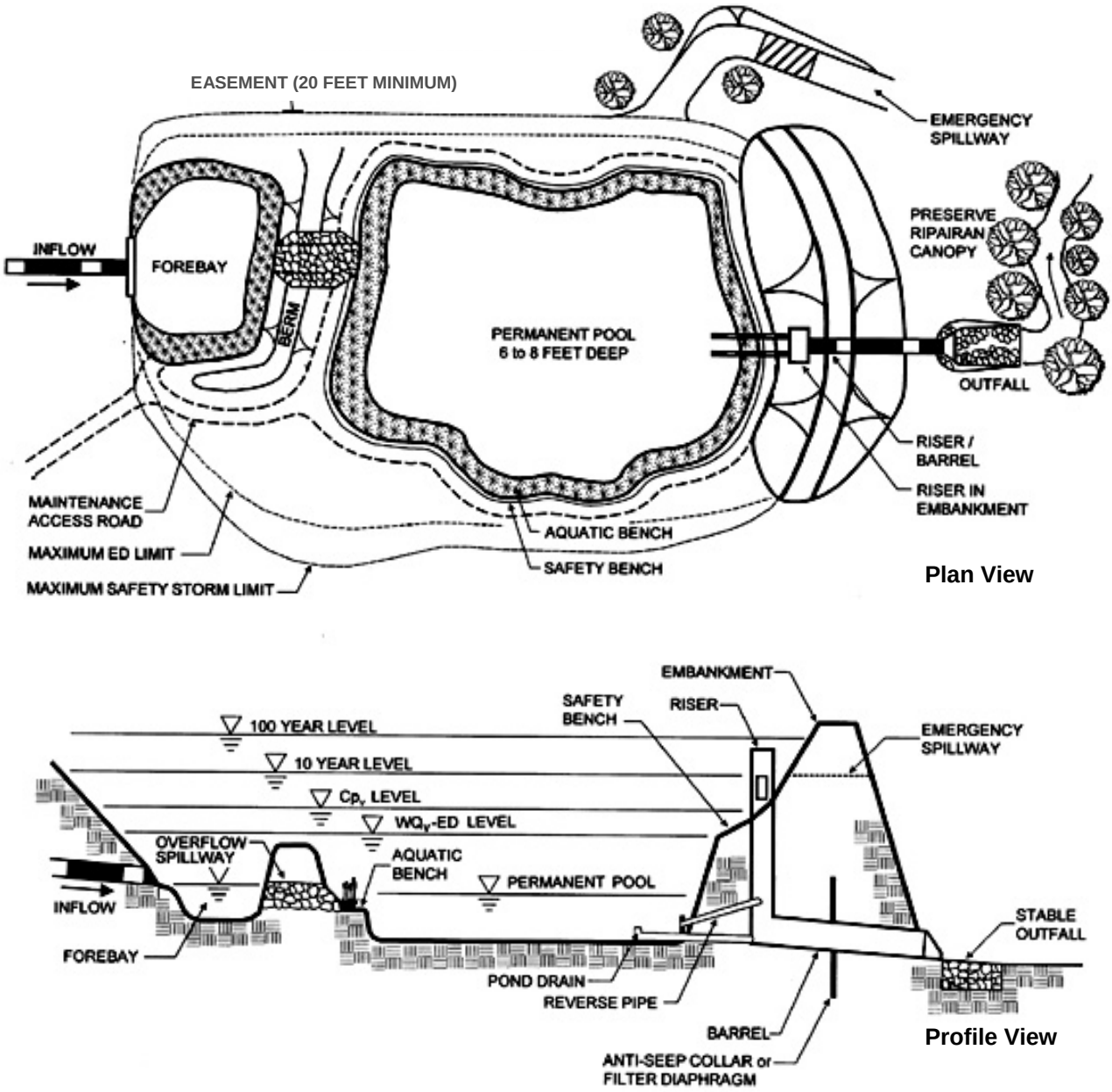


Figure 3-4. Schematic of a Typical Extended Wet Detention Basin

relocating the basin inlet or outlet where possible, or by installing berms or baffles within the basin to the full depth of the WQ_v to avoid short-circuiting and to increase travel time to the outlet.

4) The depths of open water areas within the basin shall be between 4-feet and 12-feet on average to prevent thermal stratification. The perimeter of all deep pool areas (four feet or greater in depth) shall be surrounded by an aquatic bench meeting the design criteria in Section 3.2.4.3.

5) Wherever possible, wetland plants shall be incorporated into the basin design. A landscaping plan for the basin shall be prepared to indicate how aquatic and terrestrial areas will be established with vegetation. A list of recommended Native Plant Species for the Central Ohio area is provided in Appendix B**.**

6) Additional storage equal to at least 20 percent of the WQ_v shall be provided within the basin to account for sediment deposition.

Pretreatment
A forebay or other pretreatment feature shall be provided at the inlets of all basins that are to be publicly maintained, and is recommended for basin inlets that are to be privately owned and operated. Basin forebays provided on publicly maintained basins shall meet these minimum requirements:

1) Basin forebays shall be sized to provide at least 10 percent of the WQ_v. The storage volume provided within the forebay will count toward the total WQ_v requirement.

2) The forebay shall consist of a separate cell, formed by an acceptable barrier such as a rock weir.

3) Direct maintenance access shall be provided to the forebay at a slope no steeper than 10 (H) to 1 (V).

4) Forebay side-slopes shall not exceed 4:1.

5) To make sediment removal easier, the bottom and side slopes of the forebay shall be lined with Class C concrete (per CMSC Section 499) having a minimum thickness of 6 inches. The concrete shall be reinforced with steel mesh (per CMSC Section 509) to accommodate temperature stresses.

6) A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time.

7) Forebays of basins that are privately owned and operated may be constructed upon the City's approval with alternative bottom material, provided that an access point of sufficiently compacted material is available to support equipment necessary to perform the necessary routine maintenance for cleaning the structure.

Outlet Facility and Outfall Protection Requirements
Outlet designs shall provide extended drawdown time, route flood flows, resist clogging, and facilitate maintenance. **Figure 3-5** illustrates accepted outlets for extended wet detention basins and extended dry detention basins with micropools. The outlet for extended wet detention basins shall be designed to release the extended detention volume in no less than 24 hours. Regardless of the design drawdown time, the outlet shall be designed according to the following criteria:

1) The principal spillway for flows in excess of the WQ_v shall be designed according to criteria in Section 3.2 and equipped with a removable trash rack.

2) Extended detention basins that are intended to serve as a water quality BMP only, must be designed to safely bypass all storms up to and including the 100-year storm event to an appropriately sized flood control facility.

3) City-approved orifices (smaller than 4 inches in diameter) shall be adequately protected from clogging by an acceptable external trash rack or hood.

4) The use of a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation of the permanent pool is a recommended method to reduce clogging of the WQ_v discharge pipe.

3.3.4.3 Stormwater Wetlands

Similar in design to wet basins, constructed wetlands treat stormwater by providing an extended detention zone (above shallow permanent pools) sized to capture and release the calculated WQ_v over a minimum time of 24 hours. Stormwater wetlands, illustrated in **Figure 3-6**, are depressed, heavily planted areas that are designed to maintain flow during dry periods in order to support aquatic vegetation. The amount of surface area required for a stormwater wetland is typically larger than that of a wet basin due to the limited allowable depths required for wetland design. The following criteria shall apply to the design of stormwater wetlands.

General Criteria
All stormwater wetlands shall be designed according to the following criteria:

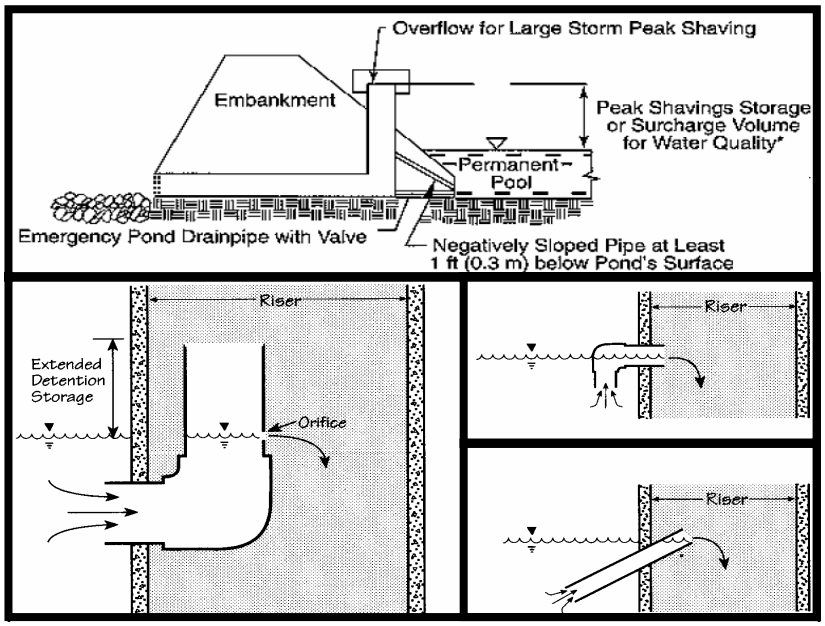
1) The general criteria for stormwater controls in Section 3.1,

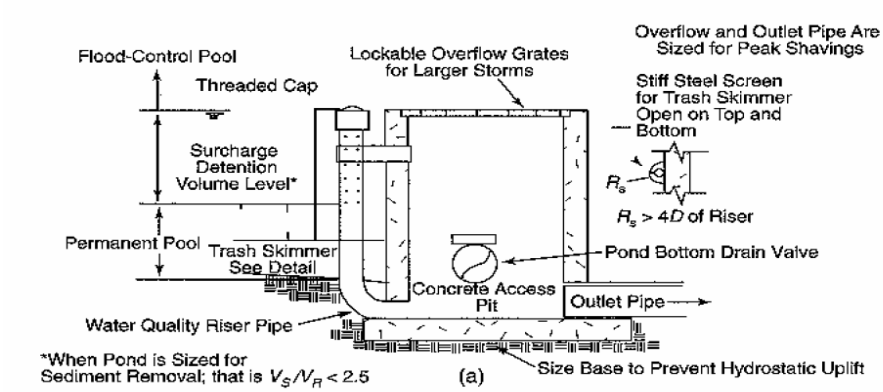
2) The general criteria for stormwater detention basins in Section 3.2.4.1,

3) The criteria for wet stormwater quantity control detention basins in Section 3.2.4.3,

4) Owners of wetland systems must agree to provide a mosquito monitoring and control plan within the maintenance plan for the BMP, and

5) Specific criteria in this section.





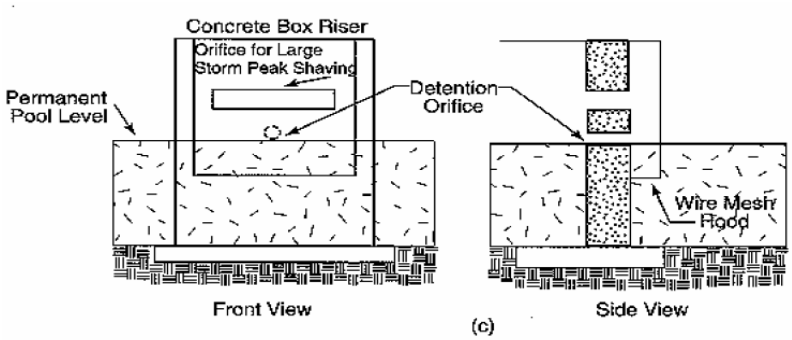


Figure 3-5. Accepted Outlet Designs for Extended Wet Detention Basins and Micropools within Extended Dry Detention Basins

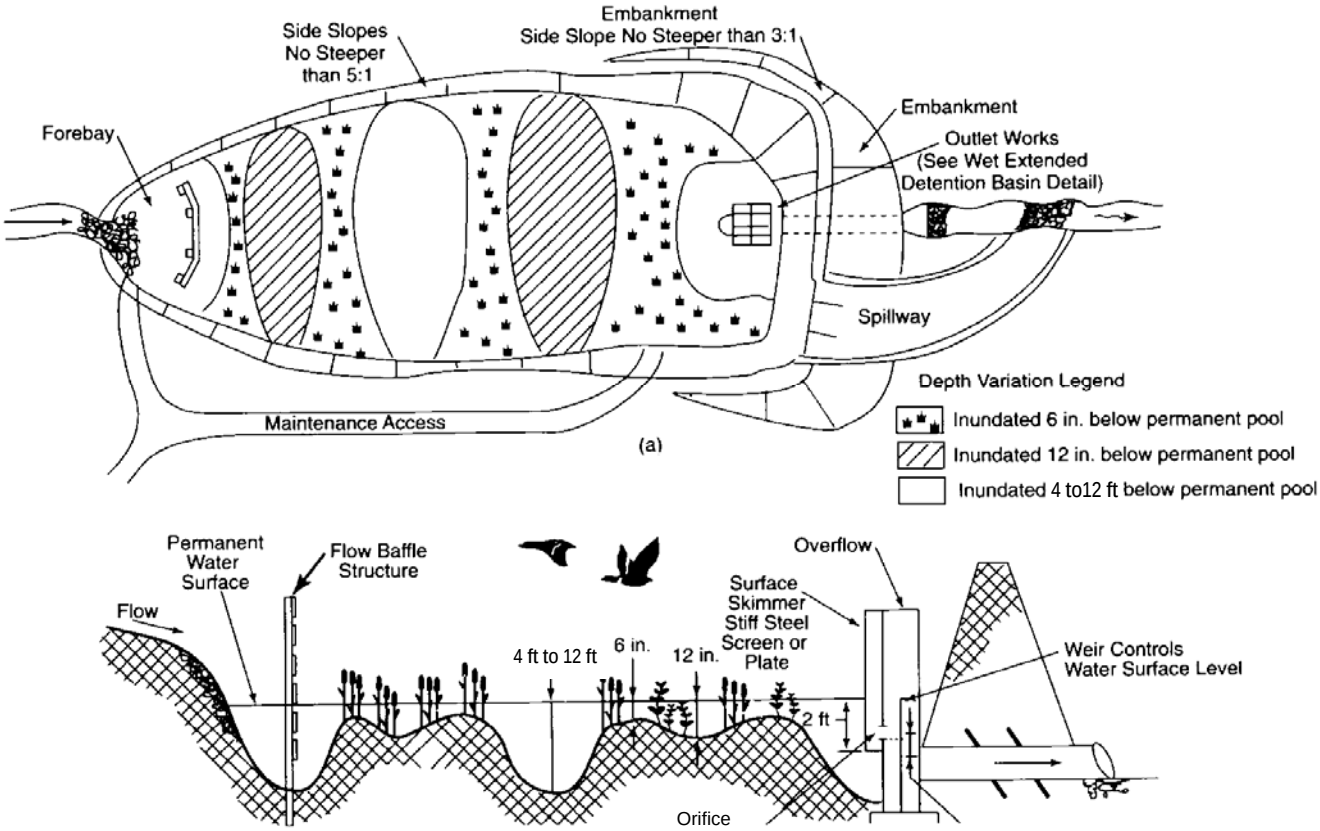


Figure 3-6 Schematic of a Typical Stormwater Wetland

Layout and Geometry Requirements

The layout and geometric requirements of stormwater wetlands shall meet the following minimum requirements:

1) The recommended minimum drainage area of 20 acres is proposed to avoid wetlands where the permanent pool completely evaporates during dry weather conditions. Alternative facilities specified in the Manual are generally preferred for drainage areas smaller than 20 acres.

2) Constructed wetlands shall only be allowed where soils categorized by the NRCS as HSG-C or HSG-D exist, where gravelly sands or fractured bedrock are not present, or where a liner is installed to sustain the permanent pool of water and avoid permanent pools that partially or completely infiltrate into the ground.

3) The permanent pool of any proposed stormwater wetland shall be at least two times the volume of evapotranspiration during a thirty day drought at summer evaporation rates or 0.75WQv, whichever is greater. In cases where subsurface infiltration into and exfiltration out of the wetland are negligible, the summer evapotranspiration rates may be estimated[12]

[12] Kadlec, Robert and Robert Knight, *Treatment Wetlands,* CRC Lewis Publishers, 1996, pp. 184-185.

as 0.75 times the pan evaporation rate of 0.2 inches/day reported for Columbus during June, July and August[13]. More rigorous water balance calculations may be required by the City where these simplifying assumptions are not valid and/or in all cases where the drainage area to the wetland is less than 20 acres. **Appendix D** provides an example water balance calculation.

4) An extended detention volume equal to the WQ_v shall be provided above the permanent pool of the stormwater wetland. The outlet structure of the stormwater wetland shall be designed to release the entire extended detention volume in no less than 24 hours.

5) The minimum length-to-width ratio for a constructed wetland shall be 2:1. Where site conditions allow, basins should be wedge-shaped, narrowest at the inlet and widest at the outlet, to achieve the required length-to-width ratio. Where site conditions do not allow this configuration, the length-to-width ratio shall be increased by relocating the basin inlet or outlet where possible, or by installing berms or baffles within the basin to the full depth of the WQ_v to avoid short-circuiting and to increase travel time to the outlet.

6) Stormwater wetlands shall be provided with a drain so that the facility can be emptied to allow maintenance activities and to dry bottom sediments (allowing natural oxidation of built-up organics). The drain shall be designed in accordance with the emergency drain systems required for detention basins as described in Section 3.2.4.1.

7) Approximately 50 percent of the permanent pool volume defined in item 3, plus a sediment storage volume equal to at least 20 percent of the WQ_v, shall be placed in deep water zones (areas with depths between 4- and 12-feet) to sustain fish communities and provide wave action to control mosquito populations. At a minimum, deep water zones shall be placed within the forebay and around the primary outlet to minimize disruption of wetland vegetation during sediment removal operations.

8) The remainder of the facility shall consist of shallow water zones. Dry weather depths in shallow water zones (i.e., areas less than 18 inches deep) should vary depending on the vegetation selected. Permanent pool depths shall be 6 inches or less within at least 35 percent of the shallow water zone.

9) The bottom of the permanent pool between the deep and shallow water zones shall be sloped no steeper than 4 (H) to 1 (V).

10) The maximum depth of the extended detention zone above the permanent pool shall not exceed 2 feet to reduce stress on herbaceous wetland plants.

11) Permanent pool areas of wetlands that are deeper than 4 feet be provided with an aquatic bench per Section 3.2.4.3.

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[13] National Oceanographic and Atmospheric Administration, Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States, NOAA Technical Report NWS 34, Washington DC, 1982.

12) Wetland plants shall be placed along the aquatic bench and other shallow pool areas (less than 4 feet). In instances where the basin is designed to support aquatic vegetation, a landscaping plan for the wetland shall be prepared to indicate how aquatic and terrestrial areas will be established with vegetation. Woody vegetation may not be planted or allowed to grow on the embankment within 15 feet of the toe of the embankment, and within 25 feet from the principal spillway structure. The establishment of woody vegetation in other areas around the wetland facility is encouraged to provide shade and moderate surface water temperatures. A list of recommended Native Plant Species for Central Ohio is provided in Appendix B.

Pretreatment

Due to the sensitivity of wetland vegetation to sedimentation, a forebay, or other pretreatment feature, shall be provided at the inlets of all stormwater wetlands that are to be either publicly or privately owned. Wetland forebays shall be three feet to six feet in depth and shall meet the following minimum requirements:

1) Wetland forebays shall be sized to provide at least 10 percent of the WQ_v . The storage volume provided within the forebay will count toward the total WQ_v requirement.

2) The forebay shall consist of a separate cell, formed by an acceptable barrier such as a rock weir.

3) Direct maintenance access shall be provided to the forebay at a slope no steeper than 10 (H) to 1 (V).

4) Forebay side-slopes shall not exceed 4:1.

5) To make sediment removal easier, the bottom and side slopes of the forebay shall be lined with Class C concrete (per CMSC Section 499) having a minimum thickness of 6 inches. The concrete shall be reinforced with steel mesh (per CMSC Section 509) to accommodate temperature stresses. These criteria apply to forebays that are to be publicly maintained, and are recommended for forebays that are to be privately owned and operated.

6) A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time.

7) Forebays of basins that are privately owned and operated may be constructed upon the City's approval with alternative bottom material, provided that an access point of sufficiently compacted material is available to support equipment necessary to perform the routine maintenance for cleaning the structure.

Landscape Requirements

1) A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of landscaping zones, selection of appropriate plant species, planting plan, sequence for preparing the wetland bed (including soil amendments, if needed), and sources of plant

material. The width of the vegetation zones and amount of emergent vegetation shall be limited to no more than 50 percent of the wetland area in order to control mosquitoes.

2) If a minimum vegetative coverage of 50 percent is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.

3) All landscaping and reinforcement plans shall be signed by a registered engineer or registered landscape architect, with direction provided by an experienced wetland scientist.

Outlet Facility and Outfall Protection Requirements
The outlet design requirements provided in Section 3.3.4.2 for extended wet detention basins shall apply to stormwater wetlands. In addition, the outlet structure shall be designed to conduct continuous dry weather flow through the wetland system while maintaining normal pool elevations.

3.3.5 Group 2 – Media Filters

Media filters remove pollutants by passing stormwater through a bed of sand, soil peat, or other media that filters particulate matter and/or absorbs the trapped pollutants. Two types of media filters are allowed by the City:

1) Bioretention Facility

2) Sand Filter

Media filter shall only be permitted where a private entity will assume maintenance responsibility.

3.3.5.1 Bioretention Facilities

A bioretention system consists of a soil bed planted with native vegetation located above an underdrained gravel layer. Stormwater runoff entering the bioretention system is filtered first through the vegetation and then the soil bed before being conveyed downstream through the underdrain system, slowing the runoff velocity and treating stormwater runoff by absorption, decomposition, and filtration[14]. Bioretention facilities are often sited adjacent to and used to treat runoff from paved surfaces such as parking lots. Sites utilizing bioretention facilities for water quality control must also meet the stormwater quantity control requirements of Section 3.2. Stormwater quantity controls may either be integrated into the bioretention system or provided in a separate downstream facility. A schematic of a bioretention facility is shown in **Figure 3-7.**

[14] New Jersey Department of Environmental Protection, *New Jersey Stormwater Best Management Practices Manual*, Chapter 9.1 Standard for Bioretention Systems, 2004

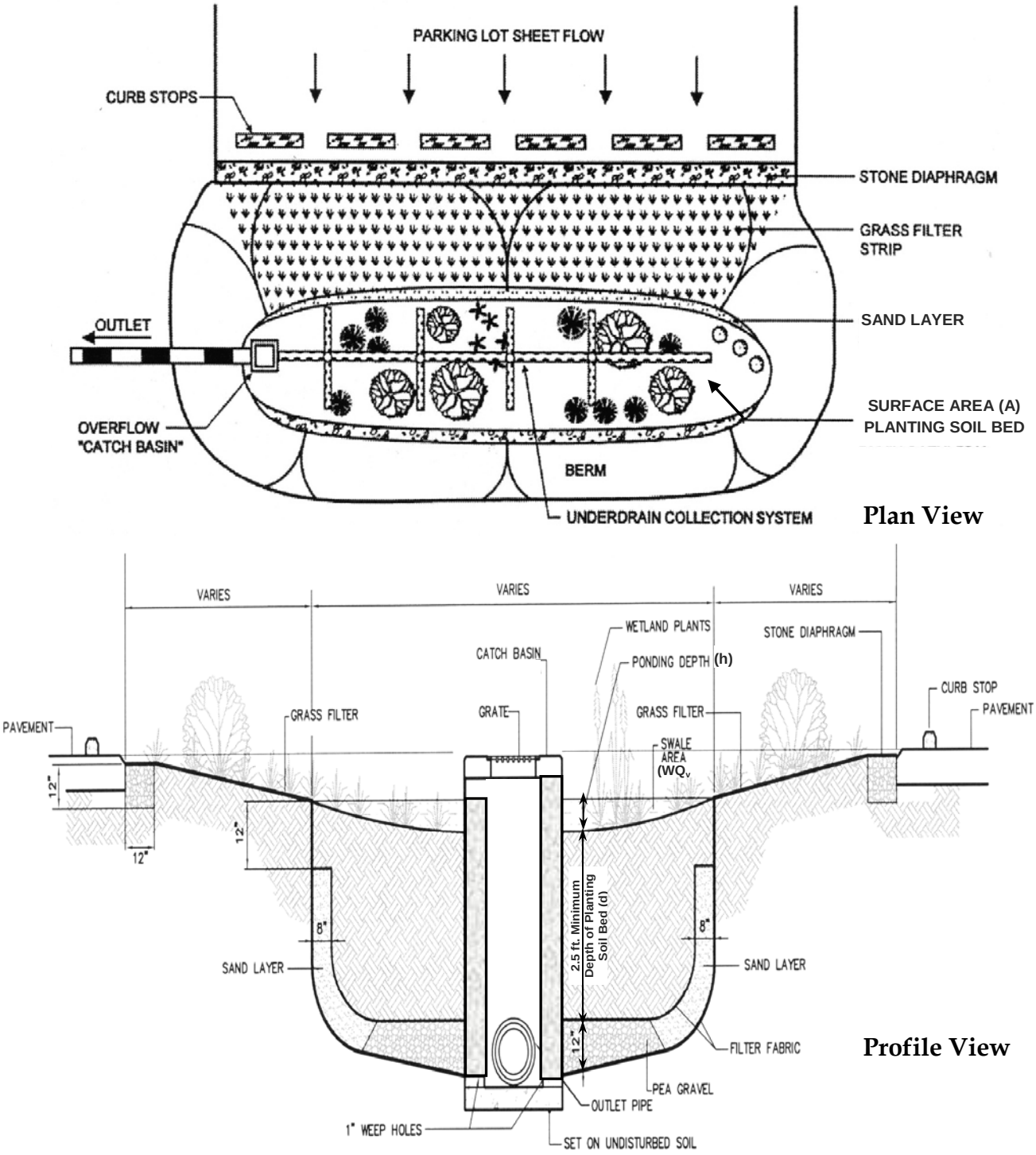

Figure 3-7. Schematic of a Typical Bioretention Facility

Hydrology Requirements

Bioretention facilities shall be designed to capture and store the WQ_v prior to filtration and shall provide a filtration time of no less than 24 hours (when the filter media is new) and no more than 40 hours (when the filter media is clogged and requires maintenance). A drawdown time of 40 hours shall be used for facility design. The following criteria shall apply to the design of bioretention facilities.

Layout and Geometry Requirements

1) The recommended maximum total drainage area of a bioretention facility is 5 acres, with drainage areas of one acre or less preferred in order to maximize sheet flow into the facility and to minimize ponding depth.

2) Bioretention systems may be constructed on-line or off-line. On-line systems receive runoff from all storms, providing treatment of the WQ_v, with runoff from larger storms conveyed and/or stored within the bioretention system and discharged through an overflow. In off-line bioretention systems, most of the runoff from storms larger than the WQ_v bypasses the system through an upstream diversion and is directed toward a stormwater quantity control device designed according to criteria in Section 3.2.

3) Bioretention facilities shall not be allowed in areas where the water table or bedrock is above the invert of the underdrain system.

4) In order to maximize treatment effectiveness, the site must be graded in such a way that minimizes erosion as sheet flow is conveyed to the treatment area.

5) Runoff from the tributary area of the bioretention facility shall be directed into a swale or other storage area sized to contain the entire WQ_v. This swale shall partially or completely overlay the bioretention facility, as long as the maximum depth of water over the filtering media is no more than 12 inches. Water shall not cover the media longer than 72 hours after a precipitation event.

6) The surface area of the bioretention soil bed shall be determined based on the following equation:

$$A = (WQ_v \cdot d)/[3600 \cdot K \cdot T \cdot (h + d)]$$

where:

A = surface area of the bioretention planting soil bed (acre)
WQ_v = water quality volume (acre-ft)
d = depth of the planting soil bed (ft)
T = drawdown time (hours)
= 40 hours
K = permeability of the planting soil within the soil bed (feet/sec)
= 1.2×10^{-5} feet/sec (minimum), which is equivalent to 0.5 inches/hr
h = average depth of water above filter bed (ft)
= half the maximum depth of water (maximum depth = 12 inches)

7) The minimum dimensions of the bioretention facility shall be 15 feet wide by 40 feet long, with facility widths of 25 feet preferred. These width criteria are established to allow enough space for a dense, randomly-distributed area of trees and shrubs to become established, enabling the bioretention area to tolerate the effects of heat stress, acid rain, runoff pollutants, and insect and disease infestations.

8) The side slopes for bioretention facilities shall not exceed 4 (H) to 1 (V).

Planting Soil (Filter Media) Requirements
The function of a bioretention facility is largely dependent on the characteristics of the planting soil (filter media) through which the runoff passes. The following criteria shall be used:

1) The planting soil for bioretention facilities shall consist of a mixture of sand, topsoil, and compost with a pH range of 5.5 and 6.5, a range where pollutants such as organic nitrogen and phosphorus can be adsorbed by the soil and microbial activity can flourish. In addition, the soil shall have infiltration rates no less than 0.5 inches per hour, achieved through the following standards[15]:

   a. 4 parts sand (per CMSC 703.06),

   b. 2 parts topsoil (per CMSC 653.02), and

   c. 2 parts compost (per ODOT CMSC 659.06). Note: Com-Til Compost from DOSD's Compost Facility is acceptable for use in bioretention facilities.

   Additional recommendations for the planting soil include a 1.5 to 3 percent organic content and a maximum 500 ppm concentration of soluble salts[16].

2) If the existing soil does not meet the above characteristics, then it shall either be adjusted to meet the criteria or removed and replaced with an acceptable planting soil. Soil tests shall be performed for every 500 cubic yards of planting soil, with the exception of pH and organic content tests, which are required only once per bioretention area.

3) To prevent root intrusion into the underdrain system, the depth of the planting soil shall be no shallower than the root zone of the vegetation planted in the bioretention cell. The minimum depth shall be 2.5 feet. In addition, the depth shall be at least 4 inches below the largest root ball.

4) Planting soil depths of greater than 4 feet may require additional construction practices such as shoring measures. Planting soil shall be placed in 18 inches or greater lifts and lightly compacted until the desired depth is reached.

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[15] ODOT, "Location and Design Manual, Volume 2, Drainage Design", Section 1116.7
[16] California BMP Handbook (Section 5-7, TC-32)

5) An 8-inch thick sand layer shall be placed along the sides of the trench, starting 12 inches below the final grade level and extending to the gravel layer in the bottom of the trench. The sand shall comply with CMSC 703.06, and shall be surrounded with a filter fabric.

6) Bioretention facilities shall be planted with a mixture of grass and other hardy, vegetation that can withstand prolonged periods in a wet environment, and be tolerant to road salts if receiving runoff from areas to be treated with deicing materials. Vegetation shall be selected from the list of Native Plant Species for Central Ohio is provided in Appendix B. Vegetation may include a mix of grasses and woody species, or may include woody species only with bare ground covered with mulch. Approximately one tree or shrub per 50 ft^2 (or 1000 per acre) of bioretention area should be included. It is recommended that three species each of both trees and shrubs are planted. Trees with high branching or open habits of growth are recommended to avoid shading and loss of grass cover. Since high canopy trees may be destroyed during maintenance the bioretention area should be vegetated to resemble a terrestrial forest community ecosystem that is dominated by understory trees. The shrub-to-tree ratio shall be 2:1 to 3:1.

7) A mulching layer 2 to 3 inches thick shall be provided above the planting soil when grass is not used, and shall be composed of shredded hardwood material to avoid floating. Mulch plays an important role in the bioretention facility. It helps maintain soil moisture, prevents erosion and helps to trap finer sediments.

Underdrain and Outlet Requirements

1) A perforated pipe underdrain shall be provided beneath the planting soil. The underdrain shall have a minimum grade of 0.5 percent. The perforated pipe shall have a diameter of 4 or 6 inches and shall meet the requirements of CMSC Section 720.07 or 720.12. A granular backfill of durable No. 57 aggregate, in accordance with CMSC Section 703.01, shall be provided up to a minimum of 4 inches above the outside diameter of the pipe.

2) An overflow designed to convey all storms up to and including the 100-year event shall be provided. Use of a vertical stand pipe or catch basin is recommended. For on-line facilities, this overflow may be designed to achieve the water quantity control criteria specified in Section 3.2.

Pretreatment

Flow entering the bioretention facility shall be limited to sheet flow to prevent eroding the side slopes of the facility. If flow has been concentrated prior to entering the bioretention facility, it shall be converted to sheet flow using a level spreader designed according to criteria in Section 2.3.6. In addition, the frequency of maintenance for bioretention facilities may be reduced by providing vegetated swales or filter strips around the facility. The purpose of the filter strip is to trap course sediments before they reach filter media, thereby reducing maintenance and increasing media longevity. Vegetated swales and filter strips can also be used as holding areas for the WQ_v prior to filtration. The design of vegetative swales and filter strips is presented in Section 3.3.6.

3.3.5.2 Sand Filters

Stormwater sand filters are usually two-chambered facilities that include a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering media in the second chamber. The two most common examples of sand filters used in the United States are the Austin sand filter[17] (**Figure 3-8**) and the Delaware sand filter[18] (**Figure 3-9**). The Austin sand filtration system is built at grade and is most commonly used for larger drainage areas that have both impervious and pervious surfaces. Delaware sand filter systems are installed underground, and thus are most commonly used for highly impervious areas where land available for structural controls is limited.

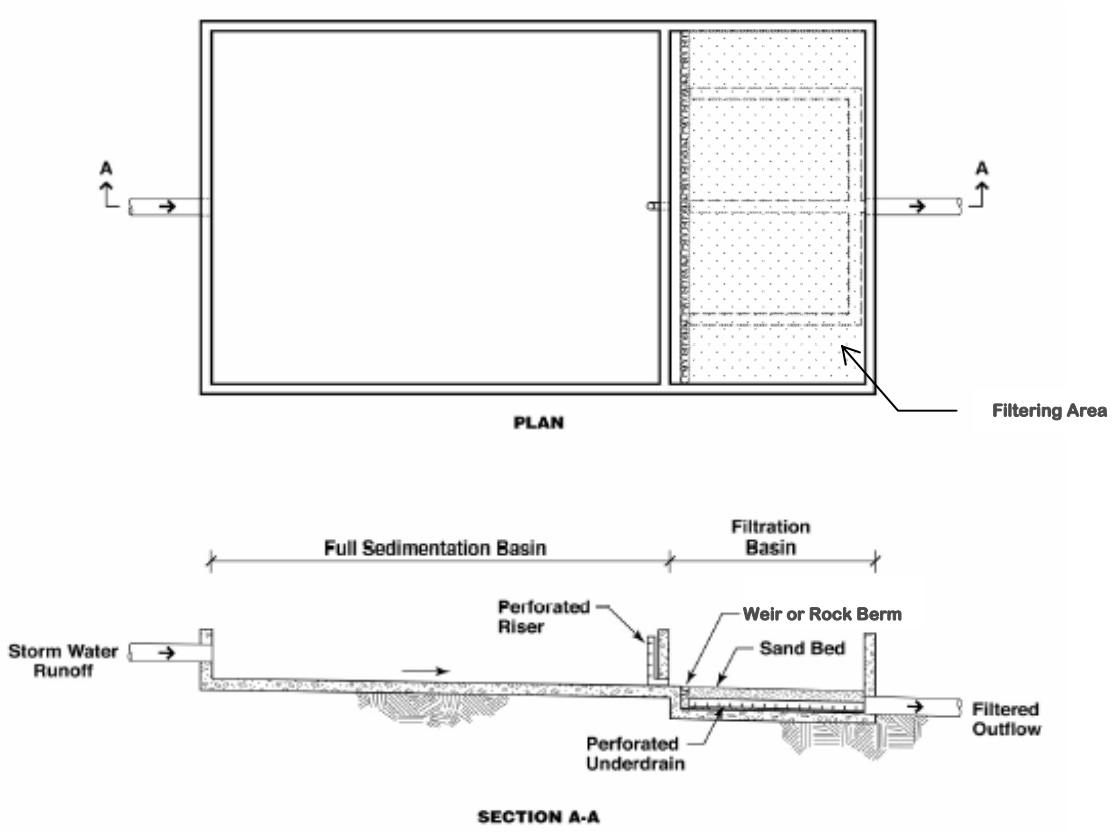

Figure 3-8. Schematic Representation of an Austin Sand Filter

[17] City of Austin, TX. "Design of Water Quality Controls". 1996.
[18] Young, G.K., et al., "Evaluation and Management of Highway Runoff Water Quality", Publication No. FHWA-PD-96-032, U.S. Department of Transportation, Federal Highway Administration, Office of Environment and Planning, 1996.

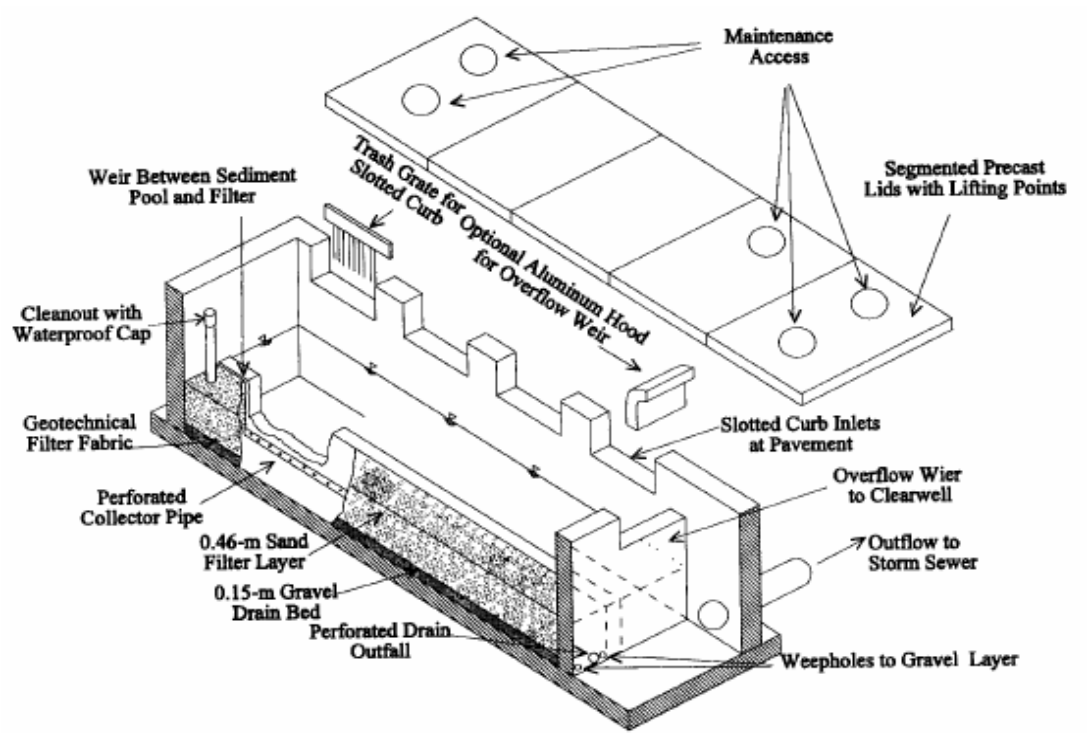

Figure 3-9. Schematic Representation of a Delaware Sand Filter

Hydrology Requirements

Sand filters shall be designed to capture and store the WQ_v prior to filtration and shall provide a filtration time of no less than 24 hours (when the filter media is new), and no more than 40 hours (when the filter media is clogged and requires maintenance). A drawdown time of 40 hours shall be used for facility design.

Layout and Geometry Requirements

1) The recommended maximum total drainage area of a Delaware sand filter is 1 acre, and the recommended maximum total drainage area of an Austin sand filter is 5 acres.

2) Sand filters require a significant amount of hydraulic head (about 4 feet), to allow flow through the system.

3) Sand filters shall be constructed with impermeable basin or chamber bottoms, which help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between contaminated runoff and groundwater.

4) A maintenance ramp shall be included in the design to facilitate access to the sedimentation and filter basins for maintenance activities (particularly for the Austin design).

5) Designs that utilize covered sedimentation and filtration basins must be accessible to vector control personnel via air-tight access doors to facilitate vector surveillance and control of the basins if needed.

Filter Media Requirements

1) The filter bed shall be sized to discharge the capture volume over a period of 40 hours using Darcy's Law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium[19]. The resulting equation, as derived by the City of Austin, Texas, (1996), is:

$$A_f = WQ_V\ d/[k\ t\ (h+d)]$$

where:

A_f = area of the filter bed (ft^2)
d = depth of the filter bed (feet)
= 1.5 feet
k = coefficient of permeability of the filtering medium (ft/day)
= 3.5 ft/day for sand satisfying CMSC 703.02(A)
t = time for the WQ_v to filter through the system (days)
= 1.67 days),
h = average water height above the sand bed (feet)
= one-half of the maximum head.

2) The sand filter shall be constructed with 18 inches of sand (CMSC 703.02(A)) overlying 6 inches of gravel (CMSC 703.04(A)). The sand and gravel media shall be separated by permeable geotextile fabric (CMSC 712.09, Type A), and the gravel layer shall be placed on geotextile fabric. Four-inch perforated PVC pipe (CMSC 720.07) shall be used to drain captured flows from the gravel layer. A minimum of 2 inches of gravel must cover the top surface of the PVC pipe. **Figure 3-10** presents a schematic representation of a standard sand bed profile.

3) The sand grain size distribution shall be comparable to that of "washed concrete sand," as specified for fine aggregate in CMSC 703.02(A).

Underdrain and Outlet Requirements

1) In an Austin filter, the underdrain piping shall consist of a main collector pipe and two or more lateral branch pipes, each with a minimum diameter of 4 inches. The pipes shall have a minimum slope of 1% (1/8 inch per foot) and the laterals shall be spaced at intervals of no more than 10 feet. There shall be no fewer than two lateral branch pipes.

2) All piping shall be Schedule 40 PVC per CMSC 720.07.

3) The maximum spacing between rows of perforations shall not exceed 6 inches.

4) Each individual underdrain pipe shall have a cleanout access location.

[19] City of Austin, TX. "Design of Water Quality Controls". 1996.

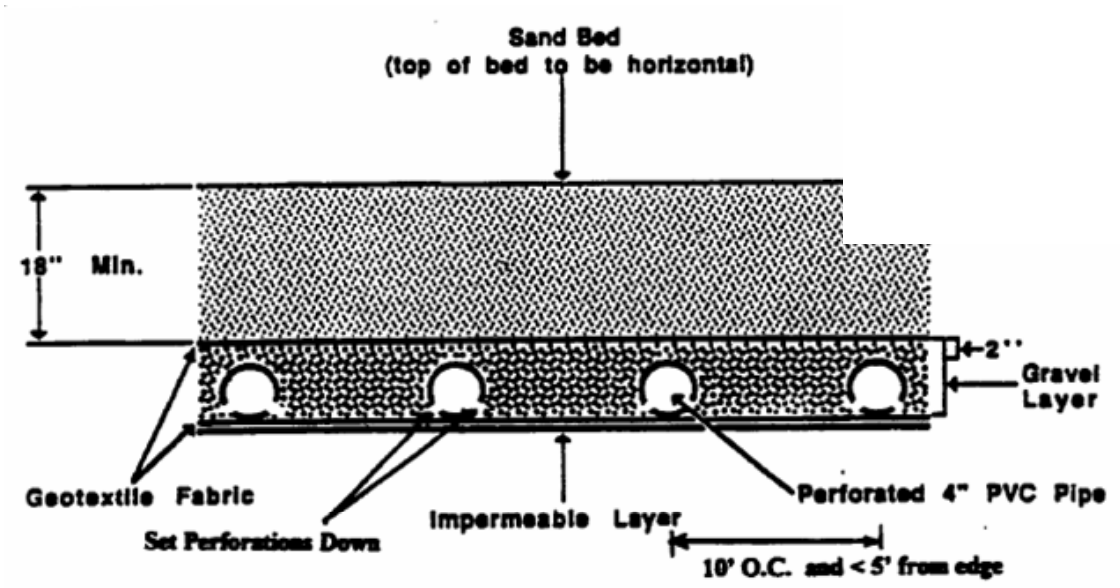

Figure 3-10. Sand Bed Profile with Gravel Filter

Pretreatment

1) A sedimentation basin shall pretreat runoff before entering the sand filter. The sedimentation basin shall be designed to capture the entire WQ_v and discharge it over 40 hours.

2) The water depth in the sedimentation basin when full should be at least 2 feet and no greater than 10 feet.

3) A fixed vertical sediment depth marker should be installed in the sedimentation basin to indicate when 20% of the basin volume has been lost because of sediment accumulation.

4) The inflow structure to the sedimentation chamber shall incorporate a flow-splitting device capable of isolating the capture volume and bypassing the peak flow of larger storms around the facility when the sedimentation/filtration basin is full.

5) Energy dissipation is required at the sedimentation basin inlet. Flows entering the basin shall be distributed uniformly and at maximum allowable velocities of 2 ft/sec in order to prevent re-suspension and encourage calm conditions necessary for deposition of solids.

6) The outflow structure from the sedimentation chamber shall be either a weir or a riser pipe through a concrete wall. Any weirs shall extend across the full width of the facility such that no short-circuiting of flows can occur.

7) The receiving end of the sand filter shall be protected (splash pad, riprap, etc.) such that erosion of the sand media does not occur and flow is spread across the entire filter bed.

8) If a riser pipe is used to connect the sedimentation and filtration basins (example[20] in **Figure 3-11**), a valve shall be included to isolate the sedimentation basin in case of a hazardous material spill in the watershed. The control for the valve must be accessible at all times, including when the basin is full. The riser pipe shall have a minimum diameter of 6 inches with four 1-inch perforations per row. The vertical spacing between rows should be 4 inches (on centers).

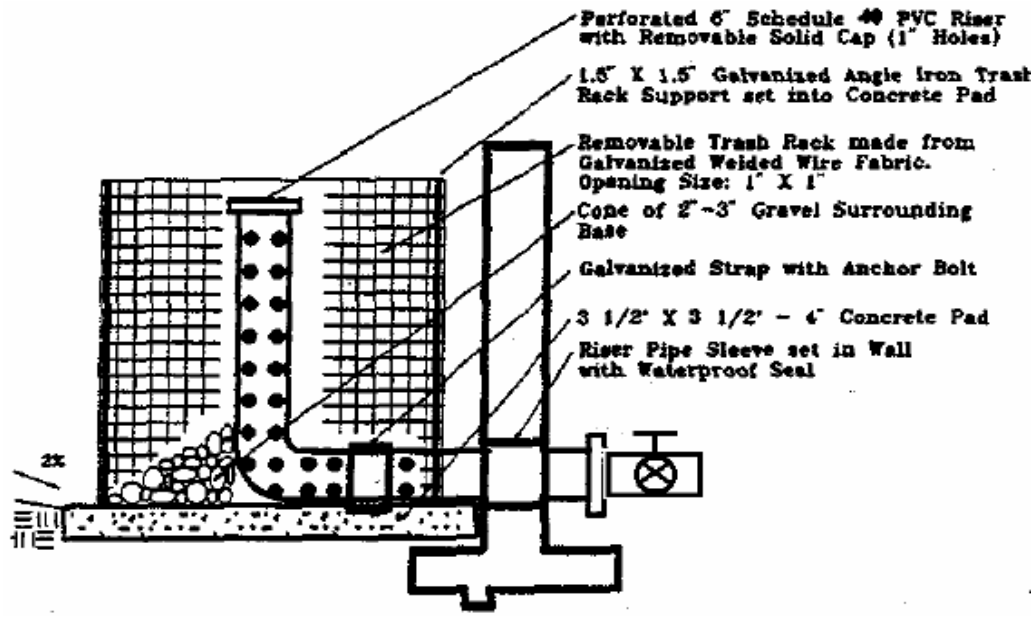

Figure 3-11. Schematic Representation of a Perforated Riser for Discharging the Sedimentation Basin into the Sand Filter

3.3.6 Group 3 – Swales and Filter Strips

Swales are shallow, mildly sloped trapezoidal channels, and filter strips are sloped surfaces with a relatively mild longitudinal slope. The surface of both are typically composed of dense turf grass, and are effective at reducing runoff peaks and removing pollutants. They are designed to convey and/or store the water quality volume (WQ_v) at shallow depths, preferably as sheet flow, with peak depths significantly less than the height of the grass. Under these conditions, vegetated swales, vegetated filter strips, and dry extended detention swales allow opportunities for infiltration and trapping of solids in the vegetation. Criteria in Ohio EPA's Construction General Permit limit use of vegetated swales and vegetated filter strips to projects that disturb less than 5 acres. Dry extended detention swales may be used for projects of any size.

[20] California Stormwater Quality Association, "California Stormwater BMP Handbook – New Development and Redevelopment", TC-40, 2003.

3.3.6.1 Vegetated Swales [21]

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. **Figure 3-12** shows a schematic diagram[22] of a typical vegetated filter strip and swale.

Hydrology Requirements

Vegetated swales are designed to treat the entire WQ_v from the tributary area. Since treatment occurs as stormwater "flows through" the swale, it is necessary to develop a design peak flow for the WQ_v representative of flow conditions that maximize treatment and retard flow. The following procedure shall be used to develop the design peak flow:

1) Determine the time of concentration for the area draining into the swale, using the methodology in Section 2.2.2.2.

2) Define the peak intensity of the design storm producing the WQ_v using the intensity-duration-frequency curve for Central Ohio (Figure 2-1). For example, a basin with a time of concentration of 10 minutes would have a peak rainfall intensity of approximately 1.5 inches/hour.

3) Use the rational method (Section 2.2.3.1) and the runoff coefficients in Table 3-3 to determine the peak flow through the swale.

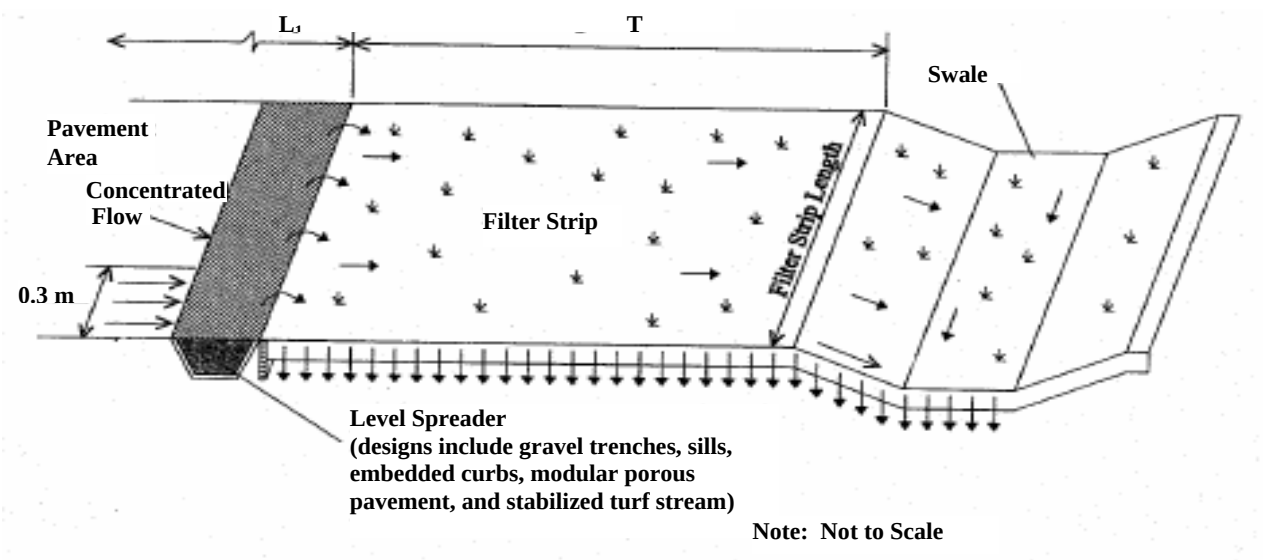

Figure 3-12. Typical Vegetated Swale and Vegetated Filter Strip

[21] California Stormwater Quality Association, "California Stormwater BMP Handbooks, New Development and Redevelopment Handbook", TC-30, January 2003.

[22] California Stormwater Quality Association, "California Stormwater BMP Handbook – New Development and Redevelopment", TC-30, 2003.

Appendix D provides an example of how to calculate a peak flow for designing vegetated swales.

Layout and Geometry Requirements
The topography of the site shall be used or re-graded as needed to design a channel with appropriate slope and cross-sectional area. Site topography may also dictate a need for additional structural controls.

1) Swales are generally recommended for drainage areas less than 5 acres, with a total drainage area of 1 to 2 acres preferred.

2) Trapezoidal channels are normally recommended, but other configurations, such as parabolic, can also provide substantial water quality improvement and may be easier to mow than designs with sharp breaks in slope.

3) If the design peak for the WQ_v calculated per the requirements of Section 3.3.6.1 is larger than 1 cfs, then more than one swale shall be provided in order to maintain sheet flow and shallow flow depths within the swale. Flow shall be distributed among the swales to keep peak flows during the WQ_v design event less than 1 cfs in each.

4) Use Manning's Equation to design the swale under peak WQ_v design storm conditions, using criteria within this section to establish design limits for the swale.

5) The swale shall be designed so that the water level does not exceed 3 inches at the design peak flow for the WQ_v.

6) It is recommended that longitudinal slopes along the swale shall not exceed 2.5 percent, and shall be milder if necessary to keep the peak velocity within the swale less than 0.9 feet/second. However, longitudinal slopes may range between 2 and 6 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

7) The width of the swale should be determined using Manning's Equation, at the peak flow during the water quality design storm, using a Manning's "n" of 0.25. The maximum bottom width shall not exceed 10 feet unless a dividing berm is provided.

8) The swale shall have a length that provides a minimum hydraulic residence time, or the time it takes for the water to pass through the swale, of at least ten minutes. Regardless of the hydraulic residence time, the length of the swale shall not be less than 100 feet.

9) Swales may be designed to safely convey storms generating more than the WQv according to criteria provided in Section 2.3.7. The peak velocity of the 10-year design storm through the swale shall be non-erosive for the soil and vegetative cover provided (See

Table 2-17 for maximum allowable velocities). Three inches of freeboard should be provided.

10) The side slopes of the swale shall be no steeper than 4 (H) to 1 (V).

Vegetation Requirements
Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses, per CMSC Section 659 on seeding and mulching and CMSC Section 653 on topsoil. Where possible, one or more of these grass seeds shall be in the seed mixes specified by CMSC. If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

The surface shall be graded flat prior to placement of vegetation. Initial establishment of vegetation shall receive attentive care, including appropriate watering, fertilization, and prevention of excessive flow, until vegetation completely covers the area and is well established. Use of a permanent irrigation system to keep the vegetation alive and healthy during droughts may help provide maximal water quality performance.

Pretreatment Requirements
Runoff shall enter swales as sheet flow. Use of a level spreading device (vegetated berm, sawtooth concrete border, rock trench, etc.) designed according to criteria in Section 2.3.6 to facilitate overland sheet flow may be allowed by the Division of Sewerage and Drainage, but is not normally recommended because of maintenance considerations and the potential for standing water.

3.3.6.2 Vegetated Filter Strips [23]

Grassed filter strips are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. In addition, the public views them as landscaped amenities and not as stormwater infrastructure.

Filter strips consume a large amount of space relative to other BMPs. They are best suited to treating runoff from roads and highways, roof downspouts, small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of the Stream Corridor Protection Zone, or as pretreatment to a structural practice. Filter strips are generally impractical in ultra-urban areas where little pervious surface exists.

[23] California Stormwater Quality Association, "California Stormwater BMP Handbooks, New Development and Redevelopment Handbook", TC-31, January 2003.

Hydrology Requirements
Vegetated filter strips are designed to treat the entire WQ_v from the tributary area. Since treatment occurs as stormwater "flows through" the filter strip, it is necessary to develop a design peak flow for the WQ_v representative of flow conditions that maximize treatment and retard flow. The following procedure shall be used to develop the design peak flow.

1) Determine the time of concentration for the area draining into the filter strip, using the methodology in Section 2.2.2.2.

2) Define the peak intensity of the design storm producing the WQ_v using the intensity-duration-frequency curve for Central Ohio (Figure 2-1). For example, a basin with a time of concentration of ten minutes would have a peak rainfall intensity of approximately 1.5 inches/hour.

3) Use the rational method (Section 2.2.3.1) and the runoff coefficients in Table 3-3 to determine the peak flow through the swale or filter strip.

Appendix D provides an example peak flow calculation for designing vegetated swales.

Layout and Geometry Requirements
Filter strips shall be gently sloping areas between 1 and 15 percent with a robust and diffuse vegetative cover. Concentrated flow shall not be allowed to occur along filter strips, as it causes erosion that effectively eliminates water quality benefits.

1) Filter strips are generally recommended for drainage areas less than 5 acres , with a total drainage area of 1 to 2 acres preferred.

2) Use Manning's Equation to design the filter strip under peak WQ_v design storm conditions, using criteria within this section to establish design limits for the strip. A wide channel assumption shall be used for determining cross-sectional parameters of the filter strip.

3) Only sheet flow shall be allowed to enter the filter strip. The maximum length "L_1" of the overland flow path (see Figure 3-12) shall be no longer than 100 ft to prevent flow from concentrating, unless a level spreader is used to convert concentrated flow to sheet flow prior to entering the filter strip.

4) The filter strip shall be designed so that the water level does not exceed 1 inch at the design peak flow for the WQ_v.

5) Runoff flow velocities shall not exceed 1 foot/second across the filter strip.

6) The vegetative surface shall extend across the full width of the filter strip area. The upstream boundary of the filter strip shall be located contiguous to the developed area.

7) Maximum length "T" on Figure 3-12, measured in the direction of flow shall comply with the criteria for determining the maximum length of sheet flow provided in Section 2.2.2.2.

8) Minimum length of the filter strip (in the direction of flow) shall be 15 feet.

9) The width of the filter strip shall be the same as the tributary area (i.e., no concentration of flow from the contributing area is allowed).

10) Both the top and toe of the slope shall be as flat as possible to encourage sheet flow and prevent erosion. The top of the filter strip shall be installed 2 to 5 inches below the adjacent pavement, so that vegetation and sediment accumulation at the edge of the strip does not prevent runoff from entering.

11) Filter strips shall be designed to drain between storms and not allow pollutants to migrate into the groundwater. To satisfy this requirement, filter strips may only be installed in areas where the seasonal groundwater level is at least 2 feet below the filter strip, based on the Franklin County Soil Survey or a soils report prepared to support project design.

Vegetation Requirements
The vegetation requirements for filter strips shall be identical to those provided for vegetated swales in Section 3.3.6.2.

Pretreatment Requirements
Runoff shall enter filter strips as sheet flow. Use of a level spreading device (vegetated berm, sawtooth concrete border, rock trench, etc.), designed according to criteria in Section 2.3.6 to facilitate overland sheet flow, may be allowed by the Division of Sewerage and Drainage, but is not normally recommended because of maintenance considerations and the potential for standing water.

3.3.6.3 Dry Extended Detention Swales

Dry extended detention swales incorporate a combination of dry cells formed by check dams or other means and filtering media to treat stormwater runoff by settling, absorption, decomposition, and filtration. The practical applications for dry extended detention swales are low density residential projects or for very small impervious areas. Sites utilizing dry extended detention swales for water quality control may incorporate additional storage and outlet structures to meet the stormwater quantity control requirements of Section 3.2. A schematic of a dry extended detention swale is shown in **Figure 3-13.**

Hydrology Requirements
Dry extended detention swales shall be designed to capture and store the entire WQ_v and release it in no less than 24 hours and no longer than 40 hours. Water retained within the swale may be released through an outlet at the downstream end of the swale and/or by infiltration into the soil. The native soils shall be replaced with a 30-inch deep layer of permeable soils underlain with an underdrain system. The following criteria shall apply to the design of dry extended detention swales.

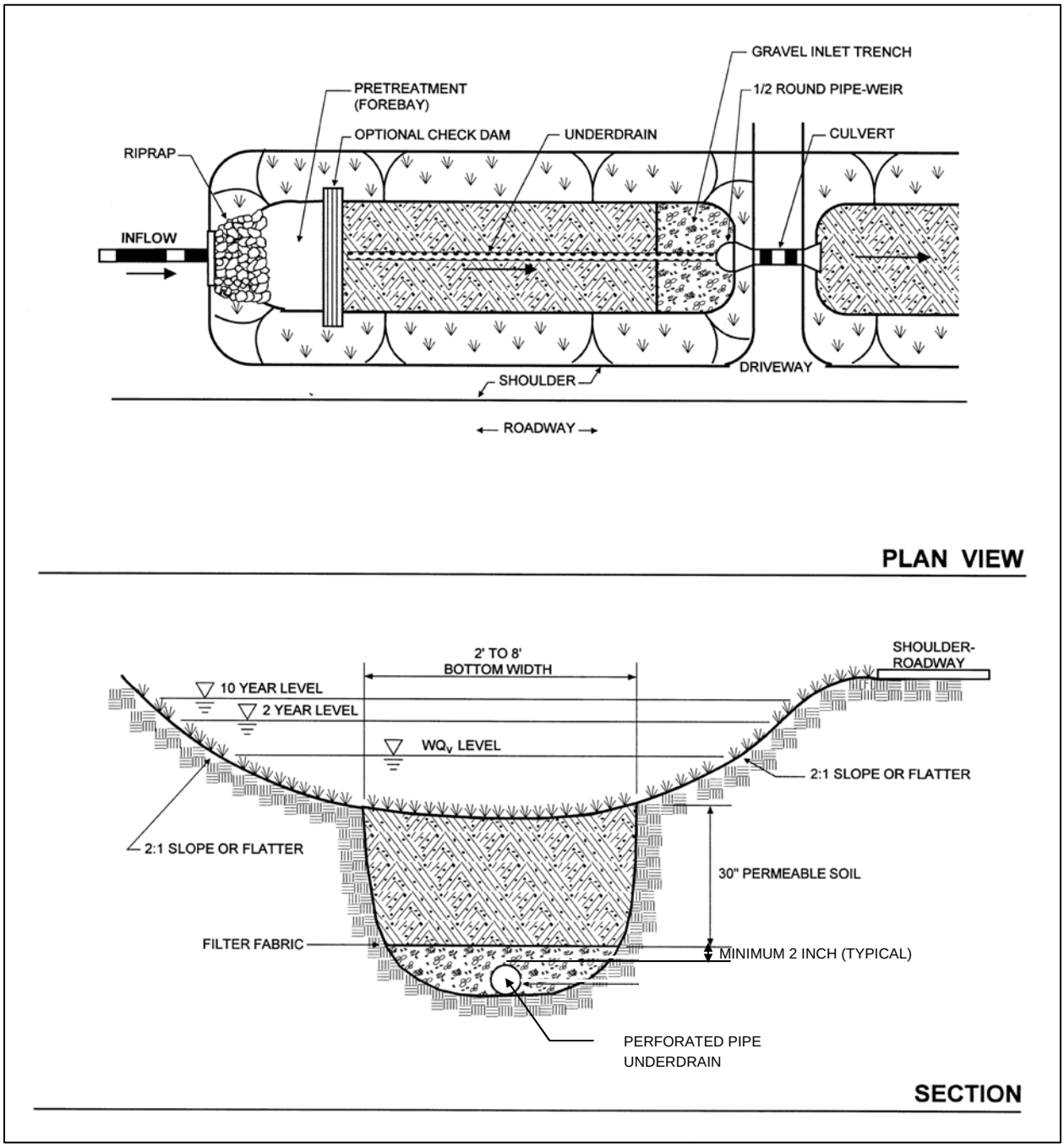

Figure 3-13. Schematic of Typical Dry Extended Detention Swale[24]

[24] Maryland Department of the Environment, *Maryland Stormwater Design Manual, Volume I*, 2000, pg. 3.43

Layout and Geometry Requirements

1) The total recommended drainage area of a dry extended detention swale is 5 acres, with a total drainage area of 1 to 2 acres preferred. Multiple cells should be considered to distribute the flow and facilitate proper drainage of the facility.

2) Dry extended detention swales shall not be allowed in areas where the water table or bedrock is above the invert of the underdrain system.

3) In order to maximize treatment effectiveness, the site must be graded in such a way that minimizes erosion as sheet flow is conveyed to the treatment area.

4) Dry extended detention swales should maintain a maximum ponding depth of one foot at the "mid-point" of the channel's longitudinal profile, and a maximum depth of 18 inches at the downstream end point of the channel for storage of the WQ_v. Check dams or similar structures may be installed along the longitudinal profile to meet this criteria.

5) The side slopes for dry extended detention swales shall not exceed 4 (H) to 1 (V).

6) Swales may be designed to safely convey storms generating more than the WQv according to criteria provided in Section 2.3.7. The peak velocity of the 10-year design storm through the swale shall be non-erosive for the soil and vegetative cover provided (See Table 2-17 for maximum allowable velocities). Three inches of freeboard should be provided.

Permeable Soil Requirements

The function of a dry extended detention swale is largely dependent on the characteristics of the soils underlying the swale. The soil underlying the swale shall be replaced with a 30-inch layer of permeable soil underlain with an underdrain system in order to provide proper drainage of the swale. The following criteria shall be used:

1) The permeable soil for dry extended detention swales shall consist of a mixture of sand, topsoil, and compost with a pH range of 5.5 and 6.5, a range where pollutants such as organic nitrogen and phosphorus can be adsorbed by the soil and microbial activity can flourish. In addition, the soil shall have infiltration rates greater than 0.5 inches per hour when saturated, achieved through the following standards[25]:

   a. 4 parts sand (per CMSC 703.06)

   b. 2 parts topsoil (per CMSC 653.02)

   c. 2 parts compost (per ODOT CMSC 659.06). Note: Com-Til Compost from DOSD's Compost Facility is acceptable for use in dry extended detention swales.

2) Soil tests shall be performed for every 500 cubic yards of soil, with the exception of pH and organic content tests, which are required only once per dry extended detention swale.

[25] ODOT, "Location and Design Manual, Volume 2, Drainage Design", Section 1116.7

3) The minimum depth of the filter media shall be at least 30 inches.

4) Dry extended detention swales shall be planted with grass that can withstand prolonged periods in a wet environment. No vegetation with a deeper root zone shall be allowed within the swale.

Underdrain and Outlet Requirements

1) A perforated pipe underdrain shall be provided beneath the permeable soil. The underdrain shall have a minimum grade of 0.5 percent. The perforated pipe shall have a diameter of 4 or 6 inches, and shall meet the requirements of CMSC Section 720.07 or 720.12. A granular backfill of durable No. 57 aggregate in accordance with CMSC Section 703.01 shall be provided up to a minimum of 4 inches above the outside diameter of the pipe.

2) The swale shall be designed to convey or divert all storms larger than the WQ_v up to and including the 100 year event. Storms larger than the WQ_v may be directed into a storm sewer system. Use of a vertical stand pipe or catch basin is recommended.

Pretreatment

Flow entering the dry extended detention swale shall be limited to sheet flow to prevent eroding the side slopes of the facility. If flow has been concentrated prior to entering the swale, it shall be converted to sheet flow using a level spreader designed according to criteria in Section 2.3.6. In addition, the frequency of maintenance for dry extended detention swales may be reduced by providing filter strips around the facility. The purpose of the filter strip is to trap course sediments before they reach permeable soil thereby reducing maintenance and preserving infiltration capacity. The design of filter strips is presented in Section 3.3.6.

3.3.7 Group 4 – Water Quality Controls for Commercial Activity Areas

The three groups of approved stormwater quality controls defined in the previous sections are appropriate for most commonly-occurring stormwater pollutants. Some pollutant sources, however, are not effectively controlled by the BMPs in the other three categories because they involve activities, materials, and/or wastes that are atypical of the commonly-occurring stormwater pollutants, in either the type or the concentration of the constituents found. These "high risk" pollutant sources must be either controlled separately or "pretreated" before being conveyed to one of the other three categories of BMPs.

A high-risk pollutant source is one possessing pollutant loads and/or concentrations that are different than typical urban runoff, as characterized by the USEPA National Urban Runoff Program (NURP), presenting an immediate threat to water quality, and/or interfering with the successful operation of other approved stormwater controls. These sources most commonly occur within commercial activity areas associated with commercial and industrial land uses. This section defines the types of businesses where such pollutants commonly are found, the specific activities known to generate these pollutants, and controls required in order to receive necessary development approvals from the City.

3.3.7.1 Businesses Subject to Controls for High-Risk Pollutant Sources

The controls in this section shall apply to the following business categories and/or activities:

1) Any business considered by U.S. EPA and Ohio EPA to involve industrial activities and require an NPDES permit for stormwater discharges from industrial activities. Such businesses are defined by Standard Industrial Classification (SIC) under 40 CFR 122.26. A comprehensive list of these businesses is not provided here, but largely falls within the following SIC Divisions:

   a. Division B: Mining

   b. Division C: Construction

   c. Division D: Manufacturing

   d. Division E: Transportation, Communications, Electric, Gas, and Sanitary Services

   e. Division F: Wholesale Trade

   Any development containing an industrial activity, as defined by Ohio EPA, shall meet all applicable requirements of Ohio EPA's permit for stormwater discharges from industrial activities. To obtain coverage, a discharger must complete and submit the NOI form available from Ohio EPA along with the appropriate fee to the following address:

   Ohio Environmental Protection Agency
   Office of Fiscal Administration
   Post Office Box 1049
   Columbus, Ohio 43216-1049

   A copy of the NOI shall be submitted to SWMS as part of the Stormwater Management Report.

2) Businesses involved in the sale, resale, recycling, repair, fueling, or cleaning of automobiles and other vehicles:

   a. Major Group 50: Wholesale Trade Durable Goods (including 5015 – Used Motor Vehicle Parts and 5093 – Scrap and Waste Materials)

   b. Major Group 51: Wholesale Trade Non-durable Goods (including 5171 – Petroleum Bulk Stations and Terminals)

   c. Major Group 55: Automotive Dealers and Gasoline Service Stations

   d. Major Group 75: Automotive Repair, Services, and Parking

3) Businesses that involve the preparation or sale of food:

   a. Major Group 54: Food Stores

   b. Major Group 58: Eating and Drinking Places

4) Other businesses that store or handle materials outdoors:

   a. Major Group 52: Building Materials, Hardware, Garden Supply, and Mobile Home Dealers

   b. Other businesses identified by the City with significant outdoor material or waste storage, handling, or disposal

3.3.7.2 Commercial Activity Areas Requiring Control

The control requirements in this section of the manual only apply to commercial activity areas of the businesses in the previous section, defined as outdoor areas where the following activities are conducted or are otherwise exposed to stormwater:

1) Processing, manufacturing, fabrication, cleaning, or other permanent outdoor equipment or work areas,

2) Areas where vehicles and equipment are repaired, maintained, stored, disassembled, or disposed, and

3) Areas where the high-risk materials defined in **Table 3-8**[26] are handled and stored, including but not limited to loading docks, fuel and other liquid storage/dispensing facilities; material bins, containers, stockpiles, and other storage containers; and waste dumpsters, bins, cans, tanks, stockpiles, and other waste containers.

3.3.7.3 Requirements for Commercial Activity Areas

Commercial activity areas that, in the judgment of the Administrator cannot be conducted indoors, shall be conducted within specified areas of the site designed to control stormwater quality. The Construction Drawings shall delineate commercial activity areas and show the location of any stormwater control measure. The Stormwater Management Report shall describe the commercial activity, the rationale for the control measure selected, and design information about the control measures. Stormwater runoff from each commercial activity area shall be controlled in the following manner:

1) Non-stormwater discharges from commercial activity areas, including discharges from any indoor areas, the lower floors of a multi-level parking structure, and/or areas under a roof, shall not be allowed to co-mingle with stormwater runoff from the remainder of the site.

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[26] City of Portland, OR, "Stormwater Management Manual", Adopted July 1, 1999, Revised September 1, 2004

Table 3-8

Control Requirements for Materials Handling Areas

High Risk Materials	Low-Risk Materials	Exempt Materials
Required controls: Conduct activities indoors, as allowed by City regulations, or outdoors with controls defined in this section.	***Required controls***: Use temporary covers of plastic film or sheeting, with runoff directed to approved BMPs for the site.	***Required controls***: Direct runoff to approved BMPs for the site.
Materials to control: • Recycled materials with potential effluent • Corrosive materials (i.e. lead-acid batteries • Storage and processing of food items • Chalk/gypsum products • Feedstock/grain • Material by-products with potential effluent • Asphalt • Fertilizer • Pesticides • Lime/lye/soda ash • Animal/human waste	***Materials to control:*** • Recycled materials with potential effluent • Scrap or salvage goods • Metal • Sawdust/bark chips • Sand/dirt/soil (including contaminated soil piles) • Material by-products with potential effluent • Unwashed gravel/rock • Compost	***Materials to control:*** • Washed gravel/rock • Finished lumber • Rubber and plastic products (hoses, gaskets, pipe, etc.) • Glass products (new, non-recycled) • Inert products • Materials with no measurable solubility or mobility in water • Materials with no hazardous, toxic, or flammable properties • Gaseous materials

2) The area shall be paved with asphalt or concrete unless otherwise approved by the Division of Sewerage and Drainage.

3) Non-stormwater discharges from commercial activity areas shall be directed to separate treatment systems approved by the Administrator that are able to adequately control stormwater pollutants generated within these areas. These systems include, but are not limited to the following:

   a. The City's separate sanitary sewer system, providing the discharge is permitted by the City, meets all applicable pretreatment requirements (determined by contacting the City's Industrial Waste Pretreatment Program at 614-645-5876), and is regulated with a shutoff valve.

   b. An oil/water separator to remove uncharacteristically high concentrations of oil and grease, with treated effluent discharged to the separate sanitary sewer system.

   c. A system appropriate for the containment of hazardous material spills, designed as specified in Ohio Fire Prevention Code Section 1301 : 7-7.

   d. An industrial treatment system covered by a discharge permit issued by Ohio EPA.

4) The following basic principles for integrated stormwater/wastewater management for commercial activity areas shall be followed:

a. Only stormwater (i.e., runoff directly caused by a precipitation event) should enter storm drains (e.g., no wash water, spills, leaks, etc.) unless specifically allowed under the City's NPDES stormwater permit. Clean rinse waters (no cleaning agents but with potable water chlorine residual) may be allowed to run onto grassed areas to infiltrate.

b. Stormwater/wastewater management strategies must be consistent with existing codes (e.g., building, plumbing, fire), sanitary sewer regulations, (e.g., pretreatment), and environmental regulations (e.g., HAZMAT, SPCC).

c. Outdoor material cleaning, storage, handling, and disposal should be minimized.

5) Minimize potential exposure of commercial activity areas to stormwater by the following methods[27]:

a. Minimize the size of the commercial activity area.

b. Prevent rainfall from entering the area using a cover or roof, with a minimum overhang of 3 feet on each side for covers 10 feet high or less, a minimum overhang of 5 feet on each side for covers higher than 10 feet, and rooftop drainage directed to the storm drainage system.

c. Surround above ground liquid containers with a containment device with enough capacity to capture at least 110 percent of the product's largest container or 10 percent of the total volume of product stored, whichever is larger.

d. Isolate high-risk pollutant areas from stormwater run-on by berming or providing grade breaks around the area perimeter.

6) Where wash waters are unavoidable, the Applicant shall propose one of the following disposal options depending upon the nature of the activity, the constituents involved, and other pertinent Federal, State, or City regulations:

a. Dispose in a sanitary sewer, with appropriate restrictions and/or pretreatment.

b. Direct to sump/containment, allow to evaporate, and sweep up residual.

c. Direct to sump/containment, pump out, and haul to appropriate disposal facility.

7) When contamination of stormwater runoff from commercial activity areas is unavoidable (according to building codes, etc.), it may be directed to a sanitary sewer at the discretion of the Stormwater and Regulatory Management Section

[27] City of Portland, OR, "Stormwater Management Manual", Adopted July 1, 1999, Revised September 1, 2004

3.3.8 Applicant-Proposed Stormwater Controls

There are many types of commercially-available proprietary systems for stormwater quality control. These systems include:

1) Hydrodynamic systems such as gravity and vortex separators,

2) Filtration systems,

3) Catch basin media inserts,

4) Chemical treatment systems,

5) Package treatment plants, and

6) Prefabricated detention structures .

This section provides stormwater treatment and quantity control criteria for vendors and/or Applicants requesting approval of these systems for use in the City. Stormwater controls proposed in lieu of those defined in this section must, at a minimum, meet the performance standards established in this section.

Performance Standards for New Development Controls

The pollutant removal effectiveness for total suspended solids (TSS) that is achieved by the other stormwater quality controls in the Manual establish the required performance standard for alternative or manufactured facilities. Total suspended solids are defined as "matter suspended in stormwater, excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter (larger than coarse sand)". Typical urban runoff contains about 100 mg/L TSS,[28]. Extended dry and wet detention basins, vegetated swales, and sand filters designed according to the criteria in the Manual are effective at removing very small particles down to the range of 10 microns to 20 microns, achieving effluent TSS concentrations of 15 to 30 mg/l, on average [29]. Based on these statistics, the Applicant must demonstrate that the BMP is able to remove all particles larger than 15 microns and yield a maximum effluent concentration of 20 mg/L.

Controls for new development shall also achieve an equivalent level of stormwater quantity control during the WQ_v event as is achieved by the controls included in the Manual. This involves controlling the increase in the peak flow rate of stormwater runoff during the WQ_v event, either by preventing volume increases and/or reducing the post-development peak flow:

1) Preventing runoff volume increases typically is achieved with stormwater infiltration, defined as a control that discharges the entire WQ_v either into the ground or through evapotranspiration. Infiltration controls are generally not feasible in the hydrologic soil groups C and D that predominate most of the City. Infiltration controls may be approved

[28] U.S. EPA, Section 403 Report to Congress, 1995.
[29] California Stormwater BMP Handbook, New Development and Redevelopment, MP-51.

by the City if the applicable NRCS soil survey indicates that the site contains hydrologic soil group A or B soils required for infiltration controls, or if the site will be modified using amended soils that yield infiltration rates and volumes equivalent to those achieved by hydrologic soil group A or B soils. Applicants shall submit appropriate information to demonstrate that stormwater infiltration is achievable in these situations.

2) Other controls recommended in the Manual control the post-development peak flow. Such decreases maintain the erosive energy of stream flow that causes stream erosion. Applicants must demonstrate that alternative controls are able to achieve this same decrease in the energy of post-development stormwater flows. This is done by demonstrating that the entire WQ_v will be released from the device in no less than 24 hours.

Performance Standards for Redevelopment Controls
Ohio EPA has established reduced stormwater quality management criteria for redevelopment projects as presented in Section 3.3.7.2. Alternative or manufactured stormwater control facilities will be considered as an acceptable alternative for redevelopment sites if the Applicant demonstrates that they are able to remove all particles larger than 100 microns and yield a maximum effluent concentration of 45 mg/L.

Required Standards Other than Treatment Performance
Applicants must demonstrate that alternative or manufactured controls meet the following additional performance standards:

1) ***Site Conditions —*** The facility design shall be appropriate for site conditions in central Ohio. The Applicant shall demonstrate that the control has operated successfully for at least three (3) years in conditions similar to central Ohio, including soils, groundwater, head loss, and climate.

2) ***Durability —*** The control must be made of materials able to withstand climatic and land use conditions in central Ohio, including exposure to stormwater, exposure to light, freeze-thaw cycles, and vandalism. The expected life of the major structural components of the control shall be at least 20 years.

3) ***Access —*** The design of the control shall facilitate maintenance. Access and/or inspection ports shall be provided to all portions of the facility where debris or sediment may collect, or maintenance shall be required. The design shall allow access for a single individual to conduct required maintenance and inspection activities using conventional sewer maintenance equipment.

4) ***Large Storms —*** The facility design shall accommodate storm events larger than the WQ_v by either bypassing its flow around the facility or passing the flow through the facility without re-suspending pollutants and other materials previously captured within the facility.

5) ***Operation and Maintenance —*** A maintenance history shall be provided for at least three (3) years of continuous operation. This history shall illustrate that the level of maintenance required for the facility is equivalent to the other facilities in the Manual.

6) ***Mosquito and Vector Control —*** The Applicant shall demonstrate that the control is designed to minimize and/or control conditions that breed mosquitoes or other vectors, defined in Section 3.3.3 of the Manual.

Testing and Submittal Requirements
The Applicant shall provide the City with studies or other documentation that the recommended control facility meets the requirements of this section. BMP performance must be conducted or prepared by an independent third-party and not by the BMP manufacturer. Final approval for the use of any alternative stormwater quality BMP will be given at the discretion of the Administrator. The testing and submittal requirements shall be based on the Protocol for Stormwater Best Management Practice Demonstrations, current edition, developed by The Technology Acceptance Reciprocity Partnership. More information on this publication can be found at the following website:

http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/

3.4 As-built Surveys

As-built surveys will be required from the developer or property owner responsible for constructing stormwater facilities and conveyance systems. At a minimum, the developer shall field survey the location of each stormwater outfall and the outfall structure of each stormwater (quantity and quality) control structure that is constructed as part of the development site. Only stormwater outfalls that discharge directly into an open watercourse need to be located. **Exhibit A** and **Exhibit B**, provided in **Appendix G**, shall be complete and submitted to the Division of Sewerage and Drainage for each outfall and stormwater control structure that were constructed as part of the project.

As a condition of final acceptance, the property owner shall be responsible for providing as-built surveys to verify the final grades and elevations of stormwater detention basins and wetlands that are to be owned and operated by the City. The City reserves the right to require as-built surveys on privately owned stormwater facilities if, in the opinion of the Division of Sewerage and Drainage:

1) The construction of the privately owned stormwater system may affect the performance of a publicly owned stormwater system, or

2) Final grading within a stormwater control facility or conveyance system appears to conflict with the approved grading plans.

The purpose of as-built surveys is to demonstrate conclusively that the facilities are constructed to the elevations, slopes, grades, and volumes shown on the approved plans on file with the City.

When ordered by the City to ensure that design grades and volumes within stormwater control facilities are achieved, an as-built survey shall be conducted once:

1) All structures on surrounding lots of a stormwater control facility are constructed and final lot grading for each lot is established, and

2) The conversion of a temporary sediment basin to a permanent stormwater control facility is complete after the site is built-out to the point where the temporary sediment basin is no longer needed. As-built surveys will only be accepted if they are conducted after the sediment in the temporary basin has been removed and regraded, vegetation has been established, and the permanent riser structure(s) is in place.

As-built surveys shall be conducted by a Professional Surveyor registered in the State of Ohio and shall employ standard survey techniques. The Professional Surveyor performing the as-built survey shall be responsible for reduction of notes and any plotting necessary to make the notes interpretable. A final report and original field notes shall be furnished to the City for review and record purposes. A minimum of two bench marks that are referenced to the same vertical datum as the construction plans shall be provided on the as-built survey drawings. As-built surveys shall be in addition to, and separate from, other construction surveys which the City or its agents may conduct. The developer, contractor, or other entity constructing the stormwater facilities shall correct the discrepancies necessary to ensure that the stormwater facility will function as designed. The as-built surveys shall be re-performed as necessary to demonstrate plan conformance.

3.5 Construction Stormwater Quality Controls

Construction stormwater quality control facilities shall be designed to control runoff from construction sites during storm events before being discharged into watercourses, lakes, and/or wetlands. The requirements for construction best management practices (BMPs) are intended to adequately reduce sediment and related pollutants contained in construction stormwater runoff. In general, a Stormwater Pollution Prevention Plan (SWPPP) is required for qualifying development sites and must be submitted with the construction plans as part of the plan approval process. Projects that are not required to submit a SWPPP are still required to implement construction BMPs regardless of size. The City's Erosion and Sediment Pollution Control Regulation (Regulations) sets forth the runoff control and erosion and sediment control standards as well as the plan requirements for SWPPPs. A copy of the City's Regulations is provided in Appendix A.

3.5.1 Additional Requirements

Over the years it has been necessary for the Division of Sewerage and Drainage to adopt additional standards for the design and placement of construction site BMPs. Changes in technology and regulatory requirements have made it necessary to develop additional criteria intended to supplement the standards provided in the Regulations. The following additional criteria shall apply to development projects planned within the City of Columbus:

1) The City of Columbus utilizes the ODNR (Ohio Department of Natural Resources) manual: Rainwater and Land Development, latest edition, as the principal reference for erosion and sediment control practices and standards.

2) Stormwater Pollution Prevention Plans – Stormwater Pollution Prevention Plans are required for sites that will disturb at least one acre or more. SWPPPs are not required on sites smaller than one acre, however, the implementation of construction stormwater BMPs is required. For sites with less than one acre of disturbance, a general note is required and provided in **Appendix F, Exhibit E**.

3) Sediment Basins – Sediment basins and appropriately sized risers are required to control sediment discharges for locations receiving runoff from tributary areas of 5 acres or more.

4) The use of straw bales for catch basin and curb inlet protection is not an approved practice in the City of Columbus.

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