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6-0100 GENERAL INFORMATION

6-0101 Drainage Systems (91-06-PFM)

6-0101.1 It is the intent of § 6-0000 *et seq*. to require that public facilities meet or exceed applicable drainage laws.

6-0101.2 The overall drainage system is divided into two parts, the minor system and the major system.

6-0101.2A The minor drainage system (normally designed for the 10-year storm) consists of storm sewer appurtenances and conduits such as inlets, manholes, street gutters, roadside ditches, swales, small underground pipe and small channels which collect the stormwater runoff and transport it to the major system.

6-0101.2B The major system (designed for the less frequent storm up to the 100-year level) consists of natural waterways, large man-made conduits, and large water impoundments. In addition, the major system includes some less obvious drainageways such as overland relief swales and infrequent temporary ponding at storm sewer appurtenances. The major system includes not only the trunk line system which receives the water from the minor system, but also the natural backup system which functions in case of overflow from or failure of the minor system. (See § 6-1500 *et seq*.)

6-0101.3 Special attention is invited to:

6-0101.3A The current "Virginia Erosion and Sediment Control Handbook and the Virginia Stormwater Management Handbook," Volumes I & II. These handbooks address State criteria for stormwater management to be applied to control flooding and erosion.

6-0101.3B Engineering Properties of Fairfax County Soils are published by Fairfax County Department of Public Works and Environmental Services.

6-0101.3C (107-11-PFM) Engineering Properties of Fairfax County Soils are available from the USDA-NRCS website.

6-0102 VDOT Requirements. See § 1-0602 *et seq*. regarding VDOT Standards.

6-0103 Metric Plan Preparation. For metric plan preparation, since hydraulic and hydrologic design aids are not available in metric units, design computations may continue to be performed in English units with the description of proposed structures converted to metric after computations are complete.

6-0200 POLICY AND REQUIREMENTS FOR ADEQUATE DRAINAGE

6-0201 Policy of Adequate Drainage (91-06-PFM)

6-0201.1 In order to protect and conserve the land and water resources of this County for the use and benefit of the public, measures for the adequate drainage of surface waters shall be taken and facilities provided in connection with all land development activities. (See also § 2-602 of the Zoning Ordinance).

6-0201.2 Adequate drainage of surface waters means the effective conveyance of storm and other surface waters through and from the development site and the discharge of such waters into a natural watercourse, i.e., a stream with a defined channel (bed and banks), or man-made drainage facility of sufficient capacity without adverse impact upon the land over which the waters are conveyed or upon the watercourse or facility into which such waters are discharged. (See § 6-0202 *et seq*.)

6-0201.3 The provision of the necessary onsite and offsite easements to accomplish this also shall be required. These are to include sufficient easement extensions to property lines to permit future development reasonable access to drainageways or drainage facilities for connections.

6-0202 Minimum Requirements (91-06-PFM)

6-0202.1 Determination of the size and capacity of the drainage system shall be based on the planned development, existing zoning or existing development, whichever is greater, within the watershed.

6-0202.2 The drainage system shall be designed:

6-0202.2A To honor natural drainage divides for both concentrated and non-concentrated stormwater runoff leaving the development site. If natural drainage divides cannot be honored, each diversion from one drainage area to another may be approved by the Director in accordance with the following conditions:

6-0202.2A(1) The increase and decrease in discharge rates, volumes, and durations of concentrated and non-concentrated stormwater runoff leaving a development site due to the diverted flow shall not have an adverse impact (e.g., soil erosion; sedimentation; yard, dwelling, building, or private structure flooding; duration of ponding water; inadequate overland relief) on adjacent or downstream properties.

6-0202.2A(2) The applicant shall demonstrate to the satisfaction of the Director that the diversion is necessary to: a) improve an existing or potentially inadequate outfall condition; b) preserve a significant naturally vegetated area or save healthy, mature trees, which otherwise could not be preserved or saved, and which may be used to meet tree cover requirements instead of newly planted trees; c) maximize the water quality control and/or water quantity control provided; d) address constraints imposed by the dimensions or topography of the site to preclude

adverse impacts from steep slopes and/or runoff; or e) minimize to a reasonable extent, as determined by the Director, the number of on-site stormwater management facilities.

6-0202.2A(3) (116-14-PFM) The construction or grading plan shall include a written justification for the proposed diversion and a detailed analysis of both concentrated and non-concentrated stormwater runoff leaving a development site for each affected downstream drainage system in accordance with the requirements of § 6-0203. The extent of downstream analysis shall be performed to a point where the diverted flow is returned to its natural course. However, the analysis for a non-bonded lot grading plan proposing a diversion of less than 0.5 cfs for the 10-year design storm may be terminated at a point that satisfies § 6-0203.2, if that point is upstream of the point where the diverted flow is returned to its natural course. Otherwise, the extent of downstream review shall be performed to a point where the diverted flow is returned to its natural course and in accordance with § 6-0203, and whichever point results in the farthest downstream review shall govern.

6-0202.2A(4) A diversion shall not be approved if it adversely impacts the adequacy of downstream drainage systems; creates new floodplain areas on adjacent or downstream properties; alters Resource Protection Area boundaries; aggravates or creates a non-compliance with provisions governing elevations and proximity to 100-year water surface elevations; changes the drainage area at points where perennial streams begin; or changes the total drainage area of a watershed depicted on the County Map of Watersheds, as may be amended.

6-0202.2B To account for both off-site and on-site surface waters.

6-0202.2C To convey such waters to a natural water course at the natural elevation, or an existing storm drainage facility. (See § 6-0201.2)

6-0202.2D To discharge the surface waters into a natural watercourse or into an existing or proposed man-made drainage facility of adequate capacity except as may be provided for in § 6-0203.

6-0202.3 (116-14-PFM) Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system or the developer must provide a drainage system satisfactory to the Director to preclude an adverse impact (e.g., soil erosion; sedimentation; yard flooding; duration of ponding water; inadequate overland relief) on downstream properties and receiving channels in accordance with § 6-0203, as well as an improvement of the pre-development conditions (§ 6-0203.4 and § 6-0203.5). If the developer chooses to install a storm drainage system, the system shall be designed in accordance with established, applicable criteria for such systems.

6-0202.4 Concentrated stormwater runoff leaving a development site shall not aggravate or create a condition where an existing dwelling or a building constructed under an approved building permit floods from storms less than or equal to the 100-year storm event. If such a

dwelling or building exists, detention for the 100-year storm event shall be provided in accordance with § 6-0203.5.

6-0202.5 Concentrated surface waters shall not be discharged on adjacent or downstream property, unless an easement expressly authorizing such discharge has been granted by the owner of the affected land or unless the discharge is into a natural watercourse, or other appropriate discharge point as set forth above.

6-0202.6 The owner or developer may continue to discharge stormwater which has not been concentrated (i.e., sheet flow) into a lower lying property if:

6-0202.6A The peak rate after development does not exceed the pre-development peak rate; or

6-0202.6B(1) The increase in peak rate or volume caused by the development will not have any adverse impact (e.g., soil erosion, sedimentation, duration of ponding water, inadequate overland relief) on the lower lying property as determined by the Director; and

6-0202.6B(2) The increase in peak rate or volume caused by the development will not aggravate any existing drainage problem or cause a new drainage problem on the downstream property.

6-0202.7 Increases in peak rates or volumes of sheet flow that may cause any adverse impact on lower lying properties shall be discharged into an adequate existing drainage system or the developer shall provide an adequate drainage system satisfactory to the Director to preclude any adverse impact upon the adjacent or downstream property.

6-0202.8 (31-90-PFM) Drainage structures shall be constructed in such a manner that they may be maintained at a reasonable cost. To facilitate design, construction, and maintenance, drainage facilities shall meet and conform, insofar as practical, to County and VDOT standards. However, small private drainage systems may be acceptable (See § 6-0205) for solving drainage problems that may develop during the course of construction of a new development or for implementation by property owners in existing developments. See § 6-0205 and Plate 1-6 for construction details and example.

6-0202.9 If off-site downstream construction and easements are necessary, no plans shall be approved until such storm drainage easements have been obtained and recorded. If the downstream owner or owners refuse to give or to sell such easements, the owner or developer may request condemnation of the easements by the County at the developer's cost. If the County declines to institute condemnation, the plan shall not be approved.

6-0202.10 Storm sewers shall be discharged into the area least likely to erode.

6-0202.10A Generally, it is better to discharge at the floodplain limit into an adequate watercourse channel leading to the main streambed, rather than disturb the floodplain by extending the storm sewer.

6-0202.10B If an adequate watercourse channel does not exist, the only alternative is to discharge into the main streambed.

6-0202.10C In either case, energy dissipation devices are required.

6-0202.11 The requirements of Chapter 104, (Erosion and Sedimentation Control) of the Code, and the further requirements for protection of streambeds by detention-retention of surface waters, set forth in § 6-0000 *et seq*. must be satisfied. Additionally, BMP requirements to protect water quality must be met, if applicable (§ 6-0400 *et seq*.).

6-0202.12 The on-site major storm drainage system must be designed in accordance with § 6-1500 *et seq*.

6-0202.13 (27-89-PFM) Consideration must be given in the preparation of the plans to preclude adverse impacts due to higher rates and volumes of flow that will occur during construction. Special consideration shall be given to the design of sediment traps which discharge into existing residential yards. In this case, in order to reduce concentrated flows and simulate existing sheet flow conditions, the 10-year peak discharge shall be designed to be not greater than 0.5 cfs using a minimum runoff C factor of 0.6 for all areas to be disturbed.

6-0202.14 In those cases in which the drainage plans of a proposed development do not satisfy these minimum requirements because necessary off-site facilities or improvements are lacking, the developer shall delay development until the necessary off-site facilities or improvements are constructed or other arrangements, satisfactory to the Director, are made.

6-0203 Analysis of Downstream Drainage System (91-06-PFM, 116-14-PFM)

6-0203.1 The downstream drainage system shall be analyzed to demonstrate the adequacy of the system (§ 6-0203.3), or it shall be shown that there is no adverse impact to the downstream system as well as an improvement of the pre-development conditions (§ 6-0203.4 and § 6-0203.5).

6-0203.2 The extent of the review of the downstream drainage system shall be as required by Chapter 124 of the County Code. Note that the extent of review for channel protection and flood protection requirements are different.

6-0203.2A The analysis must be to a point where all the cross-sections are adequate in the farthest downstream reach of 150 feet. A minimum of three cross-sections shall be provided in the 150-foot reach. If the detention method described in § 6-0203.4A is used, the three cross-sections in the farthest downstream reach of 150 feet shall be limited to showing a defined channel or a man-made drainage facility and checking for flooding as described in § 6-0203.4A(3) and § 6-0203.5.

6-0203.2B The Director may require analysis farther downstream when the submitted narrative described in § 6-0204 and all related plats and plans are insufficient to show the true impact of the development on surrounding and other lower lying properties, or if there are known drainage problems downstream.[1]

6-0203.2C Cross-section selection and information shall be determined in accordance with Chapter 5 of the latest edition of the "Virginia Erosion and Sediment Control Handbook" (Virginia Department of Conservation and Recreation) under the section titled "Determination of Adequate Channel." Cross-sections shall be shown on the plans with equal horizontal and vertical scales.

6-0203.2D If the downstream owner(s) refuse to give permission to access the property for the collection of data, the developer shall provide evidence of this refusal and make arrangements satisfactory to the Director to provide an alternative method for the collection of data to complete the outfall analysis (e.g., through the use of photos, aerial surveys, "as built" plans, County topographic maps, soils maps, and any other relevant information).

6-0203.3 Adequacy of all natural watercourses, channels and pipes shall be verified in accordance with the channel protection and flood protection requirements of Chapter 124 of the County Code and the following:

6-0203.3A Pipes, storm sewer systems and culverts, which are not maintained by VDOT, shall be analyzed by the use of a 10-year frequency storm to verify that stormwater will be contained within the pipe, system, or culvert; and

---

[1] These drainage problems may be documented as parts of County watershed or drainage studies, complaints on file with the County, or complaints on file at the offices of County Supervisors.

6-0203.3B Pipes, storm sewer systems and culverts, which are maintained by VDOT, shall be analyzed by the use of the 10-year or greater frequency storm in accordance with VDOT requirements.

6-0203.3C Determinations of the adequacy of drainage systems shall be performed in accordance with methods contained in Chapter 5 of the latest edition of the "Virginia Erosion and Sediment Control Handbook" (Virginia Department of Conservation and Recreation) under the section titled "Determination of Adequate Channel."

6-0203.4 An improvement and no adverse impact to the downstream drainage system shall be shown in accordance with the requirements of Chapter 124 of the County Code and the following:

6-0203.4A Detention Method [2]

6-0203.4A(1) It shall be presumed that no adverse impact and an improvement will occur if on-site detention is provided as follows and the outfall is discharging into a defined channel or manmade drainage facility:

In order to compensate for the increase in runoff volume, the 1-year, 2-year and 10-year post-development peak rates of runoff from the development site shall be reduced below the respective peak rates of runoff for the site in good forested condition (e.g., for NRCS method, a cover type of "woods" and a hydrologic condition of "good") in accordance with the requirements of Chapter 124 of the County Code.

The calculation of the peaks and cumulative volumes shall be based on the NRCS methodology described in § 6-0802 or other methods as approved by the Director.

6-0203.4A(2) If this method is used, each outfall from the site shall be analyzed independently and the allowable release rate shall be based on the area of the site that drains to the outfall under pre-development conditions.

6-0203.4A(3) If this method is used, the downstream review analysis shall be limited to providing cross-sections to show a defined channel or man-made drainage facility, and checking for flooding of existing dwellings or buildings constructed under an approved building permit from the 100-year storm event for the extent of review described in § 6-0203.2.

6-0203.4B Other scientifically valid methods, which show no adverse impact regarding erosion or capacity for an inadequate outfall and show an improvement, may be approved by the Director in accordance with the requirements of Chapter 124 of the County Code.

[2] Because of the long detention times resulting from this method, consideration shall be given to hydrology, soils and extended detention when choosing the appropriate landscaping for the detention facility.

6-0203.5 In accordance with § 6-0202.4, if an existing dwelling or a building constructed under an approved building permit, which is located within the extent of review described in § 6-0203.2, is flooded by the 100-year storm, the peak flow of the 100-year storm at the development site shall be reduced to a level below the pre-development condition in accordance with the requirements of Chapter 124 of the County Code.

6-0204 Submission of Narrative Description and Downstream Analysis (91-06-PFM, 116-14-PFM)

6-0204.1 In addition to plats, plans, and other documents that may be required, a description of each outfall of the storm drainage system from the development site shall be submitted as part of the relevant subdivision construction plan or site plan and shall include the following:

6-0204.1A The additional submission shall include a narrative and sketches describing the major elements (pipe, channel, natural watercourse stream, etc.) of each outfall drainage system, including any discharges of non-concentrated surface waters from the development site. Photographs may also be included to assist in the description of the outfall.

6-0204.1B Downstream Review. The downstream review, divided into reaches, as required by § 6-0203, shall:

6-0204.1B(1) Note the existing surrounding topography, soil types, embankments, vegetation, structures, abutting properties, etc., which may be impacted by drainage;

6-0204.1B(2) In cases where the developer seeks to establish that the existing downstream facilities and/or natural waterways are adequate to receive the drainage from the development site, provide sufficient cross-section information, associated graphs, and computations to support the assertion of adequacy, in accordance with § 6-0203.3;

6-0204.1B(3) In cases where the downstream facilities are inadequate and the developer proposes to use the detention method, in accordance with § 6-0203.4A, provide sufficient information to (i) establish the existence of a defined channel or man-made drainage facility to receive the concentrated discharge from the development site, and (ii) demonstrate at least the minimum required improvement, as described in § 6-0203.4A(1), will be achieved;

6-0204.1B(4) Provide sufficient information to demonstrate that (i) there will be no flooding of existing dwellings, or buildings constructed under an approved building permit, by the 100-year storm event, or (ii) any existing flooding condition will not be aggravated by drainage from the development site and an improvement is made in accordance with § 6-0203.5; and

6-0204.1B(5) Include a written opinion, certified, signed, and sealed by the submitting professional, that (i) the requirement of adequacy of the downstream drainage system(s) is met or the development will meet the no adverse impact condition and achieve the required proportional improvement of pre-development conditions; (ii) if any portion of the outfall drainage system is a

natural watercourse, the cross-sections analyzed and included on the plan are representative of stream reaches for the entire extent of review for the natural watercourse portion of the system; and (iii) there will be no flooding of existing downstream dwellings, or buildings constructed under an approved building permit, by the 100-year storm event, or that any existing flooding condition will not be aggravated by drainage from the development site.

6-0205 Small Private Drainage System (See Plate 1-6) (31-90-PFM)

6-0205.1 The intended uses for these small private drainage systems are generally meant to apply exclusively to solving existing drainage problems that may develop during the course of construction of a new development or for implementation by property owners in existing developments. They are not to be used in the design of new developments to circumvent the normal requirements for a standard public drainage system. Accordingly, they are not intended to convey large flows from major swales or drainage areas. That is, design flows will typically be in the range of 1 to 3 cfs.

6-0205.2 If the system is located on more than one private property, private easements in favor of the other system owner(s) must be mutually granted in order to ensure proper operation and maintenance of the system. In addition, when the system is located on more than one private property, a County construction permit will be required and as a part of that permit's requirements, a maintenance/hold harmless agreement, which will run with the land ownership, will need to be executed by the system owners and recorded in the land records of the County. Maintenance of these systems will be the responsibility of the system owner(s), not of the County.

6-0205.3 Extreme caution should be exercised in locating the terminal discharge point of the system so that downstream property owners will not be adversely impacted. Riprap (small rock) should be used to dissipate the discharge energy and reduce the discharge velocity to a non-erosive rate. Where connection to a County drainage system is proposed, DPWES, Maintenance and Stormwater Management Division, is to be contacted for permission.

6-0205.4 (31-90-PFM) Example: A homeowner has excessive runoff through his backyard. The estimated size of the watershed is 0.5 acres. The estimated percent impervious cover is 60 percent.

Step 1: Determine the amount of design runoff in cfs. Use Table 6.1 as a guide:

Table 6.1 Hydrology – Small Private Drainage System (31-90-PFM)

Size of Watershed Draining to Point of Interest Acres	Estimate the % of Impervious Cover in the Watershed (e.g., roofs, pavement, sidewalks)			
	20%	40%	60%	80% or more
	Low Density Residential cfs	Medium Density Residential cfs	High Density Residential cfs	Commercial Industrial cfs
0.25	.85	1.10	1.40	1.90
0.50	1.70	2.30	2.90	3.90
1.00	3.40	Public System Required	Public System Required	Public System Required

From Table 6.1 the Design Flow is estimated at 2.9 cfs or say 3 cfs.

Step 2: Determine the size of the pipe and details of the inlet structure. Use Table 6.2 as a guide.

Table 6.2 Hydraulics – Small Private Drainage System

Pipe Dia. Inches	(A) Pipe Grade (G)				(B) Available Ponding Headwater (HW)			
	.5%	1.0%	2.0%	4.0%	1 ft.	2 ft.	3 ft.	4 ft.
	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
8	1.0	1.4	2.0	2.8	1.69	2.39	2.93	3.37
10	1.8	2.6	3.6	5.2	2.52	3.56	4.36	6.65

Given: The runoff to the point of interest is 3 cfs. The elevation at the ground equals 200 ft. The elevation at the outfall 100 feet away equals 196 ft. at the watercourse (i.e., stream invert).

Solution: (1) Use a 2.25 ft^2 grate at 0.5 ft. ponding depth (capacity is 3 cfs at 0.5 ft.). Try 10 in. diameter pipe at 2% (from Table 6.2). Two percent at 100 ft. equals 2 ft. of drop in elevation for grade. Therefore, 196 ft. (invert elevation at water course) + 2 ft. (elevation needed for grade) = 198 ft. elevation of pipe invert at drop inlet. (2) Check ponding depth capacity: 200 ft. – 198 ft. – 0.42 ft. to centerline of pipe = 1.58 ft. Interpolating Table 6.2B gives 3.1 > 3.0 required; therefore OK.

Results: The grate top elevation equals 199.5. 10 in. diameter PVC rigid non-perforated pipe; invert elevation out of drop inlet equals 198.0 ft.; invert elevation at watercourse 100 ft. away equals 196.0 ft.; install "Y" or brick structure with solid ¼-in. thick steel plate on top along pipe at 50-ft. intervals for clean-out access; install 3-ft. long, 18-in. wide riprap (4 in. to 8 in. diameter stone) at terminus of pipe.

6-0205.5 (31-90-PFM) If the system must be on more than one property, the property owners must dedicate a private easement in favor of each other for maintenance purposes.

6-0300 POLICY ON DETENTION OF STORMWATERS (116-14-PFM)

6-0301 General

6-0301.1 The use of various methods for the on-site retention and detention of stormwater is required under Chapter 124 of the County Code to minimize the adverse effects of increased stormwater runoff (resulting from development of land within the County) on all downstream drainageways.

6-0301.2 Stormwater management facilities must be provided in all storm drainage plans for proposed development in the County submitted for review and approval unless exempt or waived by the Director in accordance with Chapter 124 of the County Code.

6-0301.3 The use of wet ponds, extended detention ponds, and constructed wetlands in residential developments is restricted to regional facilities or to residential developments where there are no other reasonable options available for compliance with the water quality control requirements.

6-0301.4 Dry ponds (typically designed for detention only) that do not include permanent pools of water may be used in residential developments.

6-0301.5 (46-94-PFM) A pond is a regional pond if it is approved as such as a part of the County's regional stormwater management plan. In addition, a pond may be deemed by the County to be a regional pond if it 1) is the functional equivalent of a regional pond or 2) has an upstream watershed area of 100 acres or more, and a detention capacity and BMP capacity capable of serving the entire upstream watershed.

6-0302 Detention Measures

6-0302.1 Except where otherwise prohibited, detention, either alone or in combination with other measures, is an acceptable option for meeting the County and State requirement for protecting receiving waterways from erosion and flooding resulting from (developed) runoff.

6-0302.2 On-site detention of stormwater is desirable in many cases to alleviate existing downstream drainage problems and to preclude the development of new ones.

6-0302.2A Detention is mandatory where the existing downstream drainage system is clearly inadequate and its expansion or improvement is either financially prohibitive or unacceptable for aesthetic or other compelling reasons.

6-0302.2B In some areas of a watershed, detention may cause increased peak flows to occur on the major streams and tributaries. Therefore, the downstream impact must be carefully investigated.

6-0302.2C The Director may prohibit detention of stormwater where and when it is not in the best interests of the County.

6-0302.3 The release rate from ponding areas shall approximate that of the site prior to the proposed development for the design storm, but adequate alternate drainage must be provided to accommodate major storm flows.

6-0302.4 The rooftops of buildings may be used for detention, but care should be taken to design the buildings to accommodate the additional live loading involved.

6-0302.5 Detention pools or basins in parks (subject to the approval of FCPA), playing fields, parking lots or storage areas can be constructed to reduce peak runoff downstream by providing on-site storage.

6-0302.5A Care must be taken to ensure that such ponds do not become nuisances or health hazards.

6-0302.5B The design engineer should strive to design detention facilities which require minimal maintenance. The maintenance responsibility shall be clearly stated on the plans.

6-0302.5C Where dual purpose facilities are provided, flat grades encountered, or poor draining soils found, provisions for adequate low flow drainage may be required.

6-0302.6 Porous material may be used where practical as an alternative to conventional impervious parking area paving in accordance with § 6-1300 *et seq*.

6-0302.6A This material would allow the stormwater to be absorbed more readily by the ground rather than adding to additional runoff.

6-0302.6B This practice is not applicable to areas where a high water table exists or where subsoil conditions are not suitable.

6-0302.6C Design engineers are encouraged to investigate and propose experimental uses of new or existing products and methods, subject to approval by the Director, where such use may appear appropriate.

6-0302.6D Parking areas surfaced with gravel or rock must be approved by the Director, in accordance with Paragraph 9 of § 11-202 of the Zoning Ordinance, or § 7-0504 *et seq*.

6-0303 Location and Maintenance of Stormwater Management and BMP Facilities

6-0303.1 (32-90-PFM) All non-regional "wet ponds" (ponds with a permanent water surface) and other BMPs, except as noted below, in single-family and residential condominium developments must be maintained by the homeowner's association, or individual homeowners where provided for in § 6-0303.7, and a private maintenance agreement must be executed before the construction plan is approved. Dry detention ponds, extended detention facilities, and regional wet detention ponds, including those constructed to serve as BMP facilities, located in single-family and residential condominium developments, shall be within County storm drainage easements, and shall be maintained by DPWES. County maintenance is provided for proper functioning of the facility and does not include routine aesthetic maintenance such as caring for and/or controlling vegetation, where allowed, and seasonal mowing of grass within easements. In addition, access easements are required for all facilities except for privately maintained facilities located on individual buildable single family attached and detached residential lots.

6-0303.2 (46-94-PFM) Detention and BMP facilities located in industrial, commercial, institutional, apartment developments and rental townhouses must be maintained by the property owner, and a Private Maintenance Agreement must be executed before the construction plan is approved.

6-0303.3 (38-93-PFM) Retention, detention and/or BMP facilities may not be located in RPAs unless an exception is approved under provisions of Chapter 118 (Chesapeake Bay Preservation Ordinance) of the County Code.

6-0303.4 (46-94-PFM) Wherever stormwater management facilities are planned in areas within 300 feet of a residence or active recreational area, the design shall be directed specially toward the safety aspects of the facility and shall conform to the requirements of § 6-1606; including such features as mild bottom slopes along the periphery of a detention pond extending out to a point where the depth exceeds 2 feet, flat lateral and longitudinal slopes where concrete low flow channels are used, outlet structures with properly fastened trash racks which will inhibit unauthorized entrance, and posted warning signs.

6-0303.5 In addition, credit for recreational open space shall not be allowed in those areas where detention facilities are located unless the area can reasonably be used for recreational purposes. For example, some detention ponds could be used for active recreational use if the low flows are totally separated from the play areas by a piping system.

6-0303.6 Underground Detention Facilities (24-88-PFM, 83-04-PFM, 120-15-PFM). Underground detention facilities may be used in residential or mixed use developments, commercial developments, and industrial developments subject to the conditions specified below.

6-0303.6A All underground detention facilities shall be privately maintained, shall not be located in a County stormwater-related easement, and shall have a private maintenance agreement in a form acceptable to the Director executed before the construction plan is approved. Prior to final plan

approval, any such private maintenance agreement shall be recorded in the chain of title of the property to give notice to all future owners of such maintenance requirements.

6-0303.6B Underground detention facilities may consist of reinforced concrete box-shaped vaults or large-diameter reinforced concrete, metal, or plastic pipe meeting the requirements of PFM. Other underground storage systems may be considered on a case-by-case basis by modification subject to conditions as deemed appropriate by the Director (hereinafter a "modification"). The Director may approve any such modification provided that the underground storage facility nonetheless functions in the manner intended by the PFM. The modification request shall include full details and supporting data including, but not limited to justification, design computations, material specifications, technical details, structural calculations, procedures for installation, inspection and acceptance testing, procedures for operation and maintenance, safety considerations, and estimated 20-year maintenance cost and 40% of the facility's replacement cost.

6-0303.6C An escrow equal to a 20-year maintenance cycle plus 40 percent of the facility replacement cost shall be required when:

(1) a modification is granted pursuant to § 6-0303.6(B) for a facility that will be maintained by future residential owners; or
(2) an underground detention facility is located in a residential or mixed-use development with less than 50 residential units.

The developer shall place any such escrow with the applicable homeowner or condominium association prior to bond release. No escrow shall be required for any underground detention facility in an industrial or commercial development; nor shall any escrow be required for residential developments greater than or equal to 50 units, unless a modification has been approved as set forth herein.

6-0303.6D The owner shall provide for inspection during construction of the underground detention facility by a professional engineer(s) with structural and geotechnical engineering specialization. The licensed professional shall certify that the facility was constructed and installed in accordance with the approved plans and manufacturer's recommendations. The developer or licensed engineer shall also submit product assurance documentation including, but not limited to, any material delivery tickets and certifications from material suppliers, and results of tests and inspections. For projects requiring as-built plans, the required certification and supporting documentation set forth herein shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted prior to the issuance of the Residential Use Permit or Non-Residential Use Permit. In either event, all such documents, certifications, and test and inspection results shall be submitted before bond release.

6-0303.7 (35-91-PFM) Detention or structural BMP facilities, including 10-year flood storage areas associated with such facilities, shall not be located on individual buildable single family attached and detached residential lots, or any part thereof for the purpose of satisfying the detention, water quantity, or BMP requirements of the Stormwater Management Ordinance for subdivision and site plans. However, detention and BMP facilities may be constructed on

individual lots to satisfy the detention and BMP requirements for each lot or for subdivisions of no more than seven lots where approved by the Director in accordance with § 6-1300 *et seq*. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities. County maintenance for detention and BMP facilities on such individual lots will not be provided. The use and location of BMPs is summarized in Table 6.3.

Table 6.3 Use and Location of BMPs (✓ denotes allowed) (116-14-PFM)

BMP	Non-residential	Multi-family and mixed-use	Residential subdivision lots[1, 2]	Outlots in residential subdivisions	Nonbonded subdivision lots[2,3]	VDOT right-of-way[4]
Simple Rooftop Disconnection[5] (§ 6-1312)				N/A		N/A
Rooftop Disconnection to Alternative Practice[6] (§ 6-1312)	✓	✓		✓	6	N/A
Sheet Flow to Vegetated Filter or Conserved Open Space (§ 6-1313)	✓	✓		✓	✓	N/A
Soil Compost Amendment (§ 6-1314)	✓	✓	1, 2	✓	✓	N/A
Reforestation (§ 6-1311)	✓	✓	1	✓	✓	N/A
Vegetated Roof (§ 6-1310)	✓	✓		N/A		N/A
Rainwater Harvesting (§ 6-1315)	✓	✓				N/A
Permeable Pavement (§ 6-1304)	✓	✓	2			
Infiltration Practices (§ 6-1303)	✓	✓	1	✓	✓	
Bioretention (§ 6-1307)	✓	✓	1	✓	✓	✓
Vegetated Swales (§ 6-1308)	✓	✓	1	✓	✓	✓
Wet Swale (linear wetland) (§ 6-1316)	✓	✓		✓		✓
Filtering Practice (§ 6-1317)	✓	✓		✓		✓
Constructed Wetland (§ 6-1318)	✓	✓		✓		
Wet Pond (§ 6-1319)	✓	✓		✓		

Table 6.3 (cont'd) Use and Location of BMPs (✓ denotes allowed)

BMP	Non-residential	Multi-family and mixed-use	Residential subdivision lots[1, 2]	Outlots in residential subdivisions	Nonbonded subdivision lots[2,3]	VDOT right-of-way[4]
Extended Detention Pond (§ 6-1320)	✓	✓		✓		
Manufactured (Proprietary) BMP (§ 6-1321)	✓	✓		✓		✓

1. The Director may approve the use of these BMPs on lots in residential subdivisions of no more than seven lots, provided, however, that approval by the Board of Supervisors is required for use of such BMPs on lots in residential subdivisions of no more than seven lots in conjunction with the approval of a rezoning, proffered condition amendment, special exception, or special exception amendment.

2. Soil compost amendments and pervious pavement used on residential subdivision lots may be treated as forest/open space and managed turf respectively in the runoff reduction calculation. However, a loss of 30% of the treated area over time is assumed for soil compost amendments and 50% of the pervious pavement to compensate for future conversions or disturbance of the area.

3. Nonbonded subdivision lots include five-acre lots that are not subject to subdivision control.

4. Use of the indicated practices is subject to approval by VDOT.

5. Simple rooftop disconnection is allowed with Director approval on a case-by-case basis.

6. Water from downspouts may be directed to other BMP practices and use/location would be determined by the type of alternative practice.

6-0400 STORMWATER RUNOFF QUALITY CONTROL CRITERIA (38-93-PFM, 116-14-PFM)

6-0401 General Information and Regulations

6-0401.1 In compliance with the Virginia Stormwater Management Act, Article 1.1 (§ 10.1-603.1, *et seq*.) of Chapter 6 of Title 10.1 of the Code of Virginia and the Virginia Stormwater Management Program (VSMP) Regulations (4VAC50-60 *et seq*.), the Board has adopted Chapter 124 (Stormwater Management Ordinance) of the County Code. The Stormwater Management Ordinance establishes requirements for managing stormwater and procedures whereby those requirements shall be administered and enforced. These requirements are intended to protect property, state waters, stream channels, and other natural resources from the potential harm of unmanaged stormwater. Requirements for water quality controls are included in the Stormwater Management Ordinance.

6-0401.2 The Board has established a Water Supply Protection Overlay District (WSPOD) in the Occoquan Watershed to prevent water quality degradation of the Occoquan Reservoir due to pollutant loadings within the watershed. WSPOD boundaries have been established on the Official Zoning Map. Use limitations are established which require that there shall be water quality control measures designed to reduce the projected phosphorus runoff by at least one-half for any subdivision or use requiring site plan approval unless a modification or waiver is approved by the Director. Requirements for water quality controls in the WSPOD from the Zoning Ordinance have been incorporated in the Stormwater Management Ordinance.

6-0401.3 The Board has established Chesapeake Bay Preservation Areas (CBPAs) consisting of RPAs and RMAs throughout the entire County to protect the quality of water in the Chesapeake Bay and its tributaries (Chapter 118 of the County Code). RPA and RMA components are identified in § 118-1-7 of the County Code. Performance criteria have been established which require that there shall be water quality control measures designed to prevent a net increase in nonpoint source pollution from new development based on average land cover conditions and to achieve a 10 percent reduction in nonpoint source pollution from development of previously developed land. For purposes of § 6-0400 *et seq*., the average land cover condition is 18 percent imperviousness. Compliance with the requirements of the Stormwater Management Ordinance shall be considered to meet the stormwater management requirements of Chapter 118.

6-0401.4 The Board has also adopted stormwater runoff quality control requirements with certain approved rezoning and special exception applications.

6-0401.5 The water quality control measures described in § 6-0000 *et seq*. are called Best management practices (BMPs). The term BMP means schedules of activities, prohibitions of practices, including both structural and nonstructural practices, maintenance procedures, and other management practices to prevent or reduce the pollution of surface waters and groundwater systems from the impacts of land-disturbing activities.

6-0402 Stormwater Quality Control Practices. BMP requirements are incorporated into the stormwater management program in the following manner:

6-0402.1 The Director may require the control of off-site areas draining to proposed BMPs which would not operate at the listed phosphorus removal efficiency, because of hydraulic overloading, if these areas were left uncontrolled.

6-0402.2 The state has developed design specifications and total phosphorus removal efficiencies for the 15 BMPs listed below (available on the Virginia Stormwater BMP Clearinghouse web site). BMPs shall be designed in accordance with the state design specifications except as modified herein. Whenever any provision of the PFM imposes a different standard than the state design specifications, the PFM standard shall be followed except that all designs must utilize elements of the state design specifications (e.g. sizing criteria) necessary to assure that the state's assigned total phosphorus removal is not compromised as determined by the Director. In this regard, attention is specifically directed to the dam standards, soils testing, and maintenance provisions of the PFM which shall be adhered to for all designs. The use of the term "should" is normally considered to be permissive and not mandatory. Where the state standards use the term "should" with respect to design parameters, features, and use limitations, designers may be required to provide justification for not following these recommended guidelines.

6-0402.3 For purposes of § 6-0400 *et seq*., the following standard BMPs are accepted:

6-0402.3.A(1) Rooftop Disconnection

6-0402.3.A(2) Sheet Flow to a Vegetated Filter Strip or Conserved Open Space

6-0402.3.A(3) Soil Compost Amendment

6-0402.3.A(4) Reforestation

6-0402.3.A(5) Vegetated Roof

6-0402.3.A(6) Rainwater Harvesting

6-0402.3.A(7) Permeable Pavement

6-0402.3.A(8) Infiltration Practices

6-0402.3.A(9) Bioretention

6-0402.3.A(10) Vegetated Swales (grass channels and dry swales.)

6-0402.3.A(11) Wet Swale

6-0402.3.A(12) Filtering Practices

6-0402.3.A(13) Constructed Wetland

6-0402.3.A(14) Wet Pond

6-0402.3.A(15) Extended Detention Pond

6-0402.3B Manufactured BMPs. The Virginia Stormwater BMP Clearinghouse web site also lists Manufactured BMPs that have been assigned phosphorous removal efficiencies by the state. These BMPs also may be used to meet water quality control requirements subject to review and approval by the Director. Review and approval by the Director is required so that the manufacturer's design, construction, and maintenance requirements can be evaluated for conflicts with County design, construction, and maintenance requirements and use limitations. Requests for review and approval should be submitted by the manufacturer and shall include the following:

1. Approvals from the Virginia Department of Environmental Quality (DEQ);
2. Technical details with research data supporting efficiencies including any and all materials provided to the clearinghouse for review;
3. Maintenance considerations and program (private maintenance will generally be required for manufactured BMP facilities);
4. Any safety considerations;
5. Aesthetic considerations;
6. Location and interaction with populated areas;
7. Pest control program, if required;
8. Special construction details and specifications, if needed;
9. Typical construction costs;
10. Typical maintenance costs.

6-0402.4 Other innovative BMP measures which have not been approved by the state may be used to meet proffers or development conditions that exceed the minimum requirements of the Stormwater Management Ordinance, but shall not be used to meet the minimum water quality control requirements in § 124-4-3 of the County Code. A request for use of these techniques will be reviewed on a case by case basis and approved by the Director as appropriate. The developer must provide full details and supporting data including:

1. Justification;
2. Technical details with research data supporting efficiencies;
3. Maintenance considerations and program (private maintenance will generally be required for innovative BMP facilities);
4. Any safety considerations;
5. Aesthetic considerations;
6. Location and interaction with populated areas;
7. Pest control program, if required;

8. Estimated construction cost;
9. Estimated 20-year maintenance cost.

For innovative BMPs located in residential areas that will be maintained by Homeowner Associations (HOAs) with limited resources, the Director may require the developer to transfer sufficient funds to the HOA prior to bond release to cover a 20-year maintenance cycle. These funds shall not be available for use until after bond release.

6-0402.5 The Director may preclude the use of any BMP otherwise allowed, or require more stringent conditions upon its use, for a specific land-disturbing project based on a review of the stormwater management plan and project site conditions. Such limitations shall be based on site-specific concerns.

6-0402.6 Assigned efficiencies apply only to the portion of the site served by each practice; however, credit may be allowed for control of runoff pollution from off-site areas.

6-0402.7 Developers, in coordination with DPWES, are strongly encouraged to seek cooperation with other planned developments in their watershed area in order to construct combined facilities which could serve several developing sites. This regional approach to stormwater management would result in facilities that are not only efficient in terms of stormwater quality control, but are also cost effective and land saving.

6-0402.8 The following information is required on all site and subdivision plans to demonstrate compliance with the water quality control requirements of § 6-0000 *et seq*.

6-0402.8A A brief narrative summarizing how water quality control requirements are being provided for the site.

6-0402.8B A map showing all subareas used in the computations of weighted average "C" factors, BMP storage, and phosphorus removal including off-site areas, open space, and uncontrolled areas.

6-0402.8C Open space used for BMP credit (e.g., reforested areas, conserved open space, etc.) should be delineated on the plan sheets with the note "Water quality management area. BMP credit allowed for open space. No use or disturbance of this area is permitted without the express written permission of the Director of the Department of Public Works and Environmental Services."

6-0402.8D Computations used to determine BMP outflow rates and size outlet structures.

6-0402.8E Computations of BMP facility storage requirements.

6-0402.8F Computations of BMP phosphorus reduction for the site demonstrating compliance with the water quality control requirements of Article 4 of Chapter 124 of the County Code using

the Virginia Runoff Reduction Method Worksheet, or equivalent method, as approved by the Director. In applying the Virginia Runoff Reduction Method, an annual rainfall value of 43 inches shall be used.

6-0402.8G Statement of maintenance responsibility for the BMPs (public or private). Additional information may be required by the Director to justify use of nonstandard designs or in unusual situations.

6-0402.8H If an operator intends to meet the requirements established in § 124-4-2 of the County Code through the use of off-site compliance options, then a letter of availability from the off-site provider must be included.

6-0500 POLICY ON OFF-SITE DRAINAGE IMPROVEMENTS

6-0501 Purpose and Intent. In the interest of public health, safety and welfare when the appropriate land use has been determined for any area to be developed, the Director may require the developer to show that off-site downstream drainage can be accommodated (considering the planned development of the contributing watershed) without damage to existing facilities or properties before such development is approved for construction.

6-0502 General Policy (36-92-PFM, 118-15-PFM)

6-0502.1 The County's pro rata share program for off-site drainage improvements involves assessing new development and redevelopment for a proportionate share of the cost of off-site drainage improvements. It provides the County a funding source for the portion of the cost of drainage improvements necessitated by the increased runoff from new development and redevelopment. Offsetting environmental impacts caused by local increases in runoff has far-reaching implications. Restoration needs for the Potomac River and the Chesapeake Bay are caused in part by increased runoff from the surrounding counties and states as well as the County as a whole. From this standpoint, the general drainage improvement program implemented in Fairfax County is viewed as a single, consolidated effort towards restoring these important natural resources. To this end, the County shall require pro rata share contributions for off-site storm drainage improvements as part of its general drainage improvement program.

6-0502.2 The County's general drainage improvement program is a tabulation of all the capital drainage improvement projects and their associated costs that are eligible for pro rata share funding. Specifically included are projects that mitigate flooding and environmental stream degradation caused by land disturbing activities that increase impervious cover. Also included are projects and studies related to the development of County watershed management plans. The inventory of included projects is not static over time. Projects are removed as they are completed and projects are included as they are identified. The majority of projects within the County's general drainage improvement program are from the County's adopted watershed management plans. Projects that address routine maintenance are not included in the general drainage improvement program as they are not necessitated by development or redevelopment.

6-0502.3 Pro rata share payments shall be reduced using the crediting system described in § 6-0605 and are based on a development meeting normal on-site stormwater management requirements.

6-0502.4 Pending the availability of pro rata share monies, developer costs for construction of drainage improvements available for off-site drainage such as, but not limited to, the implementation of a regional detention pond may be considered for a pro rata share assessment reduction and/or reimbursement. Developer reimbursement will be facilitated only by written agreement executed with the Board prior to construction plan approval. The developer's maximum amount of a pro rata share assessment reduction and/or reimbursement will be limited to the developer costs which are over and above the normal costs that would be incurred in

developing the property. Subject to available funding, the maximum amount of annual pro rata share reimbursement to a developer would be established in the reimbursement agreement. Pro rata share reimbursements will start after completion of the drainage improvements by the developer and acceptance of the improvements by the County. The reimbursements will continue for a maximum of 15 years pursuant to the written agreement.

6-0600 POLICY ON PROPORTIONATE COST OF OFF-SITE DRAINAGE IMPROVEMENTS (118-15-PFM)

6-0601 General Requirements

6-0601.1 (36-92-PFM) Development involving a change of land use therein normally results in an increase in impervious areas resulting in a greater quantity as well as a more rapid and frequent concentration of stormwater runoff and the discharge of pollutants associated with the development.

6-0601.2 (36-92-PFM) The construction of storm drainage improvements is required as development progresses to alleviate flood damage, arrest deterioration of existing drainageways and minimize environmental damage to the receiving waters within Fairfax County as well as the Potomac River and the Chesapeake Bay.

6-0601.3 The extent and character of such improvements shall be designed to provide for the adequate correction of deficiencies.

6-0601.4 The purpose and intent is to require a developer of land to pay a pro rata share of the cost of providing reasonable and necessary drainage facilities, as identified in the general drainage improvement program of Fairfax County, located outside the property limits of the land owned or controlled by the developer, but necessitated or required, at least in part, by the construction or improvement of his subdivision or development. The collected pro rata share payments, aggregated County-wide, will fund the drainage facilities needed to minimize environmental damage to the receiving waters within Fairfax County as well as the Potomac River and the Chesapeake Bay.

6-0602 Pro Rata Share Studies (36-92-PFM)

6-0602.1 The Director of DPWES or a designee shall study and compute the total estimated cost of the general drainage improvement program projects required to serve the County when the County is fully developed in accordance with the adopted comprehensive land use plan or the current zoning of the land, whichever is higher.

6-0602.2 The total estimated cost of projects within the general drainage improvement program shall include design, land acquisition, utility relocation, construction, and administrative costs.

6-0602.3 When this cost is computed it shall be updated annually by applying the Engineering News Record Construction Cost index value to project and study costs contained within the general drainage improvement program.

6-0603 General Drainage Improvement Program (36-92-PFM). The pro rata share of the total cost of the general drainage improvement program shall be determined as follows:

6-0603.1 The County shall determine the estimated volume and velocity of stormwater runoff, expressed as impervious area, for the County when fully developed in accordance with the adopted comprehensive land use plan or the current zoning of the land within the County, whichever is higher.

6-0603.2 The total estimated cost of the general drainage improvement program for the County divided by the impervious area for the County when fully developed in accordance with the adopted comprehensive land use plan or the current zoning of the land within the County, whichever is higher, shall be computed by the County to determine the pro rata share assessment rate.

6-0603.3 The developer shall provide the computations showing the increase in impervious area for the development within the County as part of plan submittal requirements including, but not limited to, the submittal of subdivision construction plans, site plans, infill lot grading plans, conservation plans, rough grading plans and public improvement plans. The County will compute the developer's base pro rata share assessment by multiplying the pro rata share assessment rate by the increase in impervious area for the development. The pro rata share assessment rate is available from Land Development Services, DPWES.

6-0604 Pro Rata Share Payments (36-92-PFM)

6-0604.1 The payment of the pro rata share assessment shall be due prior to the approval of plans including, but not limited to, subdivision construction plans, site plans, infill lot grading plans, conservation plans, rough grading plans and public improvement plans.

6-0604.2 When development occurs in a subdivision which has been previously approved and where no pro rata share assessment has been paid, or where a landowner is improving an existing lot which results in an increase in impervious area, the payment of the pro rata share assessment shall be made before the issuance of any building permits, in accordance with State and County codes.

6-0604.3 The pro rata share assessments received prior to the Board of Supervisors' adoption of pro rata share amendments creating a single County-wide rate shall be kept in separate accounts for each of the watershed improvement programs until such time as they are expended for the watershed improvement program.

6-0604.4 Payments received after the Board of Supervisors' adoption of amendments creating a single County-wide rate shall be expended only for the established general drainage improvement program. Any interest that accrues on such payments shall accrue to the benefit of the County.

6-0605 Pro Rata Share Credits

6-0605.1 Pro rata share payments shall be reduced by using the crediting system described herein. For the purposes of this section, the term "on-site" is defined to include sites that are part of a larger common plan of development or sale.

6-0605.2 Credit for fully meeting water quality regulations using on-site BMPs. A developer meeting or exceeding the required water quality regulations through the use of approved on-site BMPs shall receive a credit so as to reduce the developer's pro rata share assessment. The maximum credit will be a percentage of the developer's base pro rata share assessment. The maximum-credit percentage will be recalculated annually by the County based on the projects in its general drainage improvement program related to improving water quality.

6-0605.3 Credit for partially meeting water quality regulations using on-site BMPs. A developer complying with water quality regulations through the acquisition of nutrient offset credits shall not receive a pro rata share credit for the offset portion. The credit amount calculated using the procedure in § 6-0605.2 shall be limited to an amount proportional to the phosphorus load reduction achieved on-site as compared to the phosphorus load reduction required to be fully compliant.

6-0605.4 Credit for providing water quantity retention using on-site stormwater management. A developer providing on-site water quantity retention through the use of approved on-site stormwater management shall receive a credit so as to reduce the developer's pro rata share assessment. The County will calculate the credit by multiplying the total number of rainfall inches retained on-site by an annually determined rate. The maximum credit will be limited to the retention of the 100-year storm. The rate for this credit will be recalculated each year by the County based on the projects in its general drainage improvement program related to managing water quantity.

6-0605.5 Credit will not be provided for a development that is fully exempt from providing on-site water quality or water quantity controls.

6-0605.6 Pro rata share assessment payment reduction. The total allowed credit is the summation of both the credit for water quality and the credit for water quantity. The developer's final pro rata share assessment will be an amount equal to the base pro rata share assessment minus the total allowed credit received.

6-0700 POLICY ON WHAT MAY BE DONE IN FLOODPLAINS

6-0701 Applicability

6-0701.1 In the interpretation of Part 9 of Article 2 of the Zoning Ordinance and in recognition of the County's desire to participate in the National Flood Insurance Program, it is the intent of § 6-0000 *et seq*., that the following goals be met:

6-0701.1A The preservation of the hydraulic and flood carrying capacity within the altered or relocated portion of the natural channel of any adopted floodplain;

6-0701.1B The preservation of the storage characteristics of floodplains, and

6-0701.1C The preservation of the natural environment.

6-0701.2 Therefore, some improvements which will accommodate the increased runoff from changes or improvements within the watershed without unacceptably elevating floodplain or stream levels may be needed within floodplains, streams and/or drainageways, particularly within improved or developed areas.

6-0701.3 The improvements may take the form of piping or channelization with concrete, riprap, or gabions; streambed clearing; removal of obstructions; reduction of constrictions; stabilization of stream bottoms and/or banks to eliminate or reduce erosion; widening, deepening or realigning of streams. The objective of such improvements is to provide the necessary hydraulic characteristics to accommodate the anticipated stormwater flow without damaging adjacent properties.

6-0702 Alteration of Floodplains

6-0702.1 Where there is a major alteration or relocation of the natural channel of a floodplain depicted on the adopted Flood Insurance Rate Map, the Federal Insurance Administrator, the Virginia Department of Conservation and Recreation, and affected adjacent political jurisdictions shall be notified.

6-0702.2 Improvements shall include the removal of silt and debris which may clog or damage downstream drainage structures or property and the filling or draining of ponding areas and stagnant pools which are potential vermin shelters and mosquito breeding areas.

6-0702.3 The decision to perform any of the above must be in conformance with the Zoning Ordinance, Chapter 118 (Chesapeake Bay Preservation Ordinance) of the Code, and with PL 92-500, Section 404 Permit Program as administered by the COE.

6-0702.3A The intent of the Federal law is to "…insure that the chemical/biological integrity of waters of the United States is protected…."

6-0702.3B Section 404 applies to the bed and banks of navigable waterways as defined in the Federal Register, Volume 40, Number 144, Part IV, dated July 25, 1975; and to the adjacent wetlands, effective in June 1977.

6-0703 Use Regulations in Floodplain Areas (86-04-PFM)

6-0703.1 All newly proposed subdivision lots located in or adjacent to a floodplain must contain sufficient area of land above the 100-year floodplain to allow a residence to be constructed thereon, taking into consideration the minimum yard requirements of the Zoning Ordinance.

6-0703.2 No part of any building lot in a cluster subdivision may extend into a floodplain, except as provided in Part 6 of Article 9 of the Zoning Ordinance for cluster subdivisions in the R-C, R-E and R-1 Districts and cluster subdivisions in the R-3 and R-4 Districts which have a minimum district size of 2 acres but less than three-and-one-half acres, and Part 9 of Article 2 of the Zoning Ordinance and § 101-2-8 of the Code for cluster subdivisions in the R-2 District and cluster subdivisions in the R-3 and R-4 Districts which have a minimum district size of three-and-one-half acres or greater. No clearing or grading in the floodplain shall be permitted, except as provided for in Parts 6 and 9 of Article 2 of the Zoning Ordinance.

6-0703.3 The lowest part of the lowest floor of any such residence must be at least 18 inches above the 100-year flood level.

6-0704 Floodplain Development Standards. All development permitted in the floodplain area shall, at a minimum, comply with all applicable Federal and State laws and the following standards, except that the Director may impose more restrictive standards which may be warranted by the specific conditions.

6-0704.1 The developer must provide factual information that any proposed structure will not adversely affect the existing 100-year flood level; and that adequate emergency access is available to the structure during periods of maximum flooding. The applicant must specify the 100-year water surface elevation(s) on the plan.

6-0704.2 The lowest part of the lowest floor level of any proposed residential structure must be located at least 18 inches above the 100-year water surface elevation and a minimum horizontal distance of 15 feet must be provided between the 100-year water surface and the structure proper.

6-0704.3 Non-residential structures, or parts thereof, where permitted, may be constructed below the regulatory flood elevation provided that these structures are designed to preclude and/or withstand inundation to an elevation of at least the regulatory (100-year) flood elevation. The submitting engineer or architect shall specify the elevation and certify that the structure has been floodproofed, and that the elevation and flood-proofing comply with applicable Federal and State requirements.

6-0704.4 Compensatory excavation normally will be required for fills unless waived for environmental reasons.

6-0705 Warning and Disclaimer of Liability

6-0705.1 The degree of flood protection required by the PFM is considered reasonable for regulatory purposes. Larger floods may occur on rare occasions or flood heights may be increased by man-made or natural causes, such as bridge openings restricted by debris.

6-0705.2 Therefore, § 6-0000 *et seq*., does not imply that areas outside the floodplain areas, or land uses permitted within such areas, will be free from flooding or flood damages under all conditions.

6-0705.3 Additionally, the grant of a permit or approval of a site, subdivision or land development plan in an identified floodplain area or flood hazard area shall not constitute a representation, guarantee, or warranty of any kind by any official or employee of the County of the practicability or safety of the proposed use, and shall create no liability upon the County, its officials or employees.

6-0705.4 In the event that the Director issues a permit under the provisions of the PFM, the applicant may be asked to execute an agreement holding the County harmless from the effects caused by the construction or existence of the permitted use. Such an agreement shall be recorded among the land records of the County.

6-0800 HYDROLOGIC DESIGN

6-0801 Acceptable Hydrologies (27-89-PFM, 116-14-PFM)

Table 6.4 Acceptable Hydrologies – Applications

Name of Hydrology	200 Acres and Under	Over 200 Acres	Retention/Detention Facilities
NRCS*	X	X	X
Rational Formula	X	O	X***
Anderson Formula	O	X	O
Other**	X	X	X

X = Acceptable hydrology
O = Unacceptable hydrology
* = Recommended hydrology
** = With approval of the Director
*** = Watersheds less than 20 acres only, provided that the "C" factor for the unimproved areas does not exceed 0.15 on storm frequencies of 2 years or less.

6-0802 NRCS Hydrology (27-89-PFM, 116-14-PFM, 122-16-PFM)

NRCS Hydrology consists of Technical Release Number 20 (TR-20), Technical Release Number 55 (TR-55), NRCS National Engineering Handbook (NEH) Part 630, and associated software applications including the COE HEC-1 and HEC-HMS software. This hydrology is preferred and acceptable for all applications except where prior floodplain studies for adopted floodplains used the Anderson Formula. Supplemental Curve Number (CN) values developed for certain runoff reduction practices are provided herein. The NOAA_C 24-hour rainfall distribution shall be used with NRCS Hydrology (Plates 47A-6, 47B-6, & 48-6).

6-0802.1 Vegetated Roofs. For hydrologic computations using NRCS methods, the following CN values shall be used: 64 for the 1-year storm; 66 for the 2-year storm; 72 for the 10-year storm; and 75 for the 100-year storm. Other values may be approved by the Director, depending on the composition and depth of the growth media and the slope of the roof, upon submission of a hydrologic analysis of the water retention capacity of the system.

6-0803 Rational Formula (47-95-PFM, 116-14-PFM, 122-16-PFM)

The Rational Formula, $Q = C_fCIA$, is acceptable for the determination of peak flows for drainage areas of 200 acres and under, except it is not authorized for designing detention/retention facilities with drainage areas greater than 20 acres. The Rational Formula (i.e., Modified Rational Method) may be used for the design of detention/retention facilities of 20 acres and less provided that the "C" factor for unimproved areas does not exceed 0.15 on storm frequencies of 2 years or less and

the facility is in full compliance with all other requirements of § 6-1600 *et seq*. The product of C_f x C should not exceed 1.0.

Q = Rate of runoff (cfs)
C_f = Correction Factor for ground saturation
C = Runoff Coefficient (ratio of runoff to rainfall)
I = Rainfall Intensity (in./hr.)
A = Area of drainage basin (acres)

<u>C_f Values</u>
1.0 - 10-year or less
1.1 - 25-year
1.2 - 50-year
1.25 - 100-year

6-0803.1 Runoff Coefficient (C) used to compute flow to the point of interest shall be the composite of the "C" factors for all the areas tributary to the point of interest. Table 6.5 gives the runoff coefficients to be used for the different zoning classifications. For cluster areas and when clay soil is encountered the higher values of "C" shall be used.

6-0803.2 (27-89-PFM, 122-16-PFM) Rainfall Intensity (I) shall be determined from the rainfall frequency curves shown in Plate 3A-6 or the table in Plate 3B-6. The 2-hour unit hydrographs in Table 6.6 and the 2-hour rainfall distributions in Table 6.18 shall be used for the design of detention facilities unless other unit hydrographs or rainfall distributions are approved by the Director as appropriate for specific applications. When using the Modified Rational Method in determining the required storage volume for detention facilities, an iterative process is normally used to determine the critical storm duration and hydrograph that results in the maximum storage volume to be detained. For ease of application and uniformity in design of detention facilities, use of the unit hydrographs in Table 6.6 replaces that iterative process. The 10-year storm frequency shall be used to design the storm drains (minor drainage systems); the 100-year storm frequency shall be used to design the drainageways of the major drainage system.

6-0803.3 Time of Concentration (t_c) is the sum of the inlet time plus the time of flow in the conduits from the most remote inlet to the point under consideration. Flow time in conduits may be estimated by the hydraulic properties of the conduit. Inlet time is the time required for the runoff to reach the inlet of the storm sewer and includes overland flow time and flow time through established surface drainage channels such as swales, ditches and street gutters.

6-0803.3A Recommended inlet times are also shown in Table 6.5.

6-0803.3B Storm drainage systems may be designed based on zoning classification or type of surface. In general, when designing drainage facilities based on type of surface, the runoff coefficient for each inlet is selected as follows:

$$C = \frac{A_1C_1 + A_2C_2 + \ldots + A_nC_n}{A_1 + A_2 \ldots + A_n}$$

Where:
$A_1, A_2 \ldots A_n$ = Areas of different surfaces
$C_1, C_2 \ldots C_n$ = Runoff coefficients for different types of surface

Select inlet time from Table 6.5 based on C value.

6-0803.3C If an inlet time must be estimated, the following are suggestions to assist the designer:

6-0803.3C(1) (116-14-PFM) Estimate the overland flow time, time for runoff to reach established surface drainage channels such as street gutters and ditches. Plate 4-6 can be used for overland flow.

6-0803.3C(2) Estimate the time of flow through the established surface drainage channels from the channel's hydraulic properties. Plate 5-6 can be used for streets and parking lots that have curb and gutter. The Mannings Equation or methods described in § 6-1000 *et seq*., can be used for swales and ditches.

6-0803.3C(3) Specific procedures of estimating inlet times for use with NRCS hydrology are provided in the NRCS TR-55 manual, "Urban Hydrology for Small Watersheds."

6-0803.3D Judgment should be used in estimating time of concentration or any portion of time of concentration. Often the initial inlet time may be based on the first few inlet areas.

6-0803.3D(1) If the uppermost area has low runoff rates with long times of concentration (such as parks and cemeteries) and major portions of the lower area have high runoff rates with short times of concentration, then the first inlet time may not necessarily be based solely on its own land use.

6-0803.3D(2) The above statements also would be true of the converse case; that is, the uppermost area producing high runoff rates with short times of concentration and the lower areas producing low runoff rates with long time of concentration.

6-0803.4 Area (A). Areas shall be determined from field run topography, current USGS quadrangle sheets, or County Topographical Maps. Watershed maps showing applicable divides, contributing areas and adopted Comprehensive Plan recommendations or existing zoning, whichever is greater, must accompany all computations.

6-0804 Anderson Formula (27-89-PFM)

The Anderson Formula, $Q = 230\ K\ R\ A^{(x)}\ T^{(-0.48)}$, may be used for rates of runoff for areas greater than 200 acres, except it shall not be used for designing detention/retention facilities. Caution: This method was developed for use in Northern Virginia and Southern Maryland and should not be used in other areas.

Q = Rate of runoff (cfs)
K = Coefficient of imperviousness
R = Flood frequency ratio
A = Drainage basin area (mi^2)
x = Area exponent
T = Lag time (hours)

6-0804.1 Coefficient of Imperviousness (K) is obtained by K = 1.00 + 0.015(I) where I is the percentage of basin area covered with impervious surface. The percentage impervious may be computed or may be taken from Table 6.5. When the drainage basin consists of different percentages of imperviousness then the average percent imperviousness, I_{Avg}, shall be calculated as follows:

$$I_{Avg} = \frac{A_1 I_1 + A_2 I_2 + \ldots + A_n I_n}{A_1 + A_2 + \ldots + A_n}$$

Where:
$A_1, A_2 \ldots A_n$ = Areas of different percentages of imperviousness
$I_1, I_2 \ldots$ In = Percent imperviousness for each area

6-0804.2 Flood Frequency Ratio (R). For a given storm recurrence interval and percent imperviousness, the flood frequency ratio R, is obtained from Plate 6-6.

6-0804.3 Area (A). Areas shall be determined by the latest topographic information. Generally, current USGS quadrangle sheets will be adequate.

6-0804.4 Area Exponent $^{(x)}$

^{x} = 1.0 for areas greater than 200 acres but less than 1 mi^2
^{x} = 0.82 for areas 1 mi^2 and greater

6-0804.5 Lag Time (T) = $Y\ (L/S^{1/2})^z$

Where:
L = Distance in miles along the primary water point of interest to the drainage basin boundary.
S = S is an index of basin slope. It is determined as the average slope, in ft./mi., of the main watercourse between points located 10 percent and 85 percent of the length, L, upstream from the point of interest.
Y, ^{z} = The Y coefficient and z exponent are shown in Plate 7-6.

After computing the length-slope ratio, the lag time, T, may be determined using Plate 7-6.

6-0804.5A The top line shall be used for natural drainage basins, basins with fewer or no storm sewers.

6-0804.5B The middle line shall be used for developed drainage basins, basins where the tributaries are sewered and the main channels are natural and/or rough lined (rubble or grass).

6-0804.5C The bottom line shall be used for completely sewered and developed basins having smooth lined (concrete, brick or metal) main channels.

6-0804.5D The lag time line or equation used shall be based on the planned ultimate development of the drainage basin and main channels.

6-0804.6 Example using Anderson Formula:

6-0804.6A Given:

Area of drainage basin = 1,300 acres
Planned development = school
Length of drainage basin = 1.30 mi.
Elevation at 10% (0.13 mi.) upstream from point of interest = 170.0 ft.
Elevation at 85% (1.10 mi.) upstream from point of interest = 300.0 ft.

Planned drainage: Tributaries will be sewered and main channels will remain natural or grass-lined.

6-0804.6B Design Storm: 10-year frequency storm, $Q = 230\ K\ R\ A^{(x)}\ T^{(-0.48)}$

6-0804.6B(1) K (coefficient of imperviousness) = 1.000 + 0.015 I (%). From Table 6.5, for school development, the percent imperviousness I = 50%.

K = 1.000 + 0.015(50) = 1.75

6-0804.6B(2) R (flood – frequency ratio). From Plate 6-6, for 10-year recurrence interval and 50 percent imperviousness, R = 1.7.

6-0804.6B(3) A (area) = 1,300 acres x 43,560 ft^2/acre x (1 mi./5,280 feet)^2 = 2.03 mi^2

6-0804.6B(4) ^{x} = 0.82 for areas larger than 1 mi^2

6-0804.6B(5) T (lag time) = $Y(L / S^{1/2})^z$

L = length of drainage basin (mi.) from point of interest to upper boundary, L = 1.30 mi.

S (index of basin slope) ft./mi.

S = ((Elev. at 85% L) - (Elev. At 10% L)) / (75% L)

$$S = \frac{300-170}{(.75)(1.30)} = \frac{130\text{ft.}}{.975\text{mi.}} = 134 \text{ ft./mi.}$$

From Plate 7-6: Y=0.9 and ^{Z} = 0.50

$T = 0.9\ (1.30/134^{1/2})^{0.50}$
$= 0.302$

$Q = 230\ K\ R\ A^{(x)}\ T^{(-0.48)}$
$= (230)(1.75)(1.70)(2.03)^{0.82} / (0.302)^{0.48}$
$= 1{,}222.82 / 0.563$
$= 2{,}172$ cfs

6-0805 Other Hydrologies. (27-89-PFM, 122-16-PFM) It is recognized that there are many hydrologies available, especially in the form of computer software. Other hydrologies may be approved by the Director for specific applications provided it is demonstrated that the alternatives are appropriate for the purpose intended.

6-0806 Runoff Coefficients and Inlet Times (Table 6.5) (122-16-PFM)

6-0806.1 The lowest range of runoff coefficients may be used for flat areas (areas where the majority of the grades are 2 percent and less).

6-0806.2 The average range of runoff coefficients should be used for intermediate areas (areas where the majority of the grades are from 2 percent to 5 percent).

6-0806.3 The highest range of runoff coefficients shall be used for steep areas (areas where the majority of the grades are greater than 5 percent), for cluster areas, and for development in clay soils areas.

Table 6.5 Runoff Coefficients and Inlet Times (98-07-PFM, 27-89-PFM, 116-14-PFM)

Zoning Classification	Runoff Coefficients	% Impervious	Inlet Times (minutes)
Business, Commercial & Industrial	0.80 – 0.90	90	5
Apartments & Townhouses	0.65 – 0.75	75	5-10
Schools & Churches	0.50 – 0.60	50	
Single Family Units Lots 10,000 ft^2 Lots 12,000 ft^2 Lots 17,000 ft^2 Lots ½ acre or more	 0.40 – 0.50 0.40 – 0.45 0.35 – 0.45 0.30 – 0.40	 35 30 25 20	10 - 15[1]
Parks, Cemeteries and Unimproved Areas [2]	0.25 – 0.35	15	To be Computed
TYPE OF SURFACE			
Pavements & Roofs	0.90	100	According to zoning classification of composite runoff coefficient
Lawns	0.25-0.35	0	
Open Water[3,4]	0.9	0	
Reforested Areas[2]	0.25-0.35	0	
Vegetated Roofs[4] Extensive Systems Intensive Systems	 0.50 0.40	N/A[5]	
Pervious Pavement[4] Porous Asphalt Pavement Permeable Pavement Blocks Pervious Concrete	 (I-3.0) / I (I-1.0) / I (I-5.0) / I I = peak rainfall intensity (in./hr.)	N/A[5]	

1) However, for design of yard inlets, i.e., locations and throat capacities, in residential areas, drainage computations shall use a 5-minute time of concentration, or alternatively, a site specific calculation to justify usage of a longer time of concentration. Computations for design of pipes may continue to use the 10- to 15-minute time of concentration.

2) For unimproved areas containing less than 5% impervious cover and storm frequencies 2-year or less, use C = 0.10 to 0.20.

3) The runoff coefficient for open water areas such as lakes and streams is set at 0.9 because all rainfall falling on open water is converted directly to runoff. For unimproved areas containing less than a total of 5% open water plus impervious cover, the open water areas may be ignored in computing composite runoff coefficients.

4) Composite runoff coefficients for drainage areas that include significant areas of open water, pervious pavements, or vegetated roofs should not be computed directly from the percentage of impervious area. Use the weighted average of the runoff coefficients to compute the runoff.

5) Values for percent imperviousness have not been assigned to pervious pavement and green roofs. For hydrologic purposes, they respond as pervious or partially pervious surfaces. In determining land use for application of Chesapeake Bay Preservation Ordinance development/redevelopment criteria, they are treated as impervious surfaces.

6-0807 Incremental Unit Hydrograph – 1 Inch of Runoff per Acre (122-16-PFM)

Two-hour unit hydrographs for use with rational formula hydrology are presented in Table 6.6. To use the unit hydrographs, multiply the total rainfall amount (inches) in Table 6.19 for the 2-hour design storm by the rational formula runoff coefficient, including the correction factor for ground saturation, to obtain the runoff (inches). Multiply the runoff (inches) by the unit hydrograph values in Table 6.6 and the drainage area (acres) to generate the hydrograph values (cfs) for the design storm.

Table 6.6 Incremental Unit Hydrograph CFS (122-16-PFM)

TIME (Minute)	t_c=5 Minute	t_c=10 Minute	t_c=15 Minute	t_c=20 Minute	t_c=25 Minute	t_c=30 Minute
5	2.451	1.103	0.754	0.540	0.359	0.259
10	1.582	2.127	1.579	1.003	0.714	0.505
15	1.171	1.638	1.805	1.353	1.036	0.749
20	0.934	1.132	1.506	1.517	1.275	0.984
25	0.775	0.881	1.052	1.328	1.382	1.179
30	0.658	0.721	0.819	0.969	1.299	1.262
35	0.574	0.608	0.676	0.735	1.075	1.176
40	0.502	0.525	0.571	0.610	0.833	1.002
45	0.453	0.456	0.488	0.530	0.643	0.807
50	0.407	0.403	0.421	0.473	0.515	0.649
55	0.373	0.365	0.367	0.432	0.436	0.537
60	0.341	0.329	0.317	0.401	0.389	0.460
65	0.313	0.301	0.290	0.368	0.357	0.422
70	0.285	0.275	0.265	0.335	0.325	0.384
75	0.256	0.247	0.238	0.301	0.292	0.345
80	0.227	0.219	0.212	0.268	0.260	0.307
85	0.199	0.192	0.185	0.234	0.227	0.269
90	0.171	0.164	0.160	0.201	0.195	0.231
95	0.142	0.137	0.132	0.168	0.162	0.191
100	0.114	0.110	0.105	0.133	0.129	0.153
105	0.086	0.083	0.080	0.100	0.097	0.115
110	0.057	0.054	0.052	0.067	0.065	0.077
115	0.028	0.027	0.027	0.034	0.032	0.038
120	0.000	0.000	0.000	0.000	0.000	0.000

6-0900 CLOSED CONDUIT SYSTEM

6-0901 Design Flow (88-05-PFM)

The closed conduit system shall be designed for a 10-year rainfall frequency when its intended use is to function as the minor drainage system. If the system is in the VDOT right-of-way, it should be designed to have no surcharge during the 10-year design storm. Systems in the VDOT right-of-way should be designed for the 50-year storm and checked for the 100-year design storm to prevent flooding of underpasses or other depressed roadways where ponded water can only be removed through the storm sewer system. Design flows shall be determined by methods discussed in § 6-0800 *et seq*., and pipes will be sized by the amount of runoff actually entering the system.

6-0902 Storm Sewer Pipe

6-0902.1 (88-05-PFM) Size of storm sewer pipe may be determined by the Manning Formula which is expressed as:

$$Q = VA = 1.49/n \times r^{2/3} \times S^{1/2} \times A$$

Where:
Q = Quantity of flow (cfs)
V = Velocity of flow (fps)
A = Required area ($ft^{2)}$
n = Coefficient of roughness
r = Hydraulic radius (ft.)

$$r = \frac{\text{Cross-sectional area of flow}}{\text{wetted perimeter}}$$

S = Slope of energy gradient (ft./ft.)
(See § 6-1005)

6-0902.2 Adjustments of pipe sizes as determined by the Manning Formula may be necessary due to hydraulic gradient considerations. The Manning Formula is shown in nomograph form on Plate 8-6. Other guidelines related to size and configuration of storm sewer pipe are as follows:

6-0902.2A (88-05-PFM) Minimum size of pipe to be used outside of the VDOT right-of-way will be 12 inches diameter where the distance between access openings is 50 feet or less and 15 inches diameter where access openings exceed 50 feet. The minimum size of pipe permitted within the VDOT right-of-way is 15 inches unless it is the initial pipe in the system or as a lateral line when necessary. The initial pipe or lateral line in the VDOT right-of-way may be 12 inches provided there is 50 feet or less between access points.

6-0902.2B (42-94-PFM) Pipes shall be designed for flows intercepted by the inlets, with a minimum design for the 10-year storm.

6-0902.2C Pipes 18 inches in diameter and larger may be constructed on horizontal curves. Tables 6.9 thru 6.15 and Plates 10-6, 16-6 through 18-6 provide for the geometric limitation and information to assist in the design of concrete pipes on horizontal curves.

6-0902.2D (88-05-PFM) Except where noted differently under § 6-0902.2A, the maximum length between access openings shall not exceed 300 feet for pipes less than or equal to 42 inches in diameter or 800 feet for pipes greater than 42 inches in diameter. Access opening may be in the form of an inlet, manhole, junction box or other approved appurtenance.

6-0902.2E Prefabricated "T" and "Y" sections may be used under the conditions stated in the "T" and "Y" Standard (Plate 9-6) when approved by the Director.

6-0902.2F Prefabricated bend sections for storm drainage systems are not permitted within VDOT rights-of-way. Any change in horizontal and vertical alignment shall require an access opening. An exception to this is the horizontal curve shown on Plate 16-6. However, use of prefabricated reinforced concrete "T" and "Y" sections shown in Plate 9-6 and bends shown on Plate 10-6 may be approved by the Director.

6-0902.2G (47-95-PFM) In general, there may not be a reduction in pipe size greater than one standard increment along the direction of flow. Within VDOT maintained rights-of-way, reductions may only be allowed when determined by VDOT to be appropriate.

6-0902.2H Minimum cover for storm sewer pipe shall be 24 inches from finish grade to the outside top of pipe, except where approved structural correction is provided when cover requirements cannot be met.

6-0902.2I Minimum easement widths shall be determined as follows:

Table 6.7 Minimum Easement Widths/Pipe Size

Pipe Size, in.	Easement Width, ft.
15 – 18	10
21 – 33	15
36 – 48	20
54 – 72	24

Where multiple pipes are installed, the edge of the easement shall be 5 ft. clear of outside of pipe. Where easements do not generally follow established lot lines, add 5 ft. to the easement width on the side toward the building. No storm drain pipe shall be installed within 5 ft. of the loading plane of a building foundation. Storm sewers to be maintained by DPWES shall be within dedicated storm drainage easements.

6-0902.2J Storm sewers shall be designed to provide an average velocity when running full of not less than 2½ fps.

6-0902.2K The need for concrete anchors must be investigated on storm sewer lines with grades of 20 percent or greater. If anchors are required, the design engineer shall show a detail on the plans with spacing requirements.

6-0902.2L Plain concrete pipe shall conform to the requirements of ASTM Designation C-14 Extra Strength; reinforced concrete pipe shall conform to ASTM Designation C-76 Classes II, III, and IV; a minimum of Class III or equal is required under areas subject to vehicular traffic. Asbestos cement pipe shall conform to ASTM C663-73a, Type II and AASHTO M-217-75.

6-0902.2M When storm sewers are provided, they shall not outfall in the front yard of a lot, but shall be extended at least to within 20 feet of the rear property line in lots up to ½ acre in size and at least 50 feet to the rear of the house on larger size lots. If the storm sewer outfalls on a lot or adjacent to a lot, on which a building exists which will remain, the building must be shown with topography of the area between the building and the outfall. Floor elevations shall be provided, if possible.

6-0902.2N In general, drainage facilities may not be terminated short of the subdivision boundary unless an adequate outfall exists at this point. Deposits may be required for future extension(s) to the subdivision boundary.

6.0902.2O High Density Polyethylene Pipe (HDPE) (101-08-PFM, 78-03-PFM)

6-0902.2O(1) HDPE pipe shall conform to the requirements of AASHTO M 294. The maximum size permitted is 48 inches.

6-0902.2O(2) Joints shall be watertight meeting a pressure test of 10.8 psi per ASTM D 3212 and use a bell and spigot design with a rubber gasket meeting the requirements of ASTM F 477, "Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe." These joints are designed to prevent infiltration of soil and exfiltration of storm water.

6-0902.2O(3) Installations and pipe cover shall be in accordance with ASTM D 2321-"Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications", the manufacturer's recommendations and VDOT standards, whichever are more stringent. Pipe bedding and backfill shall conform to the standards set forth in Plate 93-6.

6-0902.2O(4) Filter fabric shall surround the aggregate fill material when there is a high water table or where the movement of groundwater can cause the migration of fines from the soil envelope. Provide an overlap of 2 feet minimum. Use non-woven geotextile fabric with AOS of 70-100 US Sieve or 0.22 mm – 0.15 mm as determined by ASTM D 4751 and a trapezoidal tear strength of 45 LB as determined by ASTM D 4533. Geotextile fabric shall not be exposed to direct sunlight for more than 24 hours prior to installation.

6-0902.2O(5) The installer shall use flexible waterstops, resilient connections, or other flexible systems to make watertight connections to manholes and other structures in accordance with ASTM F 2510/F 2510M, "Standard Specification for Resilient Connectors Between Reinforced Concrete

Manhole Structures and Corrugated High Density Polyethylene Drainage Pipes", or ASTM C923 "Standard Specifications for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes and Laterals" such as A-LOK, KOR-N-Seal, or approved equal. Grouting between the thermoplastic pipe and the manhole and other structures shall not be permitted.

6-0902.2O(6) All pipes shall undergo inspection and deflection testing during and after installation to ensure proper performance in accordance with § 2-0502.

6-0903 Pipe and Culvert Materials

Pipe and culvert materials acceptable for storm drain construction with the accompanying roughness coefficients are shown below:

Table 6.8 Pipe And Culvert Materials – Roughness Coefficients (101-08-PFM, 78-03-PFM)

Material	Manning "n"
Plain Concrete Culvert Pipe (PCCP)[2]	.013
Non-Reinforced Concrete Sewer Pipe (NRCSP)[2]	.013
Reinforced Concrete Culvert Pipe (RCCP)	.013
Reinforced Concrete Sewer Pipe (RCSP)	.013
Vitrified Clay Pipe, Extra Strength (VCPX)	.013
Cast Iron Pipe (CIP)	.013
Asbestos Cement Pipe (ACP)[3]	.012
Corrugated Plain Metal Pipe (CMP)[1]	.024
25% Paved	.021
50% Paved	.018
100% Paved	.013
High-Density Polyethylene Pipe (HDPE)[4]	.012

[1]Corrugated metal pipe is approved for use at residential driveway entrances, temporary installations, and privately maintained detention systems. Except for the above uses, this type of pipe may be used only when approved by the Director. In approving the use of CMP, the Director may apply certain conditions to provide for inspection and testing in accordance with AASHTO's standards, including deflection testing.

[2]Plain Concrete Culvert Pipe (PCCP) and Non-Reinforced Concrete Sewer Pipe (NRCSP) shall conform to the VDOT Road and Bridge Specifications. Pipe sizes 12 in. through 24 in. are permitted.

[3]VDOT accepts use of asbestos cement pipe under the following conditions:

Maximum size permitted in VDOT's right-of-way is 24 in.

Use is approved by the County.

VDOT shall be furnished details of the location of each installation. An extra set of those sheets of the plan showing the location of the pipe shall be required.

[4]High Density Polyethylene pipe shall conform to the classification Type S.

6-0904 Energy and Hydraulic Gradients (See Plate 12-6)

The hydraulic gradient for a storm sewer system is a line connecting points to which water will rise in manholes and inlets throughout the system during the design flow. The energy gradient is a line drawn a distance $V^2/2g$ above the hydraulic gradient of the pipes.

6-0904.1 At storm sewer junctions the total energy loss at the junction, H_L, is the difference in elevation between the energy grade lines of the upstream and downstream pipes. To establish these gradients for a system, it is necessary to start at a point where the hydraulic and energy gradients are known or can readily be determined.

6-0904.2 Generally, when the energy and hydraulic gradients must be determined, the pipes are assumed to have uniform flow. For uniform gravity flow and for pressure flow, the friction loss in storm sewer pipes may be determined by the Manning Formula as follows:

$$h_f = SL = [(nV)^2 / 2.208r^{1.33}]\ L$$

Where:
h_f = Friction loss in pipe (ft.)
S = Slope of the energy grade line
n = Roughness coefficient
V = Discharge velocity (fps)
r = Hydraulic radius (ft.)
L = Length of line (ft.)

6-0904.3 Few design situations will ever require determination of energy and hydraulic gradients for non-uniform flow conditions. Should non-uniform flow analysis be necessary, designers are referred to standard hydraulic texts for determining gradients for non-uniform flow.

6-0904.4 Where a proposed drainage system is connected to an existing drainage system the hydraulic gradient at the point of junction shall be determined from the hydraulic gradient computation of the existing system on file with DPWES.

6-0904.5 The total energy losses at a junction, H_L, is assumed to be made up of one or more of the following losses:

6-0904.5A Expansion loss, h_i, when stormwater enters the junction.

6-0904.5B Contraction loss, h_o, when stormwater leaves the junction.

6-0904.5C Bend loss, h_Δ, due to the change in horizontal direction of stormwater velocity.

These losses may be estimated as follows:

$$H_L = h_i + h_o + h_\Delta = 0.1\,\frac{V_i^2}{2g} + 0.5\,\frac{V_o^2}{2g} + K_\Delta\,\frac{V_i^2}{2g}$$

Where:
H_L = Total Energy Loss
h_i = Expansion Loss (flow in to junction)
h_o = Contraction Loss (flow out of junction)
h_Δ = Bend Loss
V_i = Velocity in fps, Q/A, of upstream pipe
V_o = Velocity in fps, Q/A, of downstream pipe
Δ = Horizontal angle in degrees between the direction of flow of incoming and outgoing pipes
K_Δ = Bend loss coefficient (see Plates 13-6 and 14-6)

6-0904.6 Considerable judgment must be used when applying the above energy loss equations. Some general rules to be used when applying these equations are as follows:

6-0904.6A When two or more pipes discharge into a manhole or inlet type structure, the expansion loss for the junction shall be calculated for the pipe discharge that produces the maximum momentum.

6-0904.6B When two or more pipes discharge into a manhole or inlet type structure at different angles of flow with the outgoing pipe, the junction bend loss shall be calculated for the pipe discharge that produces the maximum momentum.

6-0904.6C Prefabricated "T," "Y," and bend sections are assumed to have bend losses only.

Momentum may be determined as follows: $M = Q(w/g)V$

Where:
M = Momentum
Q = Pipe discharge (cfs)
w/g = Density of water (62.4 lbs./$ft^{3)}$
V = Discharge velocity (fps)

6-0904.7 Since the density of water can be considered constant, the pipe discharge with the largest product, QV, will have the maximum momentum.

6-0904.8 The energy loss for the initial inlet(s) of a storm sewer system may be assumed to be 0.3 times the velocity head in the outlet pipe.

6-0904.9 The above energy loss formulas can be readily solved with the use of Plate 14-6 and a transparency made to conform to Plate 13-6.

6-0904.10 Non-pressure Flow. Storm sewer systems generally shall be designed as non-pressure systems. In general, if a drop in the structure between the inverts of the incoming and outgoing pipes is approximated by a value equal to or greater than the junction energy loss, the system can be assumed to be non-pressure flow.

6-0904.11 Pressure Flow. Storm sewer systems may be designed for pressure flow; however, all proposed pressure flow systems should be coordinated with DPWES in the preliminary design stage. The hydraulic gradient for the design flows shall be at least 1 foot below the established ground elevation and no more than 5 feet above the crown of the pipe. For curb opening inlets the gutter flow line is considered the established ground elevation.

6-0904.12 Drop. If possible, the energy losses through a junction should be accounted for by a drop across the junction. The equations on Plate 15-6 show the method for computing the drop.

6-0905 Closed Conduit Design Calculations

In general, design calculations required for submittal to the Director are as follows:

6-0905.1 A copy of the drainage plan showing drainage divides, contributing areas and adopted Comprehensive Plan recommendation or existing zoning, whichever is higher.

6-0905.2 Stormwater runoff quantities.

6-0905.3 Pipe design calculations:

6-0905.3A For storm sewer systems or portions of systems designed for pressure flow, a storm sewer profile with energy and hydraulic gradients drawn on it shall be submitted for the portion of the system that experiences pressure flow.

6-0905.3B Energy and hydraulic gradients do not need to be submitted for non-pressure systems.

6-0905.4 Energy loss calculations at storm sewer junctions.

6-0906 Minimum Radius of Curvature for Concrete Pipeline

The following seven tables are based on Plate 16-6 equations (1) and (2) and present the radius of curvature for joint openings from 1/8-inch through 1½- inches. As illustrated in Plate 16-6, Figure 2, when concrete pipe is installed on curved alignment using deflected straight pipe, the point of curve (PC) is at the midpoint of the last undeflected pipe section and the point of tangent (PT) is at the midpoint of the last pulled pipe.

Table 6.9 Radius of Curvature for Straight Deflected Pipe Length of 4 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	736	368	245	184	147	123	105	92	82	74	67	61	18
21	848	424	283	212	170	141	121	106	94	85	77	71	21
24	960	480	320	240	192	160	137	120	107	96	87	80	24
27	1072	536	357	268	214	179	153	134	119	107	97	89	27
30	1184	592	395	296	237	197	169	148	132	118	107	99	30
33	1296	648	432	324	259	216	185	162	144	130	118	108	33
36	1408	704	469	352	282	235	201	176	156	141	128	117	36
42	1632	816	544	408	326	272	233	204	181	163	148	136	42
48	1856	928	619	464	371	309	265	232	206	186	169	155	48
54	2080	1040	693	520	416	347	297	260	231	208	189	173	54
60	2304	1152	768	576	461	384	329	288	256	230	209	192	60
66	2528	1264	843	632	506	421	361	316	281	253	230	211	66
72	2752	1376	917	688	550	459	393	344	306	275	250	229	72
78	2976	1488	992	744	595	496	425	372	331	298	271	248	78
84	3200	1600	1067	800	640	533	457	400	356	320	291	267	84
90	3434	1712	1141	856	685	571	489	428	380	342	311	285	90
96	3648	1824	1216	912	730	608	521	456	405	365	332	304	96
102	3872	1936	1291	968	774	645	553	484	430	387	352	323	102
108	4096	2048	1365	1024	819	683	585	512	455	410	372	341	108
114	4256	2128	1419	1064	851	709	608	532	473	426	387	355	114
120	4480	2240	1493	1120	896	747	640	560	498	448	407	373	120
126	4704	2352	1568	1176	941	784	672	588	523	470	428	392	126
132	4928	2464	1643	1232	986	821	704	616	548	493	448	411	132
138	5152	2576	1717	1288	1030	859	736	644	572	515	468	429	138
144	5376	2688	1792	1344	1075	896	768	672	597	538	489	448	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.10 Radius of Curvature for Straight Deflected Pipe Length of 6 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	1104	552	368	276	221	184	158	138	123	110	100	92	18
21	1272	636	424	318	254	212	182	159	141	127	116	106	21
24	1440	720	480	360	288	240	206	180	160	144	131	120	24
27	1608	804	536	402	322	268	230	201	179	161	146	134	27
30	1776	888	592	444	355	296	254	222	197	178	161	148	30
33	1944	972	648	486	389	324	278	243	216	194	177	162	33
36	2112	1056	704	528	422	352	302	264	235	211	192	176	36
42	2448	1224	816	612	490	408	350	306	272	245	223	204	42
48	2784	1392	928	696	557	464	398	348	309	278	253	232	48
54	3120	1560	1040	780	624	520	446	390	347	312	284	260	54
60	3456	1728	1152	864	691	576	494	432	384	346	314	288	60
66	3792	1896	1264	946	758	632	542	474	421	379	345	316	66
72	4128	2064	1376	1032	826	688	590	516	459	413	375	344	72
78	4464	2232	1488	1116	893	744	638	558	496	446	406	372	78
84	4800	2400	1600	1200	960	800	686	600	533	480	436	400	84
90	5136	2568	1712	1284	1027	856	734	642	571	514	467	428	90
96	5472	2736	1824	1368	1094	912	782	684	608	547	497	456	96
102	5808	2904	1936	1452	1162	968	830	726	645	581	528	484	102
108	6144	3072	2048	1536	1229	1024	878	768	683	614	559	512	108
114	6384	3192	2128	1596	1277	1064	912	798	709	638	580	532	114
120	6720	3360	2240	1680	1344	1120	960	840	747	672	611	560	120
126	7056	3528	2352	1764	1411	1176	1008	882	784	706	641	588	126
132	7392	3696	2464	1848	1478	1232	1056	924	821	739	672	616	132
138	7728	3864	2576	1932	1546	1288	1104	966	859	773	703	644	138
144	8064	4032	2688	2016	1613	1344	1152	1008	896	806	733	672	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.11 Radius of Curvature for Straight Deflected Pipe Length of 7 ½ Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	1380	690	460	345	276	230	197	172	153	138	125	115	18
21	1590	795	530	397	318	265	227	199	177	159	145	132	21
24	1800	900	600	450	360	300	257	225	200	180	164	150	24
27	2010	1005	670	502	402	335	287	251	223	201	183	167	27
30	2220	1110	740	555	444	370	317	277	247	222	202	185	30
33	2430	1215	810	607	486	405	347	304	270	243	221	202	33
36	2640	1320	880	660	528	440	377	330	293	264	240	220	36
42	3060	1530	1020	765	612	510	437	382	340	306	278	255	42
48	3480	1740	1160	870	696	580	497	435	387	348	316	290	48
54	3900	1950	1300	975	780	650	557	487	433	390	355	325	54
60	4320	2160	1440	1080	864	720	617	540	480	432	393	360	60
66	4740	2370	1580	1185	948	790	677	592	527	474	431	395	66
72	5160	2580	1720	1290	1032	860	737	645	573	516	469	430	72
78	5580	2790	1860	1395	1116	930	797	697	620	558	507	465	78
84	6000	3000	2000	1500	1200	1000	857	750	667	600	545	500	84
90	6420	3210	2140	1605	1284	1070	917	802	713	642	584	535	90
96	6840	3420	2280	1710	1368	1140	977	855	760	684	622	570	96
102	7260	3630	2420	1815	1452	1210	1037	907	807	726	660	605	102
108	7680	3840	2560	1920	1536	1280	1097	960	853	768	698	640	108
114	7980	3990	2660	1995	1596	1330	1140	997	887	798	725	665	114
120	8400	4200	2800	2100	1680	1400	1200	1050	933	840	764	700	120
126	8820	4410	2940	2205	1764	1470	1260	1102	980	882	802	735	126
132	9240	4620	3080	2310	1848	1540	1320	1155	1027	924	840	770	132
138	9660	4830	3220	2415	1932	1610	1380	1207	1073	966	878	805	138
144	10080	5040	3360	2520	2016	1680	1440	1260	1120	1008	916	840	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.12 Radius of Curvature for Straight Deflected Pipe Length of 8 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	1472	736	491	368	294	245	210	184	164	147	134	123	18
21	1696	848	565	424	339	283	242	212	188	170	154	141	21
24	1920	960	640	480	384	320	274	240	213	192	175	160	24
27	2144	1072	715	536	429	357	306	268	238	214	195	189	27
30	2368	1184	789	592	474	395	338	296	263	237	215	197	30
33	2592	1296	864	648	518	432	370	324	288	259	236	216	33
36	2816	1408	939	704	563	469	402	352	313	282	256	235	36
42	3264	1632	1088	816	653	544	466	408	363	326	297	272	42
48	3712	1856	1237	928	742	619	530	464	412	371	337	310	48
54	4160	2080	1387	1040	832	693	594	520	462	416	378	347	54
60	4608	2304	1536	1152	922	768	658	576	512	461	419	384	60
66	5056	2528	1685	1264	1011	843	722	632	562	506	460	421	66
72	5504	2752	1835	1376	1101	917	786	688	612	550	500	459	72
78	5952	2976	1984	1488	1190	992	850	744	661	595	541	496	78
84	6400	3200	2133	1600	1280	1067	914	780	711	640	582	533	84
90	6848	3424	2283	1712	1370	1141	978	856	761	685	623	571	90
96	7296	3648	2432	1824	1459	1216	1042	912	811	730	663	608	96
102	7744	3872	2581	1936	1549	1291	1106	968	860	774	704	645	102
108	8192	4096	2731	2048	1638	1365	1170	1024	910	819	745	683	108
114	8512	4256	2837	2128	1702	1419	1216	1064	946	851	774	709	114
120	8960	4480	2987	2240	1792	1493	1230	1120	996	896	815	747	120
126	9480	4704	3136	2352	1882	1568	1344	1176	1045	941	855	784	126
132	9856	4928	3285	2464	1971	1643	1408	1232	1095	986	896	821	132
138	10300	5152	3435	2576	2061	1717	1472	1288	1145	1030	937	859	138
144	10750	5376	3584	2688	2151	1792	1536	1344	1195	1075	977	896	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.13 Radius of Curvature for Straight Deflected Pipe Length of 10 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	1840	920	613	460	368	307	263	230	204	184	167	153	18
21	2120	1060	707	530	424	353	303	265	236	212	193	177	21
24	2400	1200	800	600	480	400	343	300	267	240	218	200	24
27	2680	1340	893	670	536	447	383	335	298	268	244	223	27
30	2960	1480	987	740	592	493	423	370	329	296	269	247	30
33	3240	1620	1080	810	648	540	463	405	360	324	295	270	33
36	3520	1760	1173	880	704	587	503	440	391	352	320	293	36
42	4080	2040	1360	1020	816	680	583	510	453	408	371	340	42
48	4640	2320	1547	1160	928	773	663	580	516	464	422	387	48
54	5200	2600	1733	1300	1040	867	743	650	578	520	473	433	54
60	5760	2880	1920	1440	1152	960	823	720	640	576	524	480	60
66	6320	3160	2107	1580	1264	1053	908	790	702	632	575	527	66
72	6880	3440	2293	1720	1376	1147	983	860	764	688	625	573	72
78	7440	3720	2480	1860	1488	1240	1063	930	827	744	676	620	78
84	8000	4000	2667	2000	1600	1333	1143	1000	889	800	727	667	84
90	8560	4280	2853	2140	1712	1427	1223	1070	951	856	778	713	90
96	9120	4550	3040	2280	1824	1520	1303	1140	1013	912	829	760	96
102	9680	4840	3227	2420	1936	1613	1383	1210	1076	968	880	807	102
108	10240	5120	3413	2560	2048	1707	1463	1280	1138	1024	931	853	108
114	10640	5320	3547	2660	2128	1773	1520	1330	1182	1064	967	887	114
120	11200	5600	3733	2800	2240	1867	1600	1400	1244	1120	1018	933	120
126	11760	5880	3920	2940	2352	1960	1680	1470	1307	1176	1069	980	126
132	12320	6160	4107	3080	2464	2053	1760	1540	1369	1232	1120	1027	132
138	12880	6440	4293	3220	2576	2147	1840	1610	1431	1288	1171	1073	138
144	13440	6720	4480	3360	2688	2240	1920	1680	1493	1344	1222	1120	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.14 Radius of Curvature for Straight Deflected Pipe Length of 12 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	2208	1104	736	552	442	368	315	276	245	221	201	184	18
21	2544	1272	848	636	509	424	363	318	283	254	231	212	21
24	2880	1440	960	720	576	480	411	360	320	288	262	240	24
27	3216	1608	1072	804	643	536	459	402	357	322	292	268	27
30	3552	1778	1184	888	710	592	507	444	395	355	323	296	30
33	3888	1944	1296	972	778	648	555	486	432	389	353	324	33
36	4224	2112	1408	1056	845	704	603	528	469	422	384	352	36
42	4896	2448	1632	1224	979	816	699	612	544	490	445	408	42
48	5568	2784	1856	1392	1114	928	795	696	619	557	506	464	48
54	6240	3120	2080	1560	1248	1040	891	780	693	624	567	520	54
60	6912	3456	2304	1728	1382	1152	987	864	768	691	628	576	60
66	7584	3792	2528	1896	1517	1264	1083	948	843	758	689	632	66
72	8256	4128	2752	2064	1651	1376	1179	1032	917	826	751	688	72
78	8928	4464	2976	2232	1786	1488	1275	1116	992	893	812	744	78
84	9600	4800	3200	2400	1920	1600	1371	1200	1067	960	873	800	84
90	10270	5136	3424	2568	2054	1712	1467	1284	1141	1027	934	856	90
96	10940	5472	3648	2736	2189	1824	1563	1368	1216	1094	995	912	96
102	11620	5808	3872	2904	2323	1936	1659	1452	1291	1162	1056	968	102
108	12290	6144	4096	3072	2458	2048	1755	1536	1365	1229	1117	1024	108
114	12770	6384	4256	3192	2554	2128	1824	1596	1419	1277	1161	1064	114
120	13440	6720	4480	3360	2688	2240	1920	1680	1493	1344	1222	1120	120
126	14110	7056	4704	3528	2822	2352	2016	1764	1568	1411	1283	1176	126
132	14780	7392	4928	3696	2957	2464	2112	1848	1643	1478	1344	1232	132
138	15460	7728	5152	3864	3091	2576	2208	1932	1717	1548	1405	1288	138
144	16130	8064	5376	4032	3226	2688	2304	2016	1792	1613	1466	1344	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

Table 6.15 Radius of Curvature for Straight Deflected Pipe Length of 16 Ft.

JOINT OPENING* IN INCHES

PIPE DIAMETER	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	PIPE DIAMETER
18	2944	1472	981	736	539	491	421	368	327	294	268	245	18
21	3392	1696	1131	848	678	565	485	424	377	339	308	283	21
24	3840	1920	1280	960	768	640	549	480	427	384	349	320	24
27	4288	2144	1429	1072	858	715	613	536	476	429	390	357	27
30	4736	2368	1579	1184	947	789	677	592	526	474	430	395	30
33	5184	2592	1728	1296	1037	864	741	648	576	518	471	432	33
36	5632	2816	1877	1408	1126	939	805	704	626	563	512	469	36
42	6528	3254	2176	1632	1306	1088	933	816	725	653	593	544	42
48	7424	3712	2475	1856	1485	1237	1061	928	825	743	675	619	48
54	8320	4160	2773	2080	1664	1387	1189	1040	924	832	756	693	54
60	9216	4628	3072	2304	1843	1536	1317	1152	1024	922	838	768	60
66	10110	5056	3371	2528	2022	1685	1445	1264	1124	1011	919	843	66
72	11010	5504	3669	2752	2202	1835	1573	1376	1223	1101	1001	917	72
78	11900	5952	3968	2976	2381	1984	1701	1488	1323	1190	1082	992	78
84	12800	6400	4267	3200	2560	2133	1829	1600	1422	1280	1164	1067	84
90	13700	6848	4565	3424	2739	2283	1957	1712	1522	1370	1245	1141	90
96	14590	7296	4864	3648	2918	2432	2085	1824	1621	1459	1327	1216	96
102	15490	7744	5163	3872	3098	2581	2213	1936	1721	1549	1408	1291	102
108	16380	8192	5461	4096	3277	2731	2341	2048	1820	1638	1489	1365	108
114	17020	8512	5675	4256	3405	2837	2432	2128	1892	1702	1548	1419	114
120	17920	8960	5973	4480	3584	2987	2560	2240	1991	1792	1629	1493	120
126	18820	9408	6272	4704	3763	3136	2688	2352	2091	1882	1711	1568	126
132	19710	9856	6671	4928	3942	3285	2816	2464	2190	1971	1792	1643	132
138	20610	10300	6869	5152	4122	3435	2944	2576	2290	2061	1873	1717	138
144	21500	10750	7168	5376	4301	3584	3072	2688	2389	2150	1955	1792	144

*Joint opening is the pulled distance from the home (or normal) position and the deflected position. Reference Standard No. RC-1.

6-1000 OPEN CHANNELS

6-1001 Water Surface Profiles (Standard Step Method and Direct Step Method)

6-1001.1 Water surface profiles for steady flow in nonuniform channels with frequent changes of cross-section and grade, and uniform channels with frequent changes of grade cannot be computed accurately by assuming uniform flow conditions where there is no appreciable length of constant section and grade and there is no opportunity for conditions of uniform flow to exist.

6-1001.2 Water surface profiles for steady flow in channels of this type are determined by computing separately and successively the change in surface elevation in each of a number of small portions of the total length of the profile.

6-1001.2A These small portions, called reaches, must be short enough to reduce to a permissible magnitude the error in approximating the true slope of the water surface profile through the reach by the average of the surface slopes at each end, or by the slope corresponding to the average of the hydraulic properties of the reach.

6-1001.2B These reaches shall be selected with due regard to the irregularities in the channel.

6-1001.2C The step computations are carried upstream if the flow is subcritical and downstream if the flow is supercritical.

6-1001.3 Various textbooks and publications on open-channel hydraulics explain in detail the step method of computing water surface profiles for prismatic and nonprismatic channels.

6-1001.4 Flow profiles by The Standard Step Method and Direct Step Method have been programmed for the electronic computer. Employment of these programs should not be attempted without a knowledge of energy balance and without prior experience of working flow profiles by the manual method.

6-1002 Side Ditches and Median Ditches

6-1002.1 As the necessity arises, special procedures and nomographs are developed to be used to facilitate repetitive design. Charts of the side and median ditch series have been developed to facilitate and simplify the design (see VDOT Drainage Manual).

6-1002.2 Side and Median Ditch Design. Follow the general procedure outlined below (see also § 6-1010):

6-1002.2A Note on the computation form, under Station to Station, points at 100 feet intervals where roadside ditches, median ditches or valleys, formed by fill slope and inward sloping existing ground, will be constructed.

6-1002.2B Note, by flow arrow on the form, the direction the flow will take in the side ditch.

6-1002.2C Note the average width of the strip to be drained. Use of the cross-sections, contour maps or aerial photos will facilitate this operation.

6-1002.2D Determine the design discharge, for each 100 foot interval point, starting at the first point down grade from the peak in the ditch grade and proceeding down grade. The following method of determining this "Q" will suffice: Compile a table of CA values that will cover the various width strips.

6-1002.2D(1) Multiply the appropriate CA value, or the sum of the appropriate CA values, by the rainfall intensity. The rainfall intensity will decrease approximately 0.1 inch for each additional 100 feet the flow travels in the ditch.

6-1002.2D(2) The resultant "Q" is entered in the space provided on the form.

6-1002.2E Note the slope of the ditch flow line in the space provided on the form.

6-1002.2F Enter the appropriate Side Ditch Flow Chart with "Q" and slope to determine the velocity of flow using "n" = 0.030 for unpaved ditches.

6-1002.2G (107-11-PFM) Where the velocity, as determined above, exceeds the allowable velocity, as determined from the soil classification in the geotechnical report, the ditch shall be lined.

6-1002.2G(1) To determine the depth of flow in the lined ditch, enter the appropriate Side Ditch Flow Chart, using the appropriate "n" with "Q" and slope and read the depth of flow.

6-1002.2G(2) Standard paved ditches or special design paved ditches, gutters or channels having "D" dimension sufficient to cover the majority of the maximum depths noted on the computation form shall be required where the computations indicate the maximum allowable velocity is exceeded.

6-1002.2G(3) The "D" dimension shall be noted on the plans along with the standard used.

6-1002.2G(4) A typical section of all special design paved ditches, gutters, or channels shall be included in the plans.

6-1002.2G(5) Paved ditch construction specifications are shown in § 6-1012 and Plate 19-6 shows standard ditch sections. The ditch sections transitioning from full width to yard inlet are shown on Plate 20-6.

6-1002.2H A typical example will be found in § 6-1009, 6-1010 and 6-1011.

6-1003 Channel Charts

The trapezoidal channel charts of the CC series have been developed to supplement the Federal Highway Administration Publication (see VDOT Drainage Manual).

6-1004 Design Criteria

6-1004.1 In general, roadside and median ditches shall be designed with sufficient capacity to contain the runoff for a 10-year storm. For determining whether or not special linings will be required and the lining dimensions, the 2-year storm shall be used.

6-1004.1A (61-98-PFM) For an engineered grass swale, ditch or channel designed to convey stormwater within County easements provided for swales, ditches or channels, the maximum design velocity (V) shall be no greater than 4fps, as determined by the formula cited in § 6-1005.1. Swales, ditches or channels exceeding these parameters will require special linings. This requirement does not apply to emergency spillways for dams. Vegetated spillway velocity requirements are included in § 6-1600.

6-1004.1B (61-98-PFM) All special channels shall be designed for storm frequencies in accordance with the importance of the road and its vulnerability to inundation, should the capacity be exceeded.

6-1004.1C (61-98-PFM) If the newly constructed channel (ditch) alongside, or leading from, any street providing access to lots to be occupied, or through, or alongside any such lots, is not well stabilized within 120 days after initial attempts to stabilize, or 120 days after issuance of any Residential or Non-Residential Use Permit for such lots, whichever occurs first, the channel (ditch) must be paved.

6-1004.2 In the event an exception for a winter Residential Use Permit is granted as provided for in Paragraph 2 of § 18-704 of the Zoning Ordinance, the 120 days shall run from March 15 of the following spring. "Well stabilized" shall mean a good stand of grass must be growing and not showing any visible evidence of erosive forces. Sod shall be growing well and knitted into the underlying soil.

6-1005 Channel Size and Shape

6-1005.1 The size of a channel shall primarily be established by the Manning Formula which may be expressed as:

$$Q = VA = 1.49/n \times r^{2/3} \times S^{1/2} \times A$$

Definitions of the terms are given in § 6-0902.

6-1005.2 General guidelines related to the size and shape of channels are:

6-1005.2A Low flow sections should be considered in the design of channels with large cross-sections.

6-1005.2B Channel bottom of widths greater than 10 feet shall be built with a minimum cross slope of 1:12.

6-1005.2C The side slopes of a channel shall be a function of channel material. The side slopes throughout the entire length of a channel shall be stable.

6-1005.2D Channels to be constructed on horizontal curves should be investigated to see if channel section needs to be modified. The superelevation of the water in the channel may be computed by:

$$e = V^2 w/g\, r$$

Where:
e = Difference in elevation between the water surface on the inside and outside walls of the channel (ft.)
V = Mean velocity of flow (fps)
w = Average width of channel (ft.)
g = Acceleration of gravity (32.2 fps^2)
r = Radius of channel centerline in ft. The rise in water surface may be accounted for by channel freeboard and/or superelevation of the channel sides.

6-1005.2E Minimum easement widths shall be determined as follows:

Table 6.15A Minimum Easement Widths – Channels

Top Width of Channel	Easement Width
< 2 ft.	10 ft.
2 ft. – 4 ft.	10 ft. greater than top width of channel with minimum of 5 ft. on one side.
> 4 ft.	15 ft. greater than top width of channel with minimum of 5 ft. on one side.

Channels to be maintained by DPWES shall be within dedicated storm drainage easements.

6-1006 Channel Materials

Channel materials acceptable for open channel design with the accompanying roughness coefficients are shown below:

Table 6.16 Channel Materials – "n"

Material	n
Concrete, trowel finish	0.013
Concrete, broom or float finish	0.015
Gunite	0.018
Riprap placed (VDOT Class I)	0.030
Riprap dumped (VDOT Class I)	0.035
Gabion	0.028

6-1007 Energy and Hydraulic Gradients (Reference Plates 24-6 through 26-6)

6-1007.1 The hydraulic gradient for an open channel system is the water surface. The energy gradient is a line drawn a distance $V^2/2g$ above the hydraulic gradient. At channel junctions, the total energy loss at the junction, HL, is the difference in elevation between the energy grade lines of the upstream and downstream channels. To establish these gradients for a system, it is necessary to start at a point where the energy and hydraulic gradients are known or can readily be determined.

6-1007.2 Generally, when the energy and hydraulic gradients must be determined, the channels are assumed to have uniform flow. For uniform flow the friction loss along the channel may be determined by the Manning Formula as discussed above and in § 6-0902.

6-1007.2A Energy Loss at Channel Transitions. The energy loss for open channel transitions may be calculated by:

$$h_l = k_l (V^2/2g)$$

Where:
h_l = Energy loss at transitions due to change in flow area, slope, roughness or any combination of the characteristics.
$V^2/2g$ = Change in velocity head before and after the transitions. This value is always considered positive.
k_l = 0.2 for channel expansion, i.e., velocities decreasing along direction of flow.
k_1 = 0.1 for channel contraction, i.e., velocities increasing along direction of flow.

Some general guidelines to the design of channel transitions are as follows:

6-1007.2A(1) Transition to channel connections should be connected with smooth tangent type surfaces.

6-1007.2A(2) A straight line connecting flow lines at the two ends of the transition should not make an angle greater than 12½ degrees with the axis of the channel.

6-1007.2A(3) Make transition length considerably greater than transition width.

6-1007.2B Energy Loss through Horizontal Channel Curve.

In addition to the friction loss through a channel curve, there is an additional energy loss due to the change in direction of flow. This loss may be calculated as follows:

$$h_2 = k_2 (V^2 / 2g)$$

Where:
h_2 = Energy loss in a curved channel due to change in direction of flow.
k_2 = Energy loss coefficient which may be determined from Plate 25-6.
$V^2/2g$ = Velocity head in curve.

6-1007.2C Drop. If possible the energy losses through a transition or horizontal curve should be accounted for by an increase in channel slope through the transition and/or curve. The equations above and Plate 26-6 show the method for computing the drop.

6-1008 Channel Design Calculations. In general the following design calculations shall be required for submission of plans to the County:

6-1008.1 Design flows shall be determined by methods discussed in § 6-0800 *et seq*.

6-1008.2 Plans showing channels carrying flows no greater than 30 cfs shall show channel capacity calculations.

6-1008.3 Plans showing channels carrying flows 30 cfs and greater shall show:

6-1008.3A Channel capacity calculations.

6-1008.3B Calculations showing that freeboard requirements have been met.

6-1008.3C Energy and hydraulic gradients drawn on storm sewer profiles at channel transitions and/or curves.

6-1008.4 A note stating that “All grass-lined channels must be in a well stabilized condition and show no signs of erosion at the time of final acceptance by the maintaining authority” shall be shown on all applicable plans.

6-1009 Example – Roadside Ditch Computations. (122-16-PFM)

Example based on the VDOT method for design of roadside ditches (See VDOT Drainage Manual). The Rational Formula is used to determine the flow in each ditch segment beginning with the most upstream segment and proceeding downstream. To calculate the flow in each successive downstream segment, the Rational Formula CA values from all the upstream segments are added to the CA value for the segment being analyzed. The rainfall intensity for the segment being analyzed is the lesser of the rainfall intensity for that segment or the rainfall intensity of the previous segment minus 0.1 in/hr. This is a simplifying assumption or approximation of the actual rainfall intensity that is used for computational efficiency. If the computed flow in any segment decreases from the previous segment, the flow is held at the higher value until the flow for the next segment increases. After computing the flows, determine the velocities, depth of flow, and the need for channel linings in accordance with § 6-1002. Given or assumed values below vary with projects.

6-1009.1 Q=CIA

Where:
C=0.9 for paved area
C=0.5 for unpaved drainage area within normal rights-of-way
C=0.3 for drainage area outside normal rights-of-way (ROW)

"I" is based on the 2-year rainfall curve with time of concentration dependent upon average width, grade and type of cover, (5 percent and average grass in this case).

$$A = \frac{100 \times \text{Width Strip}}{43{,}560}$$

Where:
A = area (acres)
Width Strip = width (ft.)
Length of ditch segment = 100 feet

6-1009.2 Typical Section: 24-foot pavement, road is crowned and 12 feet of pavement drains to ditch, ditch having 3:1 front slope and 2:1 back slope.

6-1009.3 (91-06-PFM) From "Virginia Erosion and Sediment Control Handbook," Chapter 5, mostly silt loam with a short section of ordinary firm load.

6-1009.4 (91-06-PFM) Allowable Velocity: From Table 5-22 in the "Virginia Erosion and Sediment Control" use 3 fps as permissible velocity for silt loam and 3.5 fps for ordinary firm loam.

6-1009.5 Normal right-of-way width = 50 feet.

6-1009.6 Width Strip Drained: To be determined from cross-sections, aerial photographs, topographical sheets or field observation (to be measured from outside edge of the ROW to the nearest multiple of 10 feet).

6-1009.7 (61-98-PFM) Where vegetative linings are used, n=0.050 should be used and a velocity of 4 fps should be the upper permitted maximum.

6-1010 Example – Roadside Ditch Computations (continued). (122-16-PFM)

"CA" Values for 100 feet of ditch, using various widths.

Width of strip outside ROW	CA unpaved area outside ROW		CA unpaved area in ROW		CA pavement in ROW		CA Total
W	$\frac{W \times 100 \times 0.3}{43{,}560}$		$\frac{13 \times 100 \times 0.5}{43{,}560}$		$\frac{12 \times 100 \times 0.9}{43{,}560}$		
30	0.021	+	0.015	+	0.025	=	0.061
40	0.028	+	0.015	+	0.025	=	0.068
60	0.041	+	0.015	+	0.025	=	0.081
100	0.069	+	0.015	+	0.025	=	0.109
150	0.103	+	0.015	+	0.025	=	0.143
200	0.138	+	0.015	+	0.025	=	0.178

From 2-year Curve – RAINFALL

Duration (minutes)	6	7	8	9	10	11	12	13	14	15
Intensity	5.0	4.7	4.5	4.4	4.2	4.0	3.9	3.8	3.6	3.5

Table 6.17 Time of Concentration to Use* – Roadside Ditch (122-16-PFM)

Width of strip outside ROW (feet)	Time of concentration (t_c) (minutes)	Rainfall intensity (I) (in./hr.)
30	6	5.0
40	7	4.7
60	9	4.4
100	10	4.2
150	12	3.9
200	14	3.6

* Time of Concentration is based on Plate 4-6.

6-1011 Example – Roadside Ditch Computations (continued). (122-16-PFM)

COMPUTATIONS

Sta. 136 + 00 to 142 + 00 (Ditch #1) and Sta. 149 + 50 to 157 + 50 (Ditch #2)

Check Point	Width of strip Outside ROW	CA segment	CA total	I	(CA) x I = Q
Ditch #1					
Sta. 136+00					
	30 feet	0.061	0.061	5.0 in/hr	0.061 x 5.0 = 0.3050 cfs
Sta. 137+00					
	40 feet	0.068	0.129	4.7 in/hr	0.129 x 4.7 = 0.6063 cfs
Sta. 138+00					
	100 feet	0.109	0.238	4.2 in/hr	0.238 x 4.2 = 0.9996 cfs
Sta. 139+00					
	100 feet	0.109	0.347	4.1 in/hr	0.347 x 4.1 = 1.4227 cfs
Sta. 140+00					
	40 feet	0.068	0.413	4.0 in/hr	0.413 x 4.0 = 1.6520 cfs
Sta. 141+00					
	40 feet	0.068	0.481	3.9 in/hr	0.481 x 3.9 = 1.8759 cfs
Sta. 142+00					
Ditch #2					
Sta. 157+ 50					
	40 feet	0.068	0.068	4.7 in/hr	0.068 x 4.7 = 0.3196 cfs
Sta. 156+50					
	60 feet	0.081	0.149	4.4 in/hr	0.149 x 4.4 = 0.6556 cfs
Sta. 155+50					
	100 feet	0.109	0.258	4.2 in/hr	0.258 x 4.2 = 1.0836 cfs
Sta. 154+50					
	200 feet	0.178	0.436	3.6 in/hr	0.436 x 3.6 = 1.5696 cfs
Sta. 153+50					
	200 feet	0.178	0.614	3.5 in/hr	0.614 x 3.5 = 2.1490 cfs
Sta. 152+50					
	150 feet	0.143	0.757	3.4 in/hr	0.757 x 3.4 = 2.5738 cfs
Sta. 151+50					
	100 feet	0.109	0.866	3.3 in/hr	0.866 x 3.3 = 2.8578 cfs
Sta. 150+50					
	60 feet	0.081	0.947	3.2 in/hr	0.947 x 3.2 = 3.0304 cfs
Sta. 149+50					

6-1012 Paved Ditch Construction Specifications (91-06-PFM)

6-1012.1 All construction and materials shall conform, where applicable, to the current VDOT Road and Bridge Specifications except as noted herein:

6-1012.1A The Director may require special designs for paved ditches as he deems necessary.

6-1012.1B The dimensions shown on the typical section are minimum.

6-1012.1C The concrete shall be A3 (Class 20).

6-1012.1D The subgrade shall be constructed to the required elevation below the finished surface of the paved ditch in accordance with the dimensions and design as shown on the approved plans.

6-1012.1E All soft and unsuitable materials shall be removed and replaced with an approved material which shall be compacted to 95 percent density in accordance with AASHTO-99-61 and finished to a smooth surface.

6-1012.1F The subgrade shall be moistened prior to the placing of the concrete.

6-1012.1G Ditches shall be formed to true typical section in accordance with the alignment dimensions and design required by the approved plans.

6-1012.1H All forms shall be inspected before the placing of concrete.

6-1012.1I A minimum 6-inches diameter underdrain shall be placed where excessive ground water conditions are encountered to limits as deemed necessary by the Director.

6-1012.1J Underdrains shall be encased in washed gravel.

6-1012.1K On curves, the paved ditch shall be formed on the specified curve as indicated on the approved plans.

6-1012.1L The finish surface of the paved ditch shall be coarse or roughened texture.

6-1012.1M 4-inch weep holes shall be provided as directed by the inspector.

6-1012.1N A minimum of 1 cubic foot of 2-inches washed gravel shall be placed at the mouth of each drain pipe.

6-1012.1O The type, dimensions (WxBxD), and limits shall be indicated on the plans.

6-1012.1P In the case of special designs, the plans will indicate a typical section with dimensions and the limits to be provided.

6-1012.1Q All transitions shall be shown on the plans and the limits indicated.

6-1012.1R Ditches shall be reinforced with 6 inch x 6 inch, No. 6 welded wire fabric. The welded wire fabric and reinforcing steel, when required, shall conform to the current VDOT Road and Bridge Specifications.

6-1012.1S PD-A, B, C & D ditches shown on Plate 19-6 shall be poured in alternate sections of 10 feet and no section shall be less than 5 feet. Construction joints shall be provided every 10 feet and ¾-inch bituminous expansion material shall be provided every 40 feet and shall extend to full depth of slab. The expansion joint filler shall conform to the current VDOT Road and Bridge Specifications.

6-1012.1T Curtain walls shall be provided at each end of the paved ditch, and at other locations where undermining can occur. This curtain wall shall extend a minimum of 18 inches below and perpendicular to the grade of the paved ditch. It shall be as thick as the concrete thickness of the ditch slab.

6-1012.1U (47-95-PFM) Paved ditches constructed of asphalt concrete shall not be permitted.

6-1012.1V Gabions may be used in lieu of paved ditches when approval has been given by the Director. These gabions will be of the Maccaferri or Bekaert type or approved equivalent. Typical gabion uses for channel section, revetment with toe wall and weir section are shown in Plates 21-6 thru 23-6.

6-1100 STORM SEWER APPURTENANCES

6-1101 General

6-1101.1 (88-05-PFM) Wherever possible, storm sewer appurtenances should conform with the standards shown in this § 6-0000 *et seq*., or the current VDOT Drainage Manual. Special designs are subject to approval by the Director.

6-1101.2 Storm sewer appurtenances shall be designed for the runoff generated by the 10-year frequency storm as determined by the methods discussed in § 6-0800 *et seq*. Standard specifications for storm sewers are in § 6-1110.

6-1102 Curb Inlets in VDOT Right-of-way (88-05-PFM)

Curb inlets to be maintained by VDOT shall be designed in accordance with the VDOT Drainage Manual. The spread of water on the pavement shall be limited to the width of one-half of the travel lane and the gutter width in each direction or 8 to 10 feet from the face of curb, whichever is less, for a rainfall intensity of 4 inches per hour. Under certain conditions, the drop inlet may need to be designed and/or checked using a rainfall intensity of 6.5 inches per hour (See chapter 9 of the VDOT Drainage Manual for the applicability of this requirement.)

6-1103 Curb Inlets on Private Streets or Parking Lots (88-05-PFM)

The length of curb inlet opening is dependent on the inlet location, pavement, geometry, and the amount of flow approaching the inlet. General guidelines pertaining to design of curb inlets in private streets and parking lots are as follows:

6-1103.1 Water shall be picked up on continuous grades of curb and gutter streets with projected traffic volumes of 1000 or less ADT before the spread into the street exceeds 15 feet.

6-1103.2 Water shall be picked up on continuous grades of curb and gutter streets with projected traffic volumes of greater than 1000 ADT before the spread into the street exceeds 12 feet.

6-1103.3 Inlets on continuous grades may be designed with a percentage of the flow bypassing the inlet. Bypass flow must be accounted for at the next downstream inlet.

6-1103.4 The amount of intercept required on continuous grades is governed by the spread of flow into the street.

6-1103.5 Inlets in sumps must be designed to take flow from the area draining toward it and any bypass flow that may occur from upstream inlets.

6-1103.6 Sump inlets located in streets shall be designed so the spread into the street does not exceed 10 feet at the low point.

6-1103.6A The spread requirements of 15 feet or 12 feet stated in § 6-1103.1 and 6-1103.2 must be met at the point above the sump location where the street grade is 0.2 percent. The design flow to a sump inlet from each direction must be calculated.

6-1103.6B It is not necessary to adhere to the spread requirements at the 0.2 percent street grade for inlets at sump locations within the turnaround of a cul-de-sac. However, flow depths and directions and grading must be checked and the turnaround designed to prevent local flooding of adjacent property.

6-1103.6C The amount of flow to the inlet must be checked to see that the flow is not directed at driveway entrances where it could "jump" the curb. Also, overland relief must be checked.

6-1103.6D The minimum length of inlet throat at sump locations shall not be less than 6 feet.

6-1103.7 When street grades are less than 2 percent, a maximum of 2 cfs may be allowed to cross the intersection of private streets, if the projected traffic volume is equal to or less than 1000 ADT. Flows in excess of 2 cfs but no more than 4 cfs will be allowed to cross intersections of private streets when the grade across the intersection is 2 percent or greater, if the projected traffic volume is equal to or less than 1,000 ADT.

6-1103.8 No flows shall be allowed to cross streets, if the projected traffic volume is greater than 1000 ADT.

6-1103.9 The minimum length of curb inlet throat shall not be less than 2 feet 6 inches.

6-1103.10 Curb inlets in private streets can easily be designed in accordance with the above guidelines by use of the charts in Plates 28-6 and 29-6.

6-1103.11 The capacity of curb inlets and the spread of gutter flow in parking lots will vary considerably if the cross slope to the inlet or curb is significantly different from the standard street cross slope of ¼ inch:1 foot. This variation should be taken into consideration if the cross slope is less than 1/16 inch:1 foot or greater than ½ inch:1 foot. Plate 30-6 may be used along with Plates 28-6 and 29-6 to account for these differences.

6-1103.12 Plate 31-6 may be used for designing curb inlets located at low points in grade.

6-1103.13 Curb inlets shall not be built within curb returns.

6-1103.14 When plans show the old Fairfax County CI-1 to be built, at the option of the developer, it is requested that it be replaced by a VDOT standard DI-3B, with a 4-foot throat. Where a CI-2 is shown on the plans, it is requested that it be replaced with a DI-3B with an 8-foot throat when located on a grade, or with a DI-3C with an 8-foot throat when located in a sump.

6-1104 Yard Inlets (88-05-PFM)

6-1104.1 The required size of yard inlet openings shall be determined by Plate 31-6.

6-1104.2 Yard inlets should be positioned in such a way that they intercept all the design flow approaching the inlet. This can generally be accomplished by depressing the inlet and/or with use of an earth berm.

6-1104.3 Any area, which is inundated by water ponding at a yard inlet, shall be within the storm drainage easement.

6-1104.4 (52-96-PFM) Yard inlet and typical details are shown on Plates 32-6, 33-6, 72-6, 73-6, 74-6 and 75-6.

6-1105 Frames & Covers (88-05-PFM)

6-1105.1 Frames and covers within VDOT rights-of-way shall conform with VDOT specifications.

6-1105.2 Frames and covers in easements outside VDOT rights-of-way are shown on Plate 34-6.

6-1106 Grate Inlets (88-05-PFM (52-96-PFM)

The capacity of grate inlets in sumps and on grades may be obtained from Plates 35-6 and 36-6. To allow for clogging, grate inlets used at sump locations shall be sized for 100 percent more capacity than the design flow (i.e., use 50 percent clogging factor). Grate inlets may be acceptable in VDOT right-of-way and privately owned and maintained systems. However, grate inlets are not acceptable for use on drainage structures to be maintained by Fairfax County or located in County drainage easements.

6-1107 Open Top Structures (88-05-PFM)

Open top structures such as VDOT's IT-1 shall not be permitted.

6-1108 Energy Dissipation Devices (88-05-PFM)

6-1108.1 The terminal ends of all pipes and paved channel storm sewer systems shall be evaluated to be sure that the receiving surface will experience no erosion due to the design discharge.

6-1108.2 Where design discharges have velocities greater than the erosive velocity of the receiving surface, an energy dissipation device shall be designed or a standard energy dissipation device shall be specified.

6-1108.3 (57-96-PFM) Riprap used for erosion control shall conform to the current version of the VDOT Road and Bridge Specifications.

6-1109 Drainage in Residential Areas (88-05-PFM)

6-1109.1 General guidelines to be observed in drainage design in residential subdivision developments in which the average lot size is less than 18,000 square feet.

6-1109.1A No quantity of design surface runoff across lots shall be erosive.

6-1109.1B (57-96-PFM, 29-89-PFM) Quantities of surface runoff greater than 2 cfs that flow through lots shall be picked up and conveyed in a closed storm drainage system except that the Director may allow the quantity of surface runoff to be increased to 3 cfs where the developer demonstrates that such increase will not result in lot drainage problems. The Director may approve an open channel where the preservation of a natural drainageway is desirable or the use of open channel will not interfere with use of the property. Open channel may also be used where the size of the storm sewer pipe exceeds 72 inches.

6-1109.1C Lots generally shall be graded in such a manner that surface runoff does not cross more than 3 lots before it is collected in a storm sewer system. This system may be open channel, closed conduit, or a combination of both.

6-1109.2 The following general guidelines are to be observed in drainage design in residential subdivision developments in which the average lot size is 18,000 square feet or greater with ditch section roads:

6-1109.2A No quantity of design surface runoff across lots shall be erosive.

6-1109.2B Drainage from rights-of-way should flow in an easement along lot lines whenever possible.

6-1109.2C Once drainage is concentrated in rights-of-way, it shall be transferred to a logical point of discharge, preferably a storm sewer system, either open channel, closed conduit, or a combination of both.

6-1109.2D In fill sections, a ditch at the toe of a fill may be necessary. If the toe of fill ditch is outside of the right-of-way, it must be in an easement.

6-1109.3 If it cannot be established how drainage concentrated in the rights-of-way ultimately will be handled, the affected lots shall be restricted until such time as a grading plan showing ultimate drainage disposition has been submitted and approved.

6-1109.4 Townhouse Downspout Discharge – Any downspout discharging onto yards (particularly on rear yards) which consist of filled ground, where the runoff will flow over a fill

grade of 15 percent or greater within 30 feet of the pipe discharge location, shall have the downspout picked up by an underdrain and carried out to the toe of the fill slope to natural ground.

6-1110 Inlet Design Calculations (88-05-PFM)

In general, design calculations required for submission to the County are as follows:

6-1110.1 Calculations showing that the spread of gutter flow in the street is within the allowable range.

6-1110.2 Calculations showing the percent of interception of gutter flow.

6-1110.3 Capacity calculations for all inlets.

6-1110.4 Evaluation of the terminal ends of piped and paved ditch systems for the possible need of energy dissipation devices.

6-1110.5 The drainage divide sheet shall clearly show both on-site and off-site areas attributing runoff to each inlet.

6-1111 Storm Sewer Construction Specifications (88-05-PFM)

6-1111.1 All construction and materials shall conform where applicable to the current VDOT Road and Bridge Specifications.

6-1111.2 All concrete shall be A3 (Class 20) if cast in place, A4 (Class 30) if precast.

6-1111.3 Drop inlets and curb inlets shall have steps. The maximum dimension from finish grade to the first step in the inlet shall not exceed 3 feet 3 inches.

6-1111.4 Unless stated on the approved plans, symmetrical channels shall be formed in the invert of all structures according to VDOT standard IS-1 to prevent standing or ponding of water.

6-1111.5 Manholes and drop inlets shall be constructed from invert to top as follows:

6-1111.5A Manholes to 8 feet deep

6-1111.5A(1) Block construction – minimum 8-inch walls

6-1111.5A(2) Poured in place concrete – minimum 8-inch walls and nonreinforced

6-1111.5A(3) Pre-cast – minimum 8-inch block walls in conjunction with precast throat and precast base slab

6-1111.5A(4) Precast

6-1111.5B Manholes over 8 feet deep

6-1111.5B(1) Precast

6-1111.5B(2) Poured in place reinforced concrete

6-1111.5B(3) Special design, i.e., bends, precast "T," precast boxes

6-1111.6 Inlets where pipe size is larger than 48 inches inside diameter require a special design. In the case of special design inlets that deviate from the standard, the precast manufacturer or design engineer must submit 5 copies of the detail drawings to the County for approval.

6-1111.7 If block construction is used, the inside and outside walls, as they are laid, shall be plastered with mortar a minimum of ½-inch thick.

6-1111.8 All precast drop inlets, curb inlets and manholes shall conform to the latest edition of ASTM C-478.

6-1111.9 The opening in precast storm sewer structures for all size pipe shall be a minimum of 4 inches and a maximum of 8 inches larger than the outside diameter of the pipe.

6-1111.10 The contractor must notify the design engineer as to which structures will be precast so that the proper stake out procedures can be followed.

6-1111.11 The "H" dimension shown on the standards and specified on the plans will be measured from the invert of the outfall pipe to the top of the structure.

6-1111.12 2-inch weep holes shall be provided in endwalls where directed by the inspector.

6-1111.13 A guardrail, fence or other protective device shall be required when the height of an endwall is 2 feet or greater and the structure is located near residence or pedestrian walkways. The protective device shall be shown on the plan. Guardrails will be so placed so as to perform the function for which it is intended and the height of the guardrail shall extend 36 inches above the surrounding area.

6-1200 CULVERTS

6-1201 Design Flow

6-1201.1 Culverts shall generally be designed for the 25-year rainfall frequency when crossing under primary roads, 10-year rainfall frequency when crossing under secondary roads and other locations.

6-1201.2 Culverts shall be checked for the effects of the 100-year storm. No flooding of building structures shall result from the 100-year design flow.

6-1201.3 Design flows shall be determined by methods discussed in § 6-0000 *et seq*.

6-1202 Size

6-1202.1 Culverts experience two major types of flow: Flow with inlet control and flow with outlet control.

6-1202.1A Under outlet control, all of the culvert parameters including the headwater depth, type of inlet, cross-sectional area, slope, roughness, length and tail water elevation influence the culvert size and capacity.

6-1202.1B Under inlet control the capacity of the entire culvert is limited by the capacity of the inlet and only the first three of the above parameters are of primary importance.

6-1202.2 The items in § 6-1202.1 shall be taken into consideration when sizing culverts. In general, culverts shall be hydraulically designed in accordance with the US Department of Transportation's latest publication, "Hydraulic Charts for the Selection of Highway Culverts."

6-1202.3 Considerable savings may be realized in designing culverts with improved inlets. These types of culverts may be hydraulically designed in accordance with "Hydraulic Design of Improved Inlets for Culverts," Hydraulics Engineering Circular #13, dated August 1972, which was prepared by the Hydraulic Branch, Bridge Division, Office of the Engineer, in collaboration with the Research Development Demonstration Division, Region 13, Federal Highway Administration, Washington, DC 20590.

6-1202.4 General guidelines in selection of culvert size are as follows:

6-1202.4A Headwater depth for design discharge shall not exceed a height greater than 1 ½ feet below the edge of the shoulder of a road.

6-1202.4B In general, maximum allowable headwater above the crown of a culvert shall not be greater than 5 feet.

6-1202.4C Headwater depth for the design discharge shall not cause water to rise above the top of approach channels which are adjacent to improved land or above the established floodplain easements.

6-1202.4D Headwater depth at design discharge shall cause no flooding of existing or proposed building structures.

6-1202.4E Outlet velocities shall be calculated. If outlet velocities equal or exceed erosive velocities of channel lining, then riprap or some other form of energy dissipation device shall be placed at the culvert outlet in accordance with § 6-1100 *et seq*.

6-1203 Culvert Materials. Materials acceptable for use in culvert construction with the accompanying roughness coefficients are as set forth in § 6-0903.

6-1300 RETENTION, DETENTION, AND LOW IMPACT DEVELOPMENT FACILITIES (98-07-PFM)

6-1301 General Requirements

6-1301.1 Stormwater retention and detention facilities are incorporated in the design of storm drainage systems to reduce the peak rate of discharge of the drainage system, reduce downstream erosion problems, possibly reduce the capital cost of the drainage system and help eliminate the environmental problems normally associated with the increased runoff of stormwater from new developments.

6-1301.2 Detention measures are extremely helpful for development in areas where downstream storm drainage systems are not adequate to receive the increased runoff being generated by the upstream development. These detention measures may be an adequate manner for meeting adequate off-site drainage requirements.

6-1301.3 Some methods for achieving stormwater detention are as follows:

6-1301.3A Rooftop storage

6-1301.3B Parking lot storage including both ponding and percolation trenches

6-1301.3C Retention and detention ponds

6-1301.3D Recreation area storage

6-1301.3E Road embankment storage

6-1301.3F Street and secondary drainage system storage during extreme intensity storms

6-1301.3G Porous asphalt pavement storage in parking areas

6-1301.3H (33-90-PFM) Underground detention structures

6-1301.4 A few of these methods will be further explained in § 6-0000 *et seq*. with examples and design calculations.

6-1301.5 (46-94-PFM) The 2-year, 2-hour and the 10-year, 2-hour storm shall be the minimum used for the design of retention and detention facilities. A 2-year, 24-hour and a 10-year, 24-hour, NRCS Type II storm (consistent with the hydrology specified in § 6-0801 and 6-0802) also may be used for design. Additionally, in the Four Mile Run Watershed, detention shall be provided for the 100-year design storm.

6-1301.6 (46-94-PFM) Emergency spillways in ponds shall be designed to conform with § 6-1600 *et seq*., except that emergency spillways for ponds with watersheds less than 20 acres may be designed to discharge the 100-year, 2-hour storm. Design of retention and detention facilities require the determination of actual volumes of rainfall occurring in a specific time and the actual volume of storm runoff in the same specified time. Routing of these volumes shall be incorporated in the design calculations.

6-1301.7 Other design parameters include the maximum allowable rate of runoff, characteristics of the developed area, and limitations of the developed area such as the maximum size of storage basin that can be incorporated in the topography, etc.

6-1302 Rooftop Storage (122-16-PFM)

6-1302.1 Rooftop storage shall be designed to meet the water quantity control requirements of the Stormwater Management Ordinance.

6-1302.2 The roof drainage system shall be designed in accordance with the Uniform Statewide Building Code, including emergency overflow requirements.

6-1302.3 The roof shall be designed to address the live load requirements of the Uniform Statewide Building Code taking into consideration the maximum water surface elevation produced by the design storm for emergency overflow.

6-1302.4 Detention rings shall be placed around all roof drains that do not have controlled flow.

6-1302.4A The number of holes or size of openings in the rings shall be computed based on the area of roof drained and runoff criteria.

6-1302.4B The minimum spacing of sets of holes is 2 inches center-to-center.

6-1302.4C The height of the ring is determined by the roof slope and shall be 2.56 inches maximum.

6-1302.4D The diameter of the rings shall be sized to accommodate the required openings and, if scuppers are not provided, to allow the emergency overflow design storm to overtop the ring (overflow design is based on weir computations with the weir length equal to the circumference of the detention ring).

6-1302.5 The maximum time of drawdown on the roof shall not exceed 24 hours for the 10-year design storm.

6-1302.6 Josam Manufacturing Company and Zurn Industries, Inc. market “controlled-flow” roof drains. These products, or their equivalent, are accepted by the County.

6-1302.7 Computations required on plans:

6-1302.7A Roof area in square feet

6-1302.7B Storage provided at 2.56 inches depth

6-1302.7C Maximum allowable discharge rate

6-1302.7D Inflow-outflow hydrograph analysis or acceptable charts. (For Josam Manufacturing Company and Zurn Industries, Inc. standard drains, the peak discharge rates as given in their charts are acceptable for drainage calculation purposes without requiring full inflow-outflow hydrograph analysis.)

6-1302.7E Number of drains required

6-1302.7F Sizing of openings required in detention rings

6-1302.7G Sizing of ring to accept openings and to pass the emergency overflow design storm

6-1302.8 Example:

Given:

Building with flat roof 200 feet x 50 feet;
Pre-development coefficient of runoff, C = 0.40;
Post-development coefficient of runoff, C = 0.9;
Pre-development time of concentration, t_c = 10 minutes;
Post-development time of concentration, t_c = 5 minutes;
Pre-development rainfall intensity for a 10-year storm with a t_c = 10 minutes, I = 5.45 in/hr;
Post-development rainfall intensity for a 100-year storm with a t_c = 5 minutes, I = 9.1 in/hr;
Total rainfall for a 2-hour 10-year storm is 2.56 inches.

Computations:

6-1302.8A Roof Area = 200 ft. x 50 ft. = 10,000 ft^2

6-1302.10B Storage provided at 2.56 inches of depth:

Vol. = (10,000 ft^2)(2.56 in.)(1/12) = 2133.33 ft^3

6-1302.10C Maximum allowable discharge (pre-development rate of runoff) for the 10-year storm

Q = CIA = (0.4)(5.45)(10,000/43,560)
Q = 0.50 cfs

6-1302.8D From Plate 37-6, One set of holes with 2.56 inches of water will have a discharge of 5.12 gpm or 0.0113 cfs. See Plate 38-6 for a diagram of a typical ponding ring.

6-1302.8E Number of drains required for 10,000 square feet roof area under the Uniform Statewide Building Code is two.

6-1302.8F Sizing of openings:

Allowable discharge per drain = 0.50 cfs/2 = 0.25 cfs
Number of hole sets = allowable discharge divided by 0.0113 cfs/one set of holes
Number of hole sets = 0.25 cfs /0.0113 cfs = 22.1 sets of holes per drain (use 22 sets of holes)

6-1302.8G Size of ring:

Hole sets spaced 2 inches on center
Circumference = π x diameter
(22 sets) (2 inches/set) = π x diameter
D =14.01 inches, use 15 inches (see below if separate emergency overflow is not provided).

6-1302.9 If detention rings are to act as emergency overflow measures and assuming a 100-year design storm:

Q100 = CIA; t_c = 5 minutes; C = 1.0 (including correction factor for 100-year frequency storm);
A = 10,000 ft^2/43,560 = 0.23 ac.
Q100 = (1.0)(9.10)(0.23 ac.) = 2.09 cfs (use 1.045 cfs per drain)

Weir formula: $Q = CLH^{3/2}$
C = 3.33
L = πD (circumference)
H = 2.56 in. or 0.21 ft.

Assume all hole sets are clogged and the maximum allowable water depth on the roof is 5 inches, or 2.44 inches above the 2.56-inch high ring.

$Q = CLH^{3/2}$
Q (per drain) = 1.045 cfs = $3.33\ \pi D(0.21)^{3/2}$

D = 1.04 ft. or 12.46 in.
Use diameter of 15 inches

Table 6.18 Rainfall Distribution (122-16-PFM)

Time minutes	Total Precip in.	Total Precip ft.	Increm Precip in.	Increm Precip ft.
1-Year, 2-Hour Storm				
5	.36	.030	.36	.03
10	.57	.047	.21	.018
15	.71	.059	.14	.012
20	.81	.067	.10	.008
30	.97	.081	.16	.014
40	1.06	.089	.09	.008
50	1.14	.095	.08	.007
60	1.21	.101	.07	.006
70	1.25	.105	.04	.004
80	1.29	.108	.04	.003
90	1.33	.111	.04	.003
100	1.36	.113	.03	.003
110	1.39	.116	.03	.003
120	1.42	.119	.03	.002
2-Year, 2-Hour Storm				
5	.44	.036	.44	.036
10	.70	.058	.26	.022
15	.88	.073	.18	.015
20	1.01	.084	.13	.011
30	1.20	.100	.19	.016
40	1.34	.112	.14	.011
50	1.44	.120	.10	.009
60	1.53	.127	.08	.007
70	1.57	.131	.04	.004
80	1.61	.134	.04	.003
90	1.65	.137	.04	.003
100	1.68	.140	.03	.003
110	1.71	.142	.03	.003
120	1.74	.145	.03	.002

(con't. next page)

Table 6.18 Rainfall Distribution (con't.)

10-Year, 2-Hour Storm				
5	.56	.047	.56	.047
10	.91	.076	.34	.029
15	1.15	.096	.25	.020
20	1.34	.112	.19	.016
30	1.63	.136	.29	.024
40	1.84	.154	.21	.018
50	2.01	.168	.17	.014
60	2.16	.180	.14	.012
70	2.24	.187	.08	.007
80	2.32	.193	.08	.006
90	2.38	.199	.07	.006
100	2.45	.204	.06	.005
110	2.51	.209	.06	.005
120	2.56	.213	.05	.005
100-Year, 2-Hour Storm				
5	0.76	.063	.76	.063
10	1.21	.101	.46	.038
15	1.55	.129	.34	.028
20	1.83	.153	.28	.023
30	2.28	.190	.45	.038
40	2.65	.221	.37	.031
50	2.97	.247	.32	.026
60	3.25	.271	.28	.023
70	3.39	.283	.14	.012
80	3.52	.293	.13	.011
90	3.64	.303	.12	.010
100	3.75	.312	.11	.009
110	3.85	.321	.10	.008
120	3.94	.328	.09	.008

Table 6.19 Storm Volume in Inches of Rainfall* (122-16-PFM)

Duration of Storm

Frequency	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	24 Hr
1 Yr	0.355	0.567	0.708	0.971	1.21	1.42	1.52	1.87	2.28	2.62
2 Yr	0.426	0.681	0.856	1.18	1.48	1.74	1.85	2.27	2.75	3.17
5 Yr	0.506	0.810	1.02	1.46	1.87	2.20	2.35	2.87	3.49	4.07
10 Yr	0.565	0.904	1.14	1.66	2.16	2.56	2.75	3.36	4.12	4.87
25 Yr	0.641	1.02	1.30	1.92	2.56	3.08	3.32	4.08	5.08	6.09
50 Yr	0.698	1.11	1.41	2.12	2.87	3.50	3.79	4.70	5.92	7.18
100 Yr	0.754	1.20	1.52	2.32	3.20	3.95	4.29	5.37	6.85	8.41
Max Prob								27.0		

* Storm Volumes from NOAA Atlas 14 for the Vienna Tysons Corner Station (Station ID:44-8737) except for the maximum probable storm which is from NWS Hydrometeorological Report No. 51.

6-1303 Infiltration Practices (116-14-PFM)

6-1303.1 General.

6-1303.1A Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to exfiltrate into underlying soils. Runoff first passes through multiple pretreatment mechanisms to trap sediment and organic matter before it reaches the practice. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants. Infiltration practices have the greatest runoff reduction capability of any stormwater practice and are suitable for use in residential and other urban areas where measured soil permeability rates exceed 0.50 inch per hour.

6-1303.1B Infiltration Practices shall conform to Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1303.2 Feasibility and Limitations.

6-1303.2A Infiltration facilities may be useful only in areas where the soil is pervious and where the water table is lower than the design depth of the facility. The design of the facility shall be in accordance with the soil testing, reporting and meeting procedures of § 4-0700 *et seq*. The use of infiltration facilities is undesirable in soil slippage areas.

6-1303.2B The effects of recharging the water table must be analyzed before this method is used for detention.

6-1303.2C It is essential to determine if raising the water table will cause flooding or damage to nearby areas.

6-1303.2D Facilities shall be located so that infiltration does not saturate soil within 4 feet of public roadway subgrades.

6-1303.2E In residential areas, infiltration facilities and their appurtenant structures must be located on homeowner association (or “common”) property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance except as noted herein. The Director may approve the location of infiltration facilities on individual buildable single-family detached lots for subdivisions creating no more than seven lots where it can be demonstrated that the requirement is not practical or desirable due to constraints imposed by the dimensions or topography of the property and where adequate provisions for maintenance are provided. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities.

6-1303.2F Infiltration facilities may be located on individual single-family detached residential lots that are not part of a bonded subdivision to satisfy the BMP requirements of the Stormwater Management Ordinance for construction on the lot.

6-1303.2G Infiltration facilities may not be constructed on fill material.

6-1303.2H Infiltration facilities may not be constructed on slopes steeper than 15 percent.

6-1303.2I Setbacks. Infiltration facilities shall meet the setback requirements of Virginia Stormwater Design Specification No. 8 Infiltration Facilities (Latest version referenced in the VSMP Regulations). Setbacks to roads and buildings vary based on the scale of the infiltration practice. In addition, infiltration facilities shall be set back a minimum of 2 feet from property lines.

6-1303.2J Infiltration systems may not be utilized in-line with the main conveyance system where the main conveyance system is maintained by the County or carries through drainage from adjoining properties.

6-1303.2K To prevent groundwater contamination, infiltration systems should not be utilized at sites designated as stormwater hotspots.

6-1303.3 Maintenance.

6-1303.3A Infiltration facilities and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Infiltration facilities may not be located in County storm drainage easements. The above does not preclude the use of infiltration facilities by the County within existing County drainage easements or on County-owned property.

6-1303.3B Maintenance of infiltration systems is a primary concern of the county and is critical to the long-term operation of these facilities. Maintenance of these systems is the responsibility of the owner. The design professional must consider the maintenance and operational requirements of these facilities, and the resources of the responsible parties, in determining the appropriateness of their use for a specific application. Underground or “buried infiltration systems” utilizing large pipes, manufactured components, modules, chambers or vaults are discouraged due to the difficulty of inspection and maintenance. If an underground infiltration system is proposed, an adequate pretreatment system appropriate for the location and type of development is required to prevent sediments from entering the system. These underground infiltration systems, as described above, should not be used under paved areas if there are other viable options because the pavement significantly increases the cost of repair and replacement.

6-1303.3C Maintenance access must be provided for all infiltration facilities not located on individual buildable single family detached lots in accordance with § 6-1306. For infiltration

facilities located on individual buildable single family detached lots, maintenance access shall be considered as an integral part of the design and designated on the plan.

6-1303.3D Infiltration facilities with above ground ponding areas shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area, water may pond after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the infiltration area with a minimum of one sign for each facility (See Plate 81-6.)

6-1303.4 Design Criteria.

6-1303.4A Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the VSMP Regulations).

6-1303.4B Detention. For facilities designed to provide detention, the 1-year storm, the 2-year storm and the 10-year storm must be routed through the facility; or the facility may be designed to infiltrate the 10-year storm volume. The 100-year design storm should be routed through the system and adequate relief provided – usually in the form of overland relief.

6-1303.4C For on-line facilities designed to provide water quality control only, the inlet must be designed to pass the peak flow rate for the 10-year storm. For off-line facilities designed to provide water quality control only, a flow splitter shall be used to capture the design storm (typically the treatment volume) and pass larger flows around the facility.

6-1303.4D Pre-Treatment. Pre-treatment shall be provided at all points of concentrated inflow to facilities. Pre-treatment shall be designed in accordance with Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the VSMP Regulations). Pre-treatment generally consists of a vegetated filter strip or channel and an energy dissipation device. However, space constraints (e.g., parking lot islands) may limit the ability to provide a vegetated filter strip or channel. Where space permits, vegetated filter strips or channels shall be provided. Energy dissipation devices are required for all facilities at points of concentrated inflow. Where inflow is in the form of sheet flow, a vegetated filter strip shall be provided where space permits. Guidelines for sizing vegetated filter strips and channels are provided in Tables 6.25 and 6.26.

6-1303.4E The maximum surface storage depth from the top of the facility to the elevation of the overflow weir or drop inlet shall be 1 foot.

6-1303.4F Berms used to pond water above infiltration facilities shall be a maximum of 2.0 feet in height measured from the downstream toe-of-slope to the top of the berm. The width of the top of the berm shall be a minimum of 2.0 feet. The side slopes of the berm shall be a maximum of 3:1. Berms and overflow weirs shall be sodded and pegged in accordance with the most recent edition of the "Virginia Erosion and Sediment Control." Facilities with berms that are equal to or less than 2.0 feet

in height or excavated facilities will not be subject to the requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1303.4G The side slopes of the facility above ground shall be a maximum of 4:1. Where space permits, gentle side slopes (e.g., 5:1) are encouraged to blend the facility into the surrounding landscape. Side slopes of the facility excavated below ground may be as steep as the *in situ* soils will permit. All excavation must be performed in accordance with Virginia Occupational Safety and Health (VOSH) requirements. If the facility is located on problem soils, as defined in Section 107-2-2 (j) of the County Code, a professional authorized by the State shall specify the maximum acceptable slope.

6-1303.4H An outlet structure must be provided to convey the peak flow for the 10-year storm. The outlet structure may be a drop inlet or weir. A minimum freeboard of 6 inches shall be provided from the maximum elevation of the 10-year storm to the top of the facility.

6-1303.4I An emergency overflow weir shall be provided for all facilities with berms. The emergency overflow weir must have the capacity to pass the peak flow from the 100-year storm without overtopping the facility. If the facility design includes a weir in the berm to convey the peak flow for the 10-year storm, it also may be designed to function as the emergency overflow weir. The minimum weir length shall be 2 feet.

6-1303.4J The outfall of all outlet structures, emergency overflow weirs, and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1303.4K Underdrains shall be provided for all infiltration facilities on marginal soils (field measured infiltration rates 0.5 -1.0 in./hr.) or where detention storage is provided except that facilities on individual single-family detached residential lots that are not part of a bonded subdivision may be constructed without underdrains if the underdrain cannot be daylighted on the lot or connected to a storm sewer structure. If there are no underdrains, observation wells shall be installed to monitor drainage from the facility.

6-1303.4L The depth between the bottom of the facility and groundwater table or bedrock shall be a minimum of 4 feet for infiltration facilities as determined by field run soil borings.

6-1303.4M For facilities requiring underdrains, the underdrain shall be provided with an end cap or a valve fitted onto the end of the underdrain. Facilities shall be designed to dewater completely within 48 hours. If at some future time the facility can no longer drain in the required time, a hole may be drilled in the end cap or the valve opened to relieve surface ponding or back-ups in the drainage system. This allows the system to continue to provide water quality control and detention, albeit at reduced levels, if the infiltration capacity of the *in situ* soils is reduced over time due to consolidation of the soil bed or clogging of the soil pores.

6-1303.4O Variations of the typical details and schematics of infiltration facilities in Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the

VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements in § 6-1303 *et seq*.

6-1303.5 Gravel Layer/Storage Chamber Design.

6-1303.5A Storage Volume. Storage for detention or infiltration may be provided by a layer of gravel or gravel in combination with storage chambers beneath the soil media. Water flows into the storage layer either through an inlet structure or through the surface layer of pea gravel and optional topsoil and sod. Water flows out of the storage layer either by infiltration into the underlying *in situ* soils or through a restricted underdrain. The design objectives are to infiltrate as much of the water as possible, to provide sufficient storage so that water can drain freely through the surface layer without being backed-up, to assure that there is complete drain down of the facility between storms, and to meet the physical constraints of the site. The flow rate through the surface layer is generally not a limiting factor and the storage volume required is determined by the treatment volume, porosity of the gravel, supplemental pipe storage, and the exfiltration rate into the underlying soils.

6-1303.5B Infiltration facilities shall be sized in accordance with Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the VSMP Regulations).

6-1303.5C After determining the depth of the gravel layer, check the invert elevation against the elevation of the water table and bedrock. Also check that the facility can drain to the intended outfall.

6-1303.5D Facility Drain Time. The final step in the design of the gravel layer is to compute the time that it takes the facility to drain. The facility must drain completely within 48 hours after the water quality volume has been captured by the filter section. The drain time is computed as follows:

$$t_d = V_s \ / \ [(k_s)(A_s) / 12 + 3{,}600(Q_u)]$$

Where:
t_d = total drain time for facility (hrs.)
V_s = volume of storage (ft^3)
k_s = soil infiltration rate (in./hr.)
A_s = area of soil bed (ft^2)
Q_u = outflow through underdrain (cfs)

6-1303.6 Underdrains. Underdrains shall consist of pipe ≥ 4 inches in diameter placed in a layer of washed VDOT #57 stone. There shall be a minimum of 2 inches of gravel above and below the pipe. Laterals shall be a minimum of 4-6 inches in diameter. Main collector lines and manifolds shall be a minimum of 6-8 inches in diameter. Underdrains shall be laid at a minimum slope of 0.5 percent. Underdrains shall extend to within 10 feet of the boundary of the facility and have a maximum internal spacing of 20 feet on center. Underdrains shall be separated from the soil media in accordance with Virginia Stormwater Design Specification No. 8

Infiltration (Latest version referenced in the VSMP Regulations). Underdrains not terminating in an observation well/clean-out shall be capped. The portion of underdrain piping beneath the surface layer must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. All stone shall be washed with less than 1 percent passing a #200 sieve.

6-1303.7 Observation Wells and Cleanouts. There shall be a minimum of one observation well or cleanout per 1,000 square feet of surface area. Observation wells and cleanouts shall be a minimum of 6 inches in diameter with a screw, or flange type cap to discourage vandalism and tampering extending above the BMP water surface elevation. Cleanouts shall be provided at the end of all pipe runs. Cleanouts and observation wells shall be solid pipe except for the portion below the surface layer which must be perforated. Observation wells that are not connected to underdrain piping shall be anchored to a footplate at the bottom of the facility.

6-1303.8 Materials Specifications.

6-1303.8A Underdrains shall be PVC pipe conforming to the requirements of ASTM F758, Type PS 28 or ASTM F949; HDPE pipe conforming to the requirements AASHTO M252 or M 294, Type S; or other approved rigid plastic pipe with a smooth interior. Underdrains shall be perforated with four rows of 3/8-inch holes with a hole spacing of 3.25 ± 0.25 inches or a combination of hole size and spacing that provides a minimum inlet area ≥ 1.76 square inches per linear foot of pipe or be perforated with slots 0.125 inch in width that provides a minimum inlet area ≥ 1.5 square inches per linear foot of pipe.

6-1303.8B Filter fabric. Filter fabric shall be a needled, non-woven, polypropylene geotextile meeting the requirements listed in Virginia Stormwater Design Specification No. 8 Infiltration (Latest version referenced in the VSMP Regulations). Heat-set or heat-calendared fabrics are not permitted.

6-1303.9 Construction Specifications.

6-1303.9A The owner shall provide for inspection during construction of the facility by a licensed design professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the tests and inspections required under § 6-1303.9E shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1303.9B Infiltration facilities shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan.

6-1303.9C The floor of the facility shall be scarified or tilled to reduce soil compaction and raked to level it before the filter fabric, stone, and soil media are placed.

6-1303.9D Fill for the berm and overflow weir shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Compaction equipment shall not be allowed within the facility on the soil bed. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1303.9E The facility shall be inspected at 12-24 and 36-48 hours after a significant rainfall (0.5-1.0 inches) or artificial flooding to determine that the facility is draining properly. Results of the inspection shall be provided to DPWES prior to bond release.

6-1303.9F Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 8 Infiltration Practices (Latest version referenced in the VSMP Regulations).

6-1303.10 Plan Submission Requirements.

6-1303.10A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1303.10B Cross section(s) of the facility showing the following: elevations and dimensions of berm, inlet, outlet, underdrain, soil media, underlying gravel layer, storage chambers, filter fabric, groundwater table, and bedrock.

6-1303.10C Sizing computations for the facility including volume of storage and surface area of facility required and provided and a computation of the ratio of the shortest flow path to overall length of the facility.

6-1303.10D Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 8.

6-1303.10E Hydrologic calculations for the facility.

6-1303.10F Design calculations and specifications for all hydraulic structures including inlet structures, overflow weirs, and underdrain piping.

6-1303.10G Infiltration calculations.

6-1303.10H Soils analysis and testing results for infiltration. Elevation of groundwater table and/or bedrock.

6-1303.10I A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1303.10J Construction and materials specifications.

6-1304 Permeable Pavement (116-14-PFM)

6-1304.1 General.

6-1304.1A Permeable pavement systems use a special asphaltic paving material (porous pavement), concrete (pervious concrete), or open-jointed concrete blocks (permeable pavement blocks) that allow stormwater to flow through the pavement or the open joints at a high rate. Water is temporarily retained below the pavement within an aggregate base and discharged to the storm sewer system or infiltrated into the underlying *in situ* soils. The principal components of permeable pavement systems are porous pavement, pervious concrete, or permeable pavement blocks, a bedding (choker) course, an optional filter fabric between the bedding course and the aggregate base in permeable pavement block systems, an open-graded aggregate base with a high void ratio, filter fabric or a layer of sand to separate the aggregate base from the underlying soils and an underdrain that is connected to the storm drain system. Water quality control is provided by adsorption, filtering, sedimentation, biological action, and infiltration into the underlying soils. Permeable pavement systems reduce the peak rate and volume of stormwater runoff through detention storage and infiltration into underlying soils. Additional infiltration capacity or storage for detention can be obtained by increasing the depth of the aggregate base alone or in combination with storage chambers.

6-1304.1B Permeable pavement systems generally may be classified by the degree of infiltration into the underlying soils (i.e., exfiltration out of the aggregate base) that the systems are designed to achieve.

6-1304.1B(1) No Exfiltration. Systems that do not rely on infiltration of the captured stormwater runoff into the underlying soils are designed to provide water quality control and detention of storm water runoff from small storms. Water that has passed through the pervious pavement is discharged to the storm drain system through an unrestricted underdrain.

6-1304.1B(2) Full or Partial Exfiltration. Systems that provide for full or partial infiltration of the captured stormwater runoff into the underlying soils are designed to provide water quality control and retention of storm water. Such systems rely on infiltration to drain down the water stored in the aggregate base between storms. Permeable pavement systems designed for exfiltration, as utilized in Fairfax County, generally include underdrains that are capped or have restricted outflow. This allows the system to continue to provide water quality control and detention, albeit at reduced levels, if the infiltration capacity of the *in situ* soils is reduced over time due to consolidation of the soil bed or clogging of the soil pores.

6-1304.1C Permeable pavement systems are applicable as a substitute for conventional asphalt or concrete pavement. Permeable pavement systems require reasonably favorable conditions of land slope, subsoil drainage, and groundwater table. Permeable pavement systems are best suited to parking areas that are not subject to muddy conditions that cause sealing or clogging of the pervious material. Examples of suitable locations are parking areas for parks, churches, schools, office buildings, and shopping centers.

6-1304.1D Post-development hydrology. For hydrologic computations using the Rational Method, the runoff coefficient ("C" factor) for permeable pavement in Table 6.5 shall be used.

For hydrologic computations using National Resource Conservation Service (NRCS) methods, see § 6-0802. For hydraulic computations, use a roughness coefficient ("n" value) of 0.01 for porous asphalt pavement and 0.03 for permeable pavement block systems and pervious concrete.

6-1304.1E Permeable paving shall conform to Virginia Stormwater Design Specification No. 7, Permeable Pavement (Latest version referenced in the VSMP Regulations) except as modified herein.

6-1304.2 Feasibility and Limitations.

6-1304.2A Permeable pavement systems may not be located in single family attached or detached residential developments for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance except as permitted under § 6-1304.2A(1) and § 6-1304.2A(2).

6-1304.2A(1) The Board of Supervisors (Board), in conjunction with the approval of a rezoning, proffered condition amendment, special exception, or special exception amendment, may approve the location of permeable pavement systems in single family attached or detached residential developments in accordance with the following criteria:

6-1304.2A(1)(a) Any decision by the Board shall take into consideration possible impacts on the environment and the burden placed on prospective owners for maintenance of the facilities;

6-1304.2A(1)(b) Permeable pavement must be part of an overall stormwater management design that does not rely exclusively on pervious pavement to meet BMP and detention requirements;

6-1304.2A(1)(c) Adequate funding for maintenance of the facilities shall be provided by the applicant where deemed appropriate by the Board;

6-1304.2A(1)(d) Permeable pavement facilities must be located on homeowners' association (or "common") property and may not be located on individual buildable single family attached or detached residential lots, or any part thereof;

6-1304.2A(1)(e) Permeable pavement facilities shall be privately maintained and a private maintenance agreement in a form acceptable to the Director, which may include but is not limited to requirements for third-party inspections and the filing of annual maintenance and inspection reports with the County, must be executed before the construction plan is approved;

6-1304.2A(1)(f) The use of and responsibility for maintenance of permeable pavement facilities shall be disclosed as part of the chain of title to all future homeowners (e.g., individual members of a homeowners' association) responsible for maintenance of the facilities; and

6-1304.2A(1)(g) In addition to the above requirements, reasonable and appropriate conditions may be imposed, where deemed appropriate by the Board, to provide for maintenance of the facilities and disclosure to property owners.

6-1304.2A(2) Permeable pavement systems may be located in single family attached or detached residential developments if the permeable pavement appears as a feature shown on a proffered development plan or a special exception plat approved prior to March 12, 2007.

6-1304.2B Notwithstanding the above, permeable pavement may be used for driveways on new residential subdivision lots to create equivalent pervious surfaces. These areas can then be treated as managed turf in the runoff reduction calculation. However, a loss of 50% of the permeable pavement area over time is assumed to compensate for inadequate or improper maintenance, driveway replacement, and sealing. The use of and responsibility for maintenance of permeable pavement facilities shall be disclosed as part of the chain of title to all future homeowners (e.g., individual members of a homeowners' association) responsible for maintenance of the facilities. Such facilities shall not be subject to the requirement for a private maintenance agreement in § 6-1304.3 or the slope limitation of § 6-1304.2E.

6-1304.2C Permeable pavement systems may not be located on individual residential lots for the purpose of satisfying the BMP requirements of the Stormwater Management Ordinance.

6-1304.2D Permeable pavement systems that utilize infiltration may not be constructed on fill material.

6-1304.2E Permeable pavement systems may not be constructed in areas where the adjacent slopes are steeper than 20 percent.

6-1304.2F The slope of permeable pavement systems shall be from 1 to 5 percent.

6-1304.2G Setbacks. Permeable pavement shall meet the setback requirements of Virginia Stormwater Design Specification No. 7, Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.2H Permeable pavement systems shall not be located in the vicinity of loading docks, vehicle maintenance areas, or outdoor storage areas, where there is the potential for high concentrations of hydrocarbons, toxics, or heavy metals in stormwater runoff entering the facility.

6-1304.2I Permeable pavement systems shall not be located in travelways, areas subject to frequent truck traffic or material storage areas, such as loading docks, where there is potential for settling or high loads of grease and oils.

6-1304.2J Concentrated flow shall not be discharged directly onto permeable pavement.

6-1304.2K For permeable pavement systems utilizing open jointed concrete blocks, handicapped parking spaces and associated pathways shall utilize concrete blocks without open joints.

6-1304.3 Maintenance.

6-1304.3A Permeable pavement systems must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. The above does not preclude the use of permeable pavement by the County on County-owned property. County maintained storm and sanitary sewer lines and their easements may be routed through areas of privately maintained permeable pavement.

6-1304.3B Permeable pavement shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the area is surfaced with permeable pavement and list the restrictions specific to that type of pavement (e.g. no sanding, no storage of dirt, mulch, or other materials that might clog the pores in the pavement, etc.). Signs shall be posted at approximately 150-foot intervals along the perimeter of the permeable pavement with a minimum of one sign for each facility. (See Plate 81-6.)

6-1304.4 General Design Requirements

6-1304.4A Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 7, Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.4B Detention. For facilities designed to provide detention, the 1-year storm, the 2-year storm, and the 10-year storm must be routed through the facility or the facility may be designed to infiltrate the 10-year storm volume. Routings shall be performed in accordance with § 6-1300 *et seq*. Inlets shall be provided or the aggregate base extended 2 feet beyond the edge of the pavement to convey stormwater in excess of the treatment volume to the aggregate base or storage chambers below the permeable pavement.

6-1304.4C For facilities designed to provide detention, the maximum water surface elevation for the 10-year storm shall be a minimum of 0.5 feet below the pavement bedding course.
6-1304.4D The detention release rate shall be controlled by a valve or cap on the end of the pavement underdrain within the structure.

6-1304.4E Pretreatment. Pretreatment for areas that sheet flow onto the pavement is not required. Inlets shall be designed to provide pretreatment of stormwater to prevent debris and sediments from entering the aggregate base or storage chambers. Where the aggregate base is extended beyond the edge of the pavement to convey stormwater to the aggregate base, an additional layer of filter fabric shall be provided 1 foot below the surface to prevent sediments from getting into the aggregate base.

6-1304.4F Underdrains shall be provided for all pervious pavement systems. The outfall of all underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1304.4G The bottom of the facility shall be a minimum of 4 feet above the groundwater table and bedrock for facilities designed to provide infiltration and a minimum of 2 feet above the groundwater table and bedrock for all other facilities as determined by field run soil borings. The bottom of the facility shall be below the frost line to prevent frost heave of the pavement.

6-1304.4H For facilities designed to provide infiltration, the underdrain shall be restricted as necessary so that the design infiltration rate plus the underdrain outflow rate equals the design draw down rate. The restriction shall be achieved by using an end cap with a hole to act as an orifice or a valve fitted onto the end of the underdrain. Alternatively, a flow control satisfactory to the Director may be provided within the outflow structure. See § 6-1604.1A(2) for orifice calculations. The minimum diameter of any orifice shall be 0.5 inch. Facilities shall be designed to dewater completely within 24 hours. If the facility can drain in the required time without any outflow through the underdrain, the end cap may be provided without a hole.

6-1304.4I (111-13-PFM) For facilities utilizing infiltration, the design of the facility shall be in accordance with the soil testing, reporting and meeting procedures of § 4-0700 *et seq*. Soils with a CBR (minimum 96 hours soaked) less than 5 or that are highly expansive are not suitable for infiltration. Such soils would require compaction or other measures to be used as a pavement subgrade that would compromise their ability to infiltrate water. Permeable pavements on these soils shall be designed for no infiltration with unrestricted underdrains.

6-1304.4J Permeable pavement block systems require edge restraints to prevent movement of the pavement blocks from vehicle loads. Edge restraints may be standard VDOT curbs, standard VDOT combination curb and gutters, or precast or cast in place reinforced concrete borders a minimum 6 inches wide and 18 inches deep constructed with Class A3 concrete. Edge restraints shall be installed flush with the paver blocks.

6-1304.4K (107-10-PFM) Side slopes of the facility excavated below ground may be as steep as the *in situ* soils will permit. The bottom of the excavated bed shall be level or nearly level. All excavation must be performed in accordance with Virginia Occupational Safety and Health (VOSH) requirements. If the facility is located on problem soils, as defined in Section 107-2-1 (j) of the County Code, a professional authorized by the State shall specify the maximum acceptable slope for the excavation.

6-1304.4L Variations of the permeable pavement designs in the typical details and schematics of permeable pavement facilities in Virginia Stormwater Design Specification No. 7, Permeable Pavement (Latest version referenced in the VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements in § 6-1304 *et seq*.

6-1304.5 Pervious Pavement Design.

6-1304.5A Because there is no above ground storage of stormwater runoff, the minimum area of the pervious pavement required to infiltrate the treatment volume into the aggregate base is governed by the permeability of the pavement. This calculation is generally used to determine how much flow from adjoining impervious surfaces can be filtered through the permeable pavement or if detention provided for larger design storms will need supplemental inlets to direct storm runoff into the storage layer. The minimum area of the pervious pavement is computed as follows:

$A_p = (T_v) / [(k_p/12)(t_s)]$

Where:
A_p = area of pervious pavement (ft^2)
T_v = treatment volume (ft^3)
k_p = coefficient of permeability (in./hr.)
t_s = time base of design storm (hrs.)

6-1304.5B For design purposes, the permeability of the pavement is 5.0 inches/hour for porous concrete, 3.0 inches/hour for porous asphalt pavement, and 1.0 inches/hour for permeable pavement block systems and the time base of the design storm is 2 hours. After incorporating these values, the above equation reduces to:

$A_p = 1.2 \times T_v$ for porous concrete
$A_p = 2.0 \times T_v$ for porous asphalt pavement
$A_p = 6.0 \times T_v$ for permeable pavement block systems

6-1304.6 Aggregate Base/Storage Chamber Design.

6-1304.6A Storage Volume. Storage for detention or infiltration may be provided by a layer of aggregate or aggregate in combination with storage chambers beneath the pervious pavement. Water flows into the storage layer either through an inlet structure or through the pavement. Water flows out of the storage layer either by infiltration into the underlying *in situ* soils or through a restricted underdrain. The design objectives are to infiltrate as much of the water as possible, to assure that there is complete drain down of the facility between storms, to meet the structural requirements for the pavement design, and to meet the physical constraints of the site.

6-1304.6B The required storage volume shall be determined in accordance with Virginia Stormwater Design Specification No. 7, Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.6C Check the computed depth of the aggregate layer against the required depth for installation of the underdrain system (4 inches plus the diameter of the largest underdrain pipe)

and the required depth of the pavement subbase (see § 7-0500 *et seq*.). The minimum required depth will be the greatest of these three values.

6-1304.6D Check the invert elevation of the aggregate layer against the elevation of the water table and bedrock. Also check that the facility can drain to the intended outfall.

6-1304.6E Facility Drain Time. The final step in the design of the aggregate layer is to compute the time that it takes the facility to drain. The facility must drain completely within 24 hours. The drain time is computed as follows:

$$t_d = V_s / [(k_s)(A_s) / 12 + 3{,}600(Q_u)]$$

Where:
t_d = total drain time for facility (hrs.)
V_s = volume of storage (ft^3)
k_s = soil infiltration rate (in./hr.)
A_s = area of soil bed (ft^2)
Q_u = outflow through underdrain (cfs)

6-1304.6F For facilities designed with unrestricted underdrains, computation of the storage volume, storage depth, and facility drain time are not necessary. However, it is still necessary to check the depth of the aggregate layer against the required depth for the pavement sub-base and the invert elevation of the bottom of the aggregate layer against the elevation of the water table, bedrock, and the intended outfall.

6-1304.6G For facilities designed to provide infiltration, the infiltration rate into the underlying *in situ* soils typically will be less than the flow rate through the pavement and the outflow through the underdrain will be restricted or absent such that some storage will be required. In performing computations of the storage volume, storage depth, and facility drain time, initially assume that the underdrain is capped and there is no outflow through the underdrain. If the allowable depth of the storage layer based on the elevation of the groundwater table or bedrock is insufficient to provide the necessary storage volume, storage may be increased by increasing the area of the aggregate layer and soil bed or by incorporating storage chambers. Alternatively, the underdrain may be provided with an orifice to decrease the amount of storage needed. If the total drain time of the facility is in excess of 24 hours, it will be necessary to increase the area of the aggregate base and soil bed or provide an orifice and recompute the total drain time through the facility. Outflow through the orifice may not exceed the pre-development peak flow rates for the 1-year, 2-year and 10-year storms.

6-1304.7 Underdrains. Underdrains shall consist of perforated pipe ≥ 4 inches in diameter placed in a layer of washed VDOT #57 stone. VDOT #2 or #3 stone may be substituted for #57 stone when #2 or #3 stone is used for the aggregate base. There shall be a minimum of 2 inches of aggregate above and below the pipe. Laterals shall be a minimum of 4-6 inches in diameter. Main collector lines and manifolds shall be a minimum of 6-8 inches in diameter. Underdrains shall be

laid at a minimum slope of 0.5 percent. Underdrains shall have a maximum internal spacing of 20 feet on center and extend to within 10 feet of the perimeter of the aggregate base. Underdrains not terminating in an observation well/clean-out shall be capped. Underdrain pipe connected to structures shall be nonperforated within 1 foot of the structure. Cleanouts and observation wells shall be nonperforated within 1 foot of the surface. All stone shall be washed with less than 1 percent passing a #200 sieve. Clean-outs and observation wells shall have a screw or flange type cap, which shall be load-bearing when in a paved area.

6-1304.8 Materials Specifications.

6-1304.8A Open jointed concrete blocks shall have a minimum thickness of 3 1/8 inches and conform to ASTM C 936-01 Standard Specification for Solid Concrete Interlocking Pavement Units. Joint openings shall be a minimum of 10 percent of the surface area of the pavement after installation. Joint openings shall be filled with VDOT #8, #8P, or #9 stone. VDOT #8 stone is recommended. VDOT #8P or #9 stone may be used where needed to fill narrow joints. All stone shall be washed with less than 1 percent passing a #200 sieve.

6-1304.8B Porous asphalt pavement shall be a minimum of 2.5 inches thick and conform to VDOT Road and Bridge Specifications for Asphalt Materials (Section 210) and Asphalt Cement (Section 211) except for aggregate gradation. The asphalt mix shall be 5.75 percent to 6.0 percent of dry aggregate by weight. The asphalt binder shall be modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22 (AASHTO MP-1) and applied at a rate of 3.0 percent by total weight of the binder. Drain down of the asphalt binder shall be no greater than 0.3 percent (ASTM D 6390). The aggregate gradation shall be as specified in Table 6.21. Porous asphalt pavement shall have a minimum connected void space of 18 percent.

Table 6.21 Aggregate Gradation

U.S. Standard Sieve Size	Percent Passing
1/2 in.	100
3/8 in.	92-98
#4	34-40
#8	14-20
#16	7-13
#30	0-4
#200	0-2

6-1304.8C Pervious concrete shall conform to VDOT Road and Bridge Specifications for Hydraulic Cement Concrete (Section 217) except where contraindicated. Pervious concrete shall be designed to have a minimum thickness of 6.0 inches and a void space of 15 - 25% with an in-place unit weight of 105 – 135 lbs/ft^3. Designs in the range of 15 - 19% voids with a unit weight of 127 – 132 lbs/ft^3 were found to be optimum for both strength and permeability in a 2006 study by the National Concrete Pavement Technology Center [*Mix Design Development for Pervious*

Concrete in Cold Weather Climates, National Concrete Pavement Technology Center (NCPTC), Iowa State University, Final Report, February 2006]. The materials proportions should be within the ranges specified in Table 6.23.

Table 6.23 Materials Proportions for Pervious Concrete

Material	Proportion
Water/Cement ratio	0.27 – 0.34 (by mass)
Aggregate/Cement ratio	4.0 – 4.5 (by mass)
Fine/Coarse Aggregate ratio	0 – 0.1 (by mass)

Coarse aggregate shall be VDOT #67, #8, or #8P. Air entrainment shall be used to improve resistance to freeze/thaw cycles. However, air entrainment cannot be verified or quantified by standard test methods and an alternative test method is not currently available. A preliminary mix design must be included in the plan. A plan revision with the final mix design, if different than the preliminary design, must be submitted to DPWES for approval prior to construction. Appendix 6 of ACI 211.3R-02 (Guide for Selecting Proportions for No-Slump Concrete) provides a procedure for determining mix proportions for pervious concrete.

6-1304.8D The bedding course for open jointed pavement blocks shall consist of 1.5 - 3 inches of washed VDOT #8, #8P, or #9 stone. VDOT #8 stone is recommended. VDOT #8P or #9 stone may be used to match the stone used in the joint openings. The thickness of the bedding course is to be based on the block manufacturer's recommendation. The bedding course for porous asphalt pavement shall consist of 1 to 2 inches of washed VDOT #57 stone. All stone shall be washed with less than 1 percent passing a #200 sieve. Pervious concrete does not require a bedding course.

6-1304.8E The aggregate base course shall consist of washed VDOT #57 stone. The thickness of the base course is determined by runoff storage needs, the infiltration rate of *in situ* soils, structural requirements of the pavement sub-base, depth to watertable and bedrock, and frost depth conditions. VDOT #2 or #3 stone may be substituted as the base course material provided an adequate choker course of VDOT #57 stone is provided between the aggregate base course and the bedding course. All stone shall be washed with less than 1 percent passing a #200 sieve.

6-1304.8F Underdrains shall be PVC pipe conforming to the requirements of ASTM F758, Type PS 28 or ASTM F949; HDPE pipe conforming to the requirements AASHTO M252 or M 294, Type S; or other approved rigid plastic pipe with a smooth interior. Underdrains shall be perforated with four rows of 3/8-inch holes with a hole spacing of 3.25 ± 0.25 inches or a combination of hole size and spacing that provides a minimum inlet area ≥ 1.76 square inches per linear foot of pipe or be perforated with slots 0.125 inch in width that provides a minimum inlet area ≥ 1.5 square inches per linear foot of pipe.

6-1304.8G Filter fabric. Filter fabric shall be a needled, non-woven, polypropylene geotextile meeting the requirements listed in Virginia Stormwater Design Specification No. 7 Permeable

Pavement (Latest version referenced in the VSMP Regulations). Heat-set or heat-calendared fabrics are not permitted.

6-1304.9 Construction Specifications.

6-1304.9A The owner shall provide for inspection during construction of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the inspections required under § 6-1304.9G(2) or § 6-1304.9H(2) and § 6-1304.9H(3) or § 6-1304.9I(3) and § 6-1304.9I(4) shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1304.9B Pervious pavement facilities shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan. Preliminary grading of the area where pervious pavement is to be installed may be performed at the time the rest of the site is mass graded provided that positive drainage is maintained and the area is stabilized. For pervious pavement applications that will utilize infiltration, preliminary grading shall be a minimum of 2 feet above the final design elevation of the bottom of the aggregate base and the area shall be immediately stabilized with no further construction traffic until the pervious pavement is installed.

6-1304.9C Areas where pervious pavement is to be installed should not be used for temporary sediment basins. Where unavoidable, the invert of the sediment basin shall be a minimum of 2 feet above the final design elevation of the bottom of the aggregate base.

6-1304.9D For facilities designed for full or partial exfiltration, the floor of the facility shall be scarified to a minimum depth of 6 inches to reduce soil compaction and leveled before the filter fabric and stone are placed. Any areas of the facility where a temporary sediment basin was located also shall have 2-3 inches of sand incorporated into the *in situ* soils.

6-1304.9E Filter fabric shall be placed on the bottom and sides of the facility. Strips of fabric shall overlap by a minimum of 2 feet. Fabric shall be secured a minimum of 4 feet beyond the edge of the excavation. Following placement of the aggregate and again after placement of the pavement or pavers, the filter fabric should be folded over placements to protect installation from sediment inputs. Excess filter fabric should not be trimmed until the site is fully stabilized.

6-1304.9F After installation of the filter fabric over the soil subgrade, a 2-inch lift of aggregate shall be placed for the underdrain bedding. Underdrain piping shall be installed and sufficient aggregate shall be placed around and over the underdrain pipe to prevent damage to the pipe prior

to compaction. Aggregate shall be placed in 4- to 8-inch lifts and compacted with a static roller. At least four passes should be made with a minimum 10-ton static roller. The initial passes of the roller can be with vibration to consolidate the base material. The final passes should be without vibration. No visible movement should occur in the base material when compaction is complete.

6-1304.9G Installation of open jointed pavement blocks.

6-1304.9G(1) Installation of open jointed pavement blocks shall be in accordance with the construction sequence in Virginia Stormwater Design Specification No. 7 Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.9G(2) The facility shall be inspected at 18-30 hours after a significant rainfall (0.5-1.0 inch) or artificial flooding to determine that the facility is draining properly.

6-1304.9H Installation of porous asphalt pavement.

6-1304.9H(1) Installation of porous asphalt pavement shall be in accordance with the construction sequence in Virginia Stormwater Design Specification No. 7 Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.9H(2) The full permeability of the pavement surface shall be tested by application of clean water at a rate of at least 5 gpm over the entire surface. All water must infiltrate directly without puddle formation or surface runoff.

6-1304.9H(3) The facility shall be inspected at 18-30 hours after a significant rainfall (0.5-1.0 inch) or artificial flooding to determine that the facility is draining properly.

6-1304.9I Installation of pervious concrete

6-1304.9I(1) Installation of pervious concrete shall be in accordance with the construction sequence in Virginia Stormwater Design Specification No. 7 Permeable Pavement (Latest version referenced in the VSMP Regulations).

6-1304.9I(2) Installation of pervious concrete should only be performed by qualified personnel. A National Ready Mixed Concrete Association (NRMCA) Certified Pervious Concrete Craftsman or Installer should be on site, overseeing each placement crew, during all concrete placement and finishing operations. Each placement crew should have at least two NRMCA certified Pervious Concrete Technicians. Information about certification requirements and programs is available from NRMCA and the Virginia Ready Mixed Concrete Association.

6-1304.9I(3) The full permeability of the pavement surface shall be tested by application of clean water at a rate of at least 5 gpm over the entire surface. All water must infiltrate directly without puddle formation or surface runoff.

6-1304.9I(4) The facility shall be inspected at 18-30 hours after a significant rainfall (0.5-1.0 inch) or artificial flooding to determine that the facility is draining properly.

6-1304.10 Plan Submission Requirements.

6-1304.10A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures including underdrains.

6-1304.10B Cross section(s) of the facility with elevations showing the following as required: elevations and dimensions of inlet, outlet, underdrain, pavement course, bedding course, choker course, aggregate base, storage chambers, filter fabric, groundwater table and bedrock.

6-1304.10C Sizing computations for the facility including volume of storage and surface area of the facility required and provided.

6-1304.10D Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 7.

6-1304.10E Hydrologic calculations for the facility.

6-1304.10F Infiltration calculations as appropriate.

6-1304.10G Soils analysis and testing results for facilities that utilize infiltration including the elevation of the groundwater table and bedrock.

6-1304.10H A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1304.10I Construction and materials specifications.

6-1305 Retention and Detention Ponds (116-14-PFM)

6-1305.1 Small ponds created by constructing low earth dams across natural drainage courses or by excavating and regrading of a development site provide capacity for stormwater runoff detention.

6-1305.1A The ponds may be located in areas where other site development is expensive or unsuitable or may be made an integral part of the site landscaping designs.

6-1305.1B Stormwater permanently retained in these ponds may be considered a potential resource suitable for a variety of uses, including firefighting, irrigation supplies and recreational sources.

6-1305.1C In addition to providing stormwater discharge reduction capabilities, detention ponds provide storage for sediment and pollution control in runoff, especially during the construction phase of development.

6-1305.1D (46-94-PFM) If embankments are used to dam natural drainage courses, they must be designed in accordance with § 6-1600 *et seq*.

6-1305.2 (46-94-PFM) Detention ponds and their primary outlet or principal spillway shall be designed to detain the increased runoff generated by development of a site based on the 1-year, 2-year, and the 10-year frequency design floods. Emergency or secondary spillways for detention ponds shall be designed in accordance with § 6-1600 *et seq*., except where the watershed is less than 20 acres, in which case the Spillway Design Flood hydrograph may be obtained using the Rational Method.

6-1305.3 Outlets and emergency spillways shall be placed on either undisturbed ground or on a stabilized foundation and not in fill areas.

6-1305.4 (32-90-PFM) The planting of trees and other landscaping, except grass and other ground covers approved by the Director, on the structural embankment of any earth dam which intermittently or permanently impounds water, including stormwater management facilities, is prohibited.

6-1305.5 (32-90-PFM) All plans containing an earth dam which intermittently or permanently impounds water shall include a restrictive easement which covers the entire structural embankment and prohibits the planting of trees and all other landscaping, except grass and other ground covers approved by the Director. This easement shall be recorded in the Land Records of the County and shall run with the land.

6-1305.6 Design calculations for detention ponds shall be submitted with the site drainage plan and shall generally include the following:

6-1305.6A (46-94-PFM) Hydrographs of the 1-year, 2-year, 10-year, emergency spillway and freeboard design storm inflow to the facility.

6-1305.6B Volume of storage vs. depth of storage curve.

6-1305.6C Outlet design calculations.

6-1305.6D Head discharge curve for the selected outlet size.

6-1305.6E (46-94-PFM) The routed or discharge hydrograph from the facility for the 1-year, 2-year, 10-year, emergency spillway and freeboard design inflows.

6-1305.6F (46-94-PFM) Emergency spillway design calculations for ponds shall conform with the requirements of § 6-1603.

6-1305.6G (46-94-PFM) Embankment design computations shall conform to the requirements of § 6-1605.

6-1305.6H Calculations or effects (if any) on established floodplain boundaries.

6-1305.7 Other items that shall be included with or on the plans are:

6-1305.7A (46-94-PFM) When possible, the shape of the pond should conform with the natural topography.

6-1305.7B (46-94-PFM) Identification of required easements.

6-1305.7C Landscaping and fencing around detention ponds when access exposes the public to unusual risk.

6-1305.7D Properly executed maintenance agreements.

6-1305.7E (46-94-PFM) For wet detention ponds a drain valve shall be provided in accordance with § 6-1604.

6-1305.7F (35-91-PFM) The developer shall be required to provide and post signs informing the public where detention and retention ponds are to be located. Signs must be located so as to be visible from the adjoining lots and roadways from which the facilities may be viewed. The number of signs required for a site will depend upon the sight characteristics to meet the above visibility requirements. Signs shall be maintained by the developer from the time the plans for the ponds are approved by DPWES until bond release. At the time of bond release, the signs shall be removed by the developer. See Plate 41B-6 for details.

6-1305.8 Kentucky 31 tall fescue, the standard grass for most planting, has limitations for use in detention ponds. If the roots are saturated for more than three days, the grass will die. If the drawdown time is less than three days, it can be used. For non-shaded locations, bermuda grass makes good cover, and is very water tolerant. It may be seeded or sprigged. If sprigged on 1-foot

centers in the spring or early summer prior to July 1, a good ground cover will develop in about six weeks. Reed canary grass is another satisfactory and water tolerant cover. It grows to a height of 3-4 feet. It will grow in some shade but must be seeded in the fall from the current year's crop.

6-1305.9 (122-16-PFM) Table 6.6 shows inflow hydrographs for various 10-year, 2-hour storms with times of concentration from 5 minutes to 30 minutes.

6-1306 Maintenance Design Considerations

6-1306.1 The maintenance impact of stormwater management and BMP facilities is considered to be a primary concern to the County and to the future operation of these facilities.

6-1306.2 Engineers in the preparation of plans for construction are urged to include maintenance and operation of these facilities as one of the primary design considerations.

6-1306.3 The following shall be included in design considerations:

6-1306.3A All access ways shall be designated on plans and cleared, graded, or constructed with the facility construction.

6-1306.3B Proximity of facilities to public right-of-way shall be considered in order to minimize the length of access way.

6-1306.3C Multiple accesses on major facilities should be provided.

6-1306.3D Standard drainage easement agreements are not acceptable for access; therefore, special access easement agreements are to be executed which shall preclude planting of shrubs, construction of fences and other structures within the easement.

6-1306.3E Grading of the access to and around facilities shall not create steep slopes (maximum 3:1) in order to accommodate easy access for maintenance vehicles.

6-1306.3F (46-94-PFM) All facilities, including wet ponds, underground chambers, etc., shall provide accessibility with an all-weather vehicular access way with a minimum 12-feet wide surface. Surfaces may be made of geosystems such as Geogrid, Grassrings, Geoweb, or Grasscrete or may be made of asphalt, concrete or gravel. The specific situation and physical conditions shall be considered when choosing surface materials and access ways shall be designed to support the anticipated maintenance vehicles.

6-1306.3F(1) When a private pipestem driveway is used for maintenance access to a stormwater management facility, the pavement section shall be constructed in accordance with Plates 23-7 and 24-7. A CBR test is required for the shared portion of the pipestem driveway, and for CBR test values less than 10, 1 inch of additional aggregate subbase shall be provided for each point below 10. Pavement sections based on Plate 23-7 may provide an equivalent thickness index through the use of thicker asphaltic concrete layers.

6-1306.3G As these facilities are generally in close proximity to dwellings and may be subject to vandalism, principal spillways and other devices shall be designed to minimize tampering.

6-1306.3H (72-01-PFM) Underground chambers shall provide two or more access points, at least one of which shall be a 4-foot x 4-foot access door, double leaf, aluminum, BILCO Model JD-

2AL or approved equal, for each major storage chamber or run of pipe for ventilation and cleaning, and be large enough to accommodate cleaning equipment. Access doors installed in areas subject to vehicle loads shall be BILCO Model JD-2AL H 20 or approved equal. Generally, the minimum height where possible, shall be 72 inches, in order to facilitate maintenance.

6-1306.3I (46-94-PFM, 116-14-PFM) The design of dry ponds used for water quantity control only shall include a concrete low flow channel (trickle ditch) in accordance with § 6-1604 or a concrete apron in front of the riser structure. The minimum pond floor grade shall be 2 percent minimum into the trickle ditch.

6-1306.3J (46-94-PFM) Trash racks for ponds shall be designed and provided in accordance with § 6-1604. Where trash racks are provided, they shall be removable as a unit by unbolting, without destroying the structure. Access to the trash rack shall be provided immediately above the rack in the underground chambers.

6-1306.3K Where pipe storage is permitted all pipes shall be reinforced concrete with parged joints in facilities maintained by DPWES. Any other material shall be specifically approved by the Director.

6-1306.3L Where utilized, underground chambers shall be only appurtenant structures to the site and through drainage storm sewer systems. The stormwater management facilities shall not be incorporated as an in-line system, but be designed as a parallel or perpendicular appurtenant structure.

6-1306.3M Underground chambers shall provide a smooth contoured bottom to facilitate silt and debris removal.

6-1307 Bioretention (116-14-PFM)

6-1307.1 General.

6-1307.1A Bioretention filters and basins (a.k.a. rain gardens) are landscaped areas in shallow depressions that are subject to temporary ponding of stormwater runoff. The principal components of bioretention facilities are plants that tolerate fluctuations in soil moisture and temporary ponding of water, a mulch layer, an engineered soil media, a gravel layer, and an underdrain that is connected to the storm drain system or day lighted. The soil media is highly permeable and well drained. Water quality control is provided by filtering storm water runoff through the soil media and mulch, biological and chemical reactions in the soil, mulch, and root zone, plant uptake, and infiltration into the underlying soil. The void spaces in the soil can be used to store runoff for detention or infiltration to provide reductions in the peak rate and volume of stormwater runoff. Additional infiltration capacity or storage for detention can be obtained by using a gravel layer alone or in combination with storage chambers below the soil media.

6-1307.1B Bioretention filters are designed to provide water quality control and detention of storm water runoff from small storms. Bioretention filters include underdrains that allow water that has passed through the soil media to be freely discharged.

6-1307.1C Bioretention basins are designed to provide water quality control and retention of storm water. Bioretention basins rely on infiltration into the underlying *in situ* soils to drain down between storms. Bioretention basins, as utilized in Fairfax County, generally include underdrains that are capped or have restricted outflow. This allows a bioretention basin to be converted to a bioretention filter if the infiltration capacity of the *in situ* soils is reduced over time due to clogging of the soil pores.

6-1307.1D Small-scale or Micro-Bioretention used on an individual residential lot is commonly referred to as a Rain Garden.

6-1307.1E Bioretention facilities are best suited for small drainage areas that have low sediment loads. Pretreatment techniques that allow runoff to flow from impervious surfaces through well-established lawns, naturally vegetated buffers, or specially constructed filter strips are used to remove coarse and fine grained sediments that may otherwise clog the surface of facilities. Level spreaders or stone energy dissipaters may be used to prevent concentrated flow from creating scour paths within the facility. Bioretention facilities should not be located where wooded areas would not otherwise need to be cleared as part of the site development.

6-1307.1F Bioretention shall conform to Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations, except as modified herein.

6-1307.2 Feasibility and Limitations.

6-1307.2A In residential areas, bioretention facilities and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance except as noted herein. The Director may approve the location of bioretention facilities on individual buildable single-family detached lots for subdivisions creating no more than seven lots where it can be demonstrated that the requirement is not practical or desirable due to constraints imposed by the dimensions or topography of the property and where adequate provisions for maintenance are provided. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities.

6-1307.2B Bioretention facilities may be located on individual single-family detached residential lots that are not part of a bonded subdivision to satisfy the BMP requirements of the Stormwater Management Ordinance for construction on the lot.

6-1307.2C Bioretention facilities may be located in the VDOT right-of-way with specific approval from VDOT.

6-1307.2D Bioretention facilities that utilize infiltration may not be constructed on fill material.

6-1307.2E Bioretention facilities may not be constructed on slopes steeper than 15 percent.

6-1307.2F Setbacks. Bioretention facilities shall meet the setback requirements of the Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). In addition, bioretention facilities shall be set back a minimum of 2 feet from property lines.

6-1307.2G Trees within bioretention facilities may be used to meet the requirements of Chapter 122 of the County Code and § 12-0000 *et seq.* of the PFM.

6-1307.3 Maintenance.

6-1307.3A Bioretention facilities and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Bioretention facilities may not be located in County storm drainage easements. The above does not preclude the use of bioretention facilities by the County on County-owned property.

6-1307.3B Maintenance access must be provided for all bioretention facilities not located on individual buildable single family detached lots in accordance with § 6-1306. For bioretention facilities located on individual buildable single family detached lots, maintenance access shall be considered as an integral part of the design and designated on the plan.

6-1307.3C Bioretention facilities shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area, water may pond after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the bioretention area with a minimum of one sign for each facility. (See Plate 81-6.)

6-1307.3D Urban bioretention facilities (tree box filters) shall be stenciled (or a plaque provided) on the inside of the box in a location clearly visible upon removal of the tree grate designating the tree box as a water quality management facility. The stenciling or plaque shall state that the facility is a water quality management facility, water may pond after a storm, and the facility is not to be disturbed except for required maintenance.

6-1307.4 Design Criteria.

6-1307.4A Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations).

6-1307.4B Detention. For facilities designed to provide detention, the 1-year storm, the 2-year storm and the 10-year storm must be routed through the facility; or the facility may be designed to infiltrate the 10-year storm volume; or the facility may be designed to filter the 10-year storm volume. Except where the facility is designed to filter the 10-year storm volume, a drop inlet with a trash rack or screen shall be provided to convey stormwater in excess of the water quality volume to a gravel layer or storage chambers below the soil media.

6-1307.4C For on-line facilities, the inlet must be designed to pass the peak flow rate for the 10-year storm. For off-line facilities, a flow splitter shall be used to capture the design storm (typically the treatment volume) and pass larger flows around the facility.

6-1307.4D Pre-Treatment. Pre-treatment shall be provided at all points of concentrated inflow to facilities. Pre-treatment shall be designed in accordance with Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). Pre-treatment generally consists of a vegetated filter strip or channel and an energy dissipation device. However, space constraints (e.g., parking lot islands) may limit the ability to provide a vegetated filter strip or channel. Where space permits, vegetated filter strips or channels shall be provided. Energy dissipation devices are required for all facilities at points of concentrated inflow. Where inflow is in the form of sheet flow, a vegetated filter strip shall be provided where space permits. Guidelines for sizing vegetated filter strips and channels are provided in Tables 6.25 and 6.26.

Table 6.25 Pretreatment Filter Strip Sizing

Inflow Surface	**Impervious**				**Pervious**			
Maximum Inflow Approach Length	35 ft.		75 ft.		75 ft.		150 ft.	
Filter Strip % Slope (6% max)	≤ 2	≥ 2	≤ 2	≥ 2	≤ 2	≥ 2	≤ 2	≥ 2
Minimum Filter Strip Length Feet	10	15	20	25	10	12	15	18

Table 6.26 Pretreatment Vegetated Channel Sizing* (101-08-PFM)

% Impervious	**≤ 33%**		**34% - 66%**		**≥ 67%**	
Channel Slope (4% max)	≤ 2%	≥ 2%	≤ 2%	≥ 2%	≤ 2%	≥ 2%
Min. Length feet	25	40	30	45	35	50
* 1-acre drainage area, 2-foot-wide channel bottom						

6-1307.4E The maximum surface storage depth from the top of the mulch layer to the elevation of the overflow weir or drop inlet shall be 1 foot.

6-1307.4F Berms used to pond water in bioretention facilities shall be a maximum of 2.0 feet in height measured from the downstream toe-of-slope to the top of the berm. The width of the top of the berm shall be a minimum of 2.0 feet. The side slopes of the berm shall be a maximum of 3:1. Berms and overflow weirs shall be sodded and pegged in accordance with the most recent edition of the "Virginia Erosion and Sediment Control." Facilities with berms that are equal to or less than 2.0 feet in height or excavated facilities will not be subject to the requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1307.4G (107-11-PFM) The side slopes of the facility above ground shall be a maximum of 3:1. Where space permits, gentle side slopes (e.g., 5:1) are encouraged to blend the facility into the surrounding landscape. Side slopes of the facility excavated below ground may be as steep as the *in situ* soils will permit. All excavation must be performed in accordance with Virginia Occupational Safety and Health (VOSH) requirements. If the facility is located on problem soils, as defined in Section 107-2-2 (j) of the County Code, a professional authorized by the State shall specify the maximum acceptable slope.

6-1307.4H An outlet structure must be provided to convey the peak flow for the 10-year storm. The outlet structure may be a drop inlet or weir. A minimum freeboard of 6 inches shall be provided from the maximum elevation of the 10-year storm to the top of the facility.

6-1307.4I An emergency overflow weir shall be provided for all facilities with berms. The emergency overflow weir must have the capacity to pass the peak flow from the 100-year storm without overtopping the facility. If the facility design includes a weir in the berm to convey the peak

flow for the 10-year storm, it also may be designed to function as the emergency overflow weir. The minimum weir length shall be 2 feet.

6-1307.4J The outfall of all outlet structures, emergency overflow weirs, and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1307.4K Underdrains shall be provided for all bioretention filters and basins except that facilities on individual single-family detached residential lots that are not part of a bonded subdivision may be constructed without underdrains if the underdrain cannot be daylighted on the lot or connected to a storm sewer structure. If there are no underdrains, observation wells shall be installed to monitor drainage from the facility.

6-1307.4L The depth between the bottom of the facility and groundwater table or bedrock shall be a minimum of 4 feet for bioretention basins and a minimum of 2 feet for bioretention filters as determined by field run soil borings.

6-1307.4M For facilities designed to provide infiltration, the underdrain shall be restricted as necessary so that the design infiltration rate plus the underdrain outflow rate equals the design draw down rate. The restriction shall be achieved by using an end cap with a hole to act as an orifice or a valve fitted onto the end of the underdrain. Alternatively, a flow control satisfactory to the Director may be provided within the overflow structure. See § 6-1604.1A(2) for orifice calculations. The minimum diameter of any orifice shall be 0.5 inches. Facilities shall be designed to dewater completely within 48 hours. If the facility can drain in the required time without any outflow through the underdrain, the end cap may be provided without a hole.

6-1307.4N The soil media depth shall be determined in accordance with Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). If large trees and shrubs are to be installed, soil depths shall be increased to a minimum of 4 feet. The bottom of the soil layer must be a minimum of 4 inches below the root ball of plants to be installed. A layer of 2-3 inches of mulch shall be placed on top of the soil media.

6-1307.4O For facilities utilizing infiltration, the design of the facility shall be in accordance with the soil testing, reporting and meeting procedures of § 4-0700 *et seq.*

6-1307.4P Variations of the bioretention filter and basin designs in the typical details and schematics of bioretention facilities in Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements in § 6-1307 *et seq*.

6-1307.4Q The design geometry shall prevent short-circuiting. The Director may waive or modify the guideline for the shortest flow path ratio in cases where (1) the outlet structure within the bioretention area is raised above the filter surface to the ponding depth elevation; and (2) the filter surface is flat.

6-1307.5 Filter Bed Design.

6-1307.5A The required surface area of the filter shall be determined in accordance with Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations).

6-1307.5B The drain time through the filter is based on the volume of water to be treated and the hydraulic properties of the soil media in accordance with Darcy's law computed as follows:

$$t_f = (T_v)(d_f) / [(k_f / 12)(0.5h_f+d_f)A_f]$$

Where:
t_f = drain time through filter (hrs.)
T_v = treatment volume (ft^3)
d_f = depth of filter (ft.)
k_f = coefficient of permeability (in./hr.)
h_f = maximum ponding depth (ft.)
A_f = area of filter (ft^2)

6-1307.5C A coefficient of permeability of 1.5 inches/hour for the soil media shall be used for sizing calculations. The treatment volume must drain through the filter section in 24 hours. In determining the drain time through the filter, assume that the rainfall event has ended and the ponding depth is at the maximum elevation prior to the initiation of drawdown.

6-1307.6 Gravel Layer/Storage Chamber Design.

6-1307.6A Storage Volume. Storage for detention or infiltration may be provided by a layer of gravel or gravel in combination with storage chambers beneath the soil media. Water flows into the storage layer either through an inlet structure or through the soil media layer. Water flows out of the storage layer either by infiltration into the underlying *in situ* soils or through a restricted underdrain. The design objectives are to infiltrate as much of the water as possible, to provide sufficient storage so that water can drain freely through the filter without being backed-up, to assure that there is complete drain down of the facility between storms, and to meet the physical constraints of the site.

6-1307.6A(1) For facilities designed to infiltrate the treatment volume, the amount of storage required is based on the flow rate through the filter minus the infiltration rate into the underlying *in situ* soils and the outflow through the underdrain during the filling period. The required storage volume is computed as follows:

$$V_s = T_v - [(k_s)(A_s)(t_f) / 12] - [3{,}600(Q_u)(t_f)]$$

Where:
V_s = volume of storage (ft^3)
T_v = treatment volume (ft^3)

k_s = soil infiltration rate (in./hr.)
A_s = area of soil bed (ft^2)
t_f = drain time through filter (hrs.)
Q_u = outflow through underdrain (cfs)

6-1307.6A(2) For facilities designed to provide detention in addition to filtering the treatment volume, the treatment volume is replaced in the above equation by the total storm runoff volume for the design storm (V_{ds}). The required storage volume is computed as follows:

$$V_s = V_{ds} - [(k_s)(A_s)(t_f) / 12] - [3{,}600(Q_u)(t_f)]$$

6-1307.6B Storage Depth. Typically, the area of the soil bed will be known (approximately equal to the area of filter bed for larger facilities) and the depth of the gravel layer will be computed from the required storage and the porosity of the gravel as follows:

$$d_g = V_s / [(n_g)(A_s)]$$

Where:
d_g = depth of gravel layer (ft.)
V_s = volume of storage (ft^3)
n_g = porosity of gravel
A_s = area of soil bed (ft^2)

6-1307.6C After determining the depth of the gravel layer, check the invert elevation against the elevation of the water table and bedrock. Also check that the facility can drain to the intended outfall.

6-1307.6D Facility Drain Time. The final step in the design of the gravel layer is to compute the time that it takes the facility to drain. The facility must drain completely within 48 hours after the water quality volume has been captured by the filter section. The drain time is computed as follows:

$$t_d = V_s / [(k_s)(A_s) / 12 + 3{,}600(Q_u)] + t_f$$

Where:
t_d = total drain time for facility (hrs.)
V_s = volume of storage (ft^3)
k_s = soil infiltration rate (in./hr.)
A_s = area of soil bed (ft^2)
Q_u = outflow through underdrain (cfs)
t_f = drain time through filter (hrs.)

6-1307.6E For facilities designed as bioretention filters with unrestricted underdrains, computation of the storage volume, storage depth, and facility drain time are not necessary.

However, it is still necessary to check the invert elevation of the gravel layer against the elevation of the water table, bedrock, and the intended outfall.

6-1307.6F For facilities designed as bioretention basins, the infiltration rate into the underlying *in situ* soils typically will be less than the flow rate through the filter and the outflow through the underdrain will be restricted or absent such that some storage will be required. In performing computations of the storage volume, storage depth, and facility drain time, initially assume that the underdrain is capped and there is no outflow through the underdrain. If the allowable depth of the storage layer based on the elevation of the groundwater table or bedrock is insufficient to provide the necessary storage volume, storage may be increased by increasing the area of the filter and soil bed or by incorporating storage chambers. Alternatively, the underdrain may be provided with an orifice to decrease the amount of storage needed. If the total drain time of the facility is in excess of 48 hours, it will be necessary to provide an orifice and recompute the total drain time through the facility. Outflow through the orifice may not exceed the pre-development peak flow rates for the 1-year, 2-year and 10-year storms.

6-1307.6G A porosity of 0.40 for VDOT #57 stone shall be used for volume calculations.

6-1307.7 Underdrains. Underdrains shall consist of pipe ≥ 4 inches in diameter placed in a layer of washed VDOT #57 stone. There shall be a minimum of 2 inches of gravel above and below the pipe. Laterals shall be a minimum of 4-6 inches in diameter. Main collector lines and manifolds shall be a minimum of 6-8 inches in diameter. Underdrains shall be laid at a minimum slope of 0.5 percent. Underdrains shall extend to within 10 feet of the boundary of the facility and have a maximum internal spacing of 20 feet on center. Underdrains shall be separated from the soil media in accordance with Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). Underdrains not terminating in an observation well/clean-out shall be capped. The portion of underdrain piping beneath the planting soil bed must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. All stone shall be washed with less than 1 percent passing a #200 sieve.

6-1307.8 Observation Wells and Cleanouts. There shall be a minimum of one observation well or cleanout per 1,000 square feet of surface area. Observation wells and cleanouts shall be a minimum of 6 inches in diameter with a screw, or flange type cap to discourage vandalism and tampering extending above the BMP water surface elevation. Cleanouts shall be provided at the end of all pipe runs. Cleanouts and observation wells shall be solid pipe except for the portion below the planting soil bed which must be perforated. Observation wells that are not connected to underdrain piping shall be anchored to a footplate at the bottom of the facility.

6-1307.9 Materials Specifications.

6-1307.9A The bioretention soil media shall meet the requirements of Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). Topsoil used to create bioretention soil media should be a sandy loam or loamy sand per USDA textural classification. The textural class of the topsoil should be verified by a laboratory analysis.

Topsoil shall be of uniform composition, containing no more than 5 percent clay, free of stones, stumps, brush, roots, or similar objects larger than 2 inches. Topsoil shall be free of Bermuda Grass, Quackgrass, Johnson Grass, Mugwort, Nutsedge, Poison Ivy, Canadian Thistle, Tearthumb, or other noxious weeds. Sand shall meet AASHTO M-6, ASTM C-33, or VDOT Section 202 Grade "A" Fine Aggregate specifications. Sand shall be clean and free of deleterious materials. Any organic material added to create the final soil mixture shall consist of leaf compost or compost meeting the requirements of Virginia Stormwater Design Specification No. 4 Soil Compost Amendment. The final soil mixture shall not contain any material or substance that may be harmful to plant growth, or a hindrance to plant growth or maintenance. Each bioretention area shall have a minimum of one soil test performed on the final soil mixture to demonstrate compliance with the mixture requirements for sand, soil fines, organic matter, P-Index (phosphorus content) and cation exchange capacity (CEC) using standard test methods. Test results and materials certifications shall be submitted to DPWES prior to bond release.

6-1307.9B Mulch shall be double shredded aged hardwood bark with a particle size greater than 0.5 inches. Mulch shall be well aged, uniform in color, and free of salts, harmful chemicals, and extraneous material including soil, stones, and plant material. Well aged mulch is mulch that has been stockpiled or stored for 6-12 months.

6-1307.9C Underdrains shall be PVC pipe conforming to the requirements of ASTM F758, Type PS 28 or ASTM F949; HDPE pipe conforming to the requirements AASHTO M252 or M 294, Type S; or approved equivalent pipe. Underdrains shall be perforated with four rows of 3/8-inch holes with a hole spacing of 3.25 ± 0.25 inches or a combination of hole size and spacing that provides a minimum inlet area $\geq$ 1.76 square inches per linear foot of pipe or be perforated with slots 0.125 inches in width that provides a minimum inlet area $\geq$ 1.5 square inches per linear foot of pipe.

6-1307.9D Filter fabric. Filter fabric shall be a needled, non-woven, polypropylene geotextile meeting the requirements listed in Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations). Heat-set or heat-calendared fabrics are not permitted.

6-1307.10 Bioretention Planting Plans.

6-1307.10A Bioretention planting plans and specifications shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0500.

6-1307.10B Depending on the bioretention planting plan type and application as detailed in § 6-1307.10G, a mixture of trees, shrubs, and perennial herbaceous plants with a high density of fibrous roots is required. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant

materials will be determined by the Director. Guidance on the use and selection of plants for bioretention facilities is available from Urban Forest Management.

6-1307.10C All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1307.10D Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size. Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1307.10E The planting plan shall provide for plant community diversity and should consider aesthetics from plant form, color, and texture year-round. The bioretention facility design and selection of plant material shall serve to visually link the facility into the surrounding landscape. If trees and shrubs are part of the design, woody plant species shall not be placed directly within the inflow section of the bioretention facility.

6-1307.10F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1307.10G Bioretention Planting Plan Types and Applications.

6-1307.10G(1) Wooded planting plans. Wooded bioretention facilities are appropriate where the facility is located at wooded edges, in the rear of residential lots, or where a wooded buffer is required. Design guidelines include:

6-1307.10G(1)(a) A density of 10 trees per 1,000 square feet of basin shall be used.

6-1307.10G(1)(b) A minimum of three species of trees and three species of shrubs shall be planted, with trees located on the perimeter to maximize shading of the bioretention area;

6-1307.10G(1)(c) Of the three species of trees, at a minimum one shall be a mid or understory species; 30-50 percent of the total quantity of trees planted shall be mid or understory trees;

6-1307.10G(1)(d) Two to three shrubs shall be planted for each tree (2:1 to 3:1 ratio of shrubs to trees);

6-1307.10G(1)(e) At least three species of perennial herbaceous ground cover shall be planted;

6-1307.10G(1)(f) (106-10-PFM) Where the basin is planted at the specified density, interior and peripheral parking lot landscaping and 10-year tree canopy credit will be granted if planting conforms to the requirements of Article 13 of the Zoning Ordinance and Chapter 122 of the County Code (Tree Conservation Ordinance) and PFM § 12-0000 *et seq.*

6-1307.10G(1)(g) Trees planted in wooded bioretention facilities may also fulfill the requirements of transitional screening if the planting conforms to the provisions of Article 13-300 of the Zoning Ordinance.

6-1307.10G(2) Ornamental garden planting plans. Ornamental garden bioretention facilities are appropriate on commercial sites, as a focal point within residential developments or located in the front yard of an individual residential lot. Design guidelines include:

6-1307.10G(2)(a) The facility should be considered as a mass planting bed with plants that have ornamental characteristics linking it to the surrounding landscape;

6-1307.10G(2)(b) The facility should contain a variety of plant species which will add interest to the facility with each changing season;

6-1307.10G(2)(c) A mixture of trees, shrubs and perennial herbaceous groundcover at an approximate ratio of 10 percent trees, 20 percent shrubs and 70 percent perennials shall be planted;

6-1307.10G(2)(d) When the size or location of the facility precludes the use of large shade trees, use of small ornamental trees shall be considered. Alternatively, a mixture of shrubs and perennials at an approximate ratio of 40 percent shrubs, 60 percent perennials may be used;

6-1307.10G(2)(e) Spacing of plant material is species specific and will be subject to review and approval of the Director. In general the facility shall be planted at a density that the vegetation will cover 80-90 percent of the facility after the second growing season.

6-1307.10G(3) Meadow garden planting plans. Meadow garden bioretention facilities lack woody material and are appropriate for small facilities, either on commercial or residential sites. Design guidelines include:

6-1307.10G(3)(a) Plant material shall consist of a variety of grasses and wildflowers. Other groundcovers, rushes and sedges may be part of the mixture as well;

6-1307.10G(3)(b) Species of different heights, texture, as well as flowering succession shall be selected;

6-1307.10G(3)(c) Spacing of plant material is species specific and will be subject to review and approval of the Director. In general the facility shall be planted at a density that the perennial herbaceous vegetation will cover 80-90 percent of the facility after the second growing season.

6-1307.11 Construction Specifications.

6-1307.11A The owner shall provide for inspection during construction of the facility by a licensed design professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the tests and inspections required under § 6-1307.9A, § 6-1307.11D, and § 6-1307.11K shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1307.11B Bioretention facilities shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan.

6-1307.11C The components of the soil media shall be thoroughly mixed until a homogeneous mixture is obtained. It is preferable that the components of the soil media be mixed at a batch facility prior to delivery to the site. The soil media shall be moistened, as necessary, to prevent separation during installation.

6-1307.11D The soil media shall be tested for pH, organic matter, grain size distribution, P-Index (phosphorus content) and cation exchange capacity (CEC) using standard test methods prior to installation. If the results of the tests indicate that the required specifications are not met, the soil represented by such tests shall be amended or corrected as required and retested until the soil meets the required specifications. If the pH is low, it may be raised by adding lime. If the pH is too high, it may be lowered by adding iron sulfate plus sulfur.

6-1307.11E For bioretention basins, the floor of the facility shall be scarified or tilled to reduce soil compaction and raked to level it before the filter fabric, stone, and soil media are placed.

6-1307.11F The soil media may be placed by mechanical methods with minimal compaction in order to maintain the porosity of the media. Spreading shall be by hand. The soil media shall be placed in 8- to 12-inch lifts with no machinery allowed over the soil media during or after construction. The soil media should be overfilled above the proposed surface elevation as needed to allow for natural settlement. Lifts may be lightly watered to encourage settlement. After the final lift is placed, the soil media shall be raked to level it, saturated, and allowed to settle for at least one week prior to installation of plant materials.

6-1307.11G Fill for the berm and overflow weir shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications.

Compaction equipment shall not be allowed within the facility on the soil bed. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1307.11H Plant material shall be installed per § 12-0705.

6-1307.11I Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1307.11J All areas surrounding the facility that are graded or denuded during construction of the facility and are to be planted with turf grass shall be sodded.

6-1307.11K The facility shall be inspected at 12-24 and 36-48 hours after a significant rainfall (0.5-1.0 inches) or artificial flooding to determine that the facility is draining properly. Results of the inspection shall be provided to DPWES prior to bond release.

6-1307.11L Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 9 Bioretention (Latest version referenced in the VSMP Regulations).

6-1307.12 Plan Submission Requirements.

6-1307.12A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures including underdrains.

6-1307.12B Cross section(s) of the facility showing the following: elevations and dimensions of berm, inlet, outlet, underdrain, soil media, underlying gravel layer, storage chambers, filter fabric, groundwater table, and bedrock.

6-1307.12C Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1307.12D Sizing computations for the facility including volume of storage and surface area of facility required and provided and a computation of the ratio of the shortest flow path to overall length of the facility.

6-1307.12E Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 9.

6-1307.12F Hydrologic calculations for the facility.

6-1307.12G Design calculations and specifications for all hydraulic structures including inlet structures, overflow weirs, and underdrain piping.

6-1307.12H Infiltration calculations as appropriate.

6-1307.12I Soils analysis and testing results for facilities that utilize infiltration. Elevation of groundwater table and/or bedrock.

6-1307.12J A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1307.12K Construction and materials specifications.

6-1308 Vegetated Swales (116-14-PFM)

6-1308.1 General.

6-1308.1A Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey stormwater runoff to downstream discharge points. The principal components of vegetated swales are a dense covering of plants, with a deep root system to resist scouring, that tolerate fluctuations in soil moisture and temporary ponding of water, check dams (where needed) to pond water along the length of the swale, an engineered soil media or compost amended soil, and an underdrain in a gravel layer that is connected to the storm drain system or daylighted. The soil media is highly permeable and well drained. Water quality control is provided by sedimentation, filtering of stormwater runoff through the vegetation and soil media, biological and chemical reactions in the soil and root zone, plant uptake, and infiltration into the underlying soils. Reductions in the peak rate of runoff are achieved due to increases in the time of concentration compared to conventional conveyance systems and the temporary storage provided by the check dams and the void spaces in the soil and underdrain gravel. Infiltration into the underlying soils may provide some volume reduction. Vegetated swales are best suited for small drainage areas that have low sediment loads. The following specifications cover both simple grass channels and dry swales that function similarly to bioretention facilities.

6-1308.1B Grass channels can provide a modest amount of runoff filtering and volume attenuation within the stormwater conveyance system resulting in the delivery of less runoff and pollutants than a traditional system of curb and gutter, storm drain inlets and pipes. The performance of grass channels will vary depending on the underlying soil permeability. Grass channels, however, are not capable of providing the same stormwater functions as dry swales because they lack the storage volume associated with the engineered soil media. Their runoff reduction performance can be boosted when compost amendments are added to the bottom of the swale. Grass channels are a preferable alternative to both curb and gutter and storm drains as a stormwater conveyance system, where development density, topography and soils permit. Grass channels can also be used to treat runoff from the managed turf areas of turf-intensive land uses, such as sports fields and golf courses, and drainage areas with combined impervious and turf cover (e.g., roads and yards).

6-1308.1C Dry swales essentially are bioretention facilities that are shallower, configured as linear channels, and covered with turf or other surface material (other than mulch and ornamental plants). The dry swale is a soil filter system that temporarily stores and then filters the desired Treatment Volume (Tv). Dry swales rely on a pre-mixed soil media filter below the channel that is similar to that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. In most cases, however, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system farther downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Dry swales may appear as simple grass channels with the same shape

and turf cover, while others may have more elaborate landscaping. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

6-1308.1D Grass channels shall conform to Virginia Stormwater Design Specification No. 3 Grass Channels (Latest version referenced in the VSMP Regulations), except as modified herein. Dry swales shall conform to Virginia Stormwater Design Specification No. 10 Dry Swales (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1308.2 Location and Siting.

6-1308.2A In residential areas, vegetated swales and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management except as noted herein. The Director may approve the location of vegetated swales on individual buildable single-family detached lots for subdivisions creating no more than seven lots where it can be demonstrated that the requirement is not practical or desirable due to constraints imposed by the dimensions or topography of the property and where adequate provisions for maintenance are provided. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities.

6-1308.2B Vegetated swales may be located on individual single-family detached residential lots that are not part of a bonded subdivision to satisfy the BMP requirements of the Stormwater Management Ordinance for construction on the lot.

6-1308.2C Vegetated swales may be located in the VDOT right-of-way with specific approval from VDOT.

6-1308.2D Setbacks. Vegetated swales shall meet the setback requirements for bioretention facilities in § 6-1307 *et seq*. In addition, vegetated swales shall be set back a minimum of 2 feet from property lines except where swales are located in the right-of-way.

6-1308.2E Vegetated swales shall not be located in the vicinity of loading docks, vehicle maintenance areas, or outdoor storage areas, where there is the potential for high concentrations of hydrocarbons, toxics, or heavy metals in stormwater runoff.

6-1308.2F In order to maintain healthy growth, swales vegetated solely with grass shall be located so that they receive a minimum of six hours of sunlight daily during the summer months throughout the entire length of the swale.

6-1308.2G The maximum drainage area to a vegetated swale shall be 2 acres. The maximum impervious area draining to a vegetated swale shall be 1 acre.

6-1308.2H Vegetated swales typically are designed as online conveyance systems but may be used offline as pre-treatment for other types of BMPs.

6-1308.3 Maintenance.

6-1308.3A Vegetated swales and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Vegetated swales may not be located in County storm drainage easements. The above does not preclude the use of vegetated swales by the County within existing County drainage easements or on County-owned property.

6-1308.3B Maintenance access must be provided for all vegetated swales not located on individual buildable single family detached lots in accordance with § 6-1306 except that the access way may have a grass surface rather than an all-weather surface. For vegetated swales located on individual buildable single family detached lots, maintenance access shall be considered as an integral part of the design and designated on the plan.

6-1308.3C Vegetated swales shall be posted with permanent signs designating the area as a water quality management area. Signs for vegetated swales with check dams shall state that the facility is a water quality management area, water may pond after a storm, and the area is not to be disturbed except for required maintenance. Signs for vegetated swales (grass) without check dams shall state that the facility is a water quality management area and that the grass is to be maintained at a 4- to 8-inch height. Signs shall be posted at approximately 150-foot intervals along the length of the vegetated swale on alternating sides with a minimum of one sign for each swale. See Plate 81-6.

6-1308.4 Dry Swale Design.

6-1308.4A Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 10 Dry Swales (Latest version referenced in the VSMP Regulations.

6-1308.4B Check dams may be provided along the length of the swale to provide storage of a portion of the treatment volume or to reduce the effective slope. The maximum height of check dams shall be 1.5 feet. Check dams shall be located and sized such that the ponded water does not reach the toe of the next upstream check dam or create a tailwater condition on incoming pipes. The length of the channel segment over which water is ponded is a function of the slope of the swale and the height of the check dam computed as follows:

$L = h / s$

Where:
L = length of channel segment (ft.)

H = height of check dam (ft.)
S = channel slope (ft./ft.)

Channel segment lengths for various combinations of check dam height and channel slope that may be used for preliminary design are listed in Table 6.30. In determining the minimum spacing between check dams, add 5 feet to the computed channel segment length to assure that the ponded water does not reach the toe of the next upstream check dam.

Table 6.30 Channel Segment Length ft.

		Check Dam Height ft.		
		0.5	**1.0**	**1.5**
Channel Slope %	**1**	50	100	150
	2	25	50	75
	3	16.7	33.3	50
	4	12.5	25	37.5
	5	10	20	30

6-1308.4C The volume stored behind a check dam is the average channel cross-section area at the ponding elevation multiplied by the length of the channel reach subject to ponding. Because the channel cross-section area is zero at the head of the reach, the average cross-section area is one half of the channel cross-section area at the low point of the check dam. The storage volume provided behind an individual check dam is computed as follows:

$V_s = L \times 0.5A_s$

Where:
V_s = volume of storage (ft^3)
L = length of channel segment (ft.)
A_s = cross-section area (ft^2) at the check dam

The channel cross-section area for a trapezoidal channel is computed as follows:

$A = by + Zy^2$

Where:
b = bottom width
y = flow depth
Z = side slope length per unit height (e.g., Z = 3 if side slopes are 3H:1V)

The channel cross-section area of a trapezoidal channel with 3:1 side slopes for various combinations of check dam height and bottom width that may be used for preliminary design are listed in Table 6.31.

Table 6.31 Channel Cross-section Area
ft^2

		Check Dam Height ft.		
		0.5	**1.0**	**1.5**
Bottom Width ft.	**2**	1.75	5.0	9.75
	3	2.25	6.0	11.25
	4	2.75	7	12.75
	5	3.25	8	14.25
	6	3.75	9	15.75
	7	4.25	10	17.25
	8	4.75	11	18.75
	9	5.25	12	20.25
	10	5.75	13	21.75

6-1308.4D Underdrains shall be provided for all dry swales.

6-1308.4E The depth between the bottom of the gravel underdrain and the groundwater table or bedrock shall be a minimum of 2 feet as determined by field run soil borings.

6-1308.4F The outfall of all vegetated swales and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1308.4G Variations of the dry swale designs in the typical details and schematics dry swales in Virginia Stormwater Design Specification No. 10 Dry Swales (Version 1.9, March 1, 2011) may be approved by the Director provided the facility meets all of the requirements in § 6-1308 *et seq*.

6-1308.4H The sides of the excavation for placement of the bioretention soil media, underdrain, and gravel sump shall be lined with geotextile fabric for its' full depth and the bottom of the excavation shall be lined with geotextile fabric or 6-8 inches of sand.

6-1308.5 Grass Channel Design

6-1308.5A Design flow. Design flows shall be determined in accordance with Virginia Stormwater Design Specification No. 3 Grass Channels (Latest version referenced in the VSMP Regulations).

6-1308.5B Check dams may be provided along the length of the swale to reduce the effective slope. See § 6-1308.4B.

6-1308.5C The use of compost amended soils is required for all grass channels.

6-1308.5D The outfall of all vegetated swales and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1308.5E Variations of the grass channel designs in the typical details and schematics of grass channels in Virginia Stormwater Design Specification No. 3 Grass Channels (Latest version referenced in the VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements in § 6-1308 *et seq*.

6-1308.6 Underdrains. Underdrains shall consist of pipe ≥ 6 inches in diameter placed in a layer of washed VDOT #57 stone. There shall be a minimum of 2 inches of gravel above and below the pipe. The underdrain shall begin within 10 feet of the upstream boundary of the swale. Underdrains shall be separated from the soil media in accordance with Virginia Stormwater Design Specification No. 10 Dry Swales (Latest version referenced in the VSMP Regulations). Underdrain pipe shall be perforated. All stone shall be washed with less than 1 percent passing a #200 sieve.

6-1308.7 Cleanouts. Cleanouts shall be placed every 100 feet along the length of dry swales beginning at the upper end of the swale with a minimum of one cleanout per swale. Cleanouts shall be a minimum of 6 inches in diameter with a screw, or flange type cap to discourage vandalism and tampering. Cleanouts shall be nonperforated pipe except for the portion below the planting soil bed which must be perforated. For swales with check dams, the cap shall be above the BMP water surface elevation. For swales without check dams, the cap shall be above the ground surface.

6-1308.8 Materials Specifications.

6-1308.8A The bioretention soil media shall meet the requirements of § 6-1307.9A. Each vegetated swale shall have a minimum of one soil test performed on the final soil mixture. Test results and materials certifications shall be submitted to DPWES prior to bond release.

6-1308.8B Mulch shall meet the requirements of § 6-1307.9B.

6-1308.8C Underdrains shall meet the requirements of § 6-1307.9C.

6-1308.8D Filter fabric. Filter fabric shall meet the requirements of § 6-1307.9D.

6-1308.8E Check dams. Check dams may be constructed of non-erosive material such as wood, gabions, rip-rap, or concrete. Earthen berms or bio-logs also may be used to create check dams. Whatever material is used, check dams shall be designed to prevent erosion where the check dams intersect the channel side walls. Check dams shall be anchored into the swale wall a minimum of 2 feet on each side with the toe protected by a suitable non-erodible material (e.g.,

stone). A notch or depression shall be placed in the top of the check dam to allow the 2-year flow to pass without coming into contact with the check dam abutments.

6-1308.8F Compost. Compost shall meet the requirements of Virginia Stormwater Design Specification No. 4 Soil Compost Amendment.

6-1308.9 Vegetated Swale Planting Plans.

6-1308.9A Planting plans are required for all vegetated swales planted with a mixture of shrubs, perennial herbaceous plants, and trees (optional). Planting plans are not required for vegetated swales only planted with grass.

6-1308.9B (102-08-PFM) Vegetated swale planting plans and specifications shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0515.

6-1308.9C A mixture of shrubs, perennial herbaceous plants, and grasses with a high density of fibrous roots is required. The use of trees is optional. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation, retard and withstand stormwater flows, and filter pollutants. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant materials will be determined by the Director. Guidance on the use and selection of plants for vegetated swales is available from Urban Forest Management.

6-1308.9D Plant materials shall meet the requirements of § 6-1307.10C and § 6-1307.10D.

6-1308.9E The planting plan shall provide for plant community diversity and should consider aesthetics from plant form, color, and texture year-round. The vegetated swale design and selection of plant material shall serve to visually link the facility into the surrounding landscape. If trees and shrubs are part of the design, woody plant species shall not be placed directly within the inflow section of the swale.

6-1308.9F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1308.9G Design Guidelines for Vegetated Swale Planting Plans

6-1308.9G(1) The facility should be considered as a mass planting bed with plants that have ornamental characteristics linking it to the surrounding landscape;

6-1308.9G(2) The facility should contain a variety of plant species which will add interest to the facility with each changing season;

6-1308.9G(3) A mixture of shrubs and perennial herbaceous groundcover at an approximate ratio of 25 percent shrubs and 75 percent perennials shall be planted;

6-1308.9G(4) If trees are part of the design, only small ornamental trees may be used (Category I & II per Table 12.17). Trees may be substituted for shrubs up to an approximate ratio of 10 percent trees, 20 percent shrubs, and 70 percent perennials;

6-1308.9G(5) The plants shall be placed along the bottom of the swale. The side slopes of the swale shall be fully stabilized with vegetation. Spacing of plant material is species specific and will be subject to review and approval of the Director. In general the facility shall be planted at a density that the vegetation will cover 80-90 percent of the facility after the second growing season.

6-1308.10 Grassed Swale Vegetation. A dense cover of water-tolerant, erosion-resistant grass must be established. The selection of an appropriate species or mixture of species is based on several factors including climate, soils, topography, and sun tolerance. Grasses used in swales shall have the following characteristics: a deep root system to resist scouring; a high stem density, with well-branched top growth; water-tolerance; resistance to being flattened by runoff; and an ability to recover growth following inundation. Swales shall be sodded and pegged to provide immediate stabilization of the swale.

6-1308.11 Construction Specifications.

6-1308.11A The owner shall provide for inspection during construction of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the tests and inspections required under § 6-1308.8A, § 6-1308.11D, and § 6-1308.11J shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1308.11B Vegetated swales shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan.

6-1308.11C The components of the soil media shall be thoroughly mixed until a homogeneous mixture is obtained. It is preferable that the components of the soil media be mixed at a batch

facility prior to deliver to the site. The soil media shall be moistened, as necessary, to prevent separation during installation.

6-1308.11D The soil media shall be tested for pH, organic matter, and soluble salts prior to installation. If the results of the tests indicate that the required specifications are not met, the soil represented by such tests shall be amended or corrected as required and retested until the soil meets the required specifications. If the pH is low, it may be raised by adding lime. If the pH is too high, it may be lowered by adding iron sulfate plus sulfur.

6-1308.11E The soil media may be placed by mechanical methods with minimal compaction in order to maintain the porosity of the media. Spreading shall be by hand. The soil media shall be placed in 8- to 12-inch lifts with no machinery allowed over the soil media during or after construction. The soil media should be overfilled above the proposed surface elevation as needed to allow for natural settlement. Lifts may be lightly watered to encourage settlement. After the final lift is placed, the soil media shall be raked to level it, saturated, and allowed to settle for at least one week prior to installation of plant materials.

6-1308.11F Fill for earthen check dams shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to 12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Compaction equipment shall not be allowed within the facility on the soil bed. The top of the check dam shall be constructed level at the design elevation.

6-1308.11G Plant material shall be installed per § 12-0705.

6-1308.11H Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1308.11I All areas surrounding the facility that are graded or denuded during construction of the facility and are to be planted with turf grass shall be sodded.

6-1308.11J Vegetated swales designed with check dams shall be inspected at 12-24 and 36-48 hours after a significant rainfall (0.5-1.0 inch) or artificial flooding to determine that the facility is draining properly. Results of the inspection shall be provided to DPWES prior to bond release.

6-1308.12 Plan Submission Requirements.

6-1308.12A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures including underdrains.

6-1308.12B Typical cross section(s) of the swale showing the following: dimensions of swale, underdrain, soil media, underlying gravel layer, filter fabric, groundwater table, and bedrock. Cross section(s) of the check dams.

6-1308.12C Profile showing the following: invert of the swale, gravel underdrain and pipe, groundwater table, bedrock, and check dams.

6-1308.12D Detail(s) of check dams.

6-1308.12E Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1308.12F Sizing computations for the facility including volume of storage, channel cross-section, and spacing of check dams required and provided.

6-1308.12G Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 10.

6-1308.12H Hydrologic and hydraulic calculations for the swale.

6-1308.12I Field run soil borings used to determine the elevation of the groundwater table and/or bedrock.

6-1308.12J A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1308.12K Construction and materials specifications.

6-1309 Tree Box Filters (deleted under 116-14-PFM)

6-1310 Vegetated Roofs (98-07-PFM, 116-14-PFM)

6-1310.1 General.

6-1310.1A A vegetated roof (a.k.a. green roof) is a roof system consisting of the structural components of the roof, a waterproof membrane, a drainage layer, a layer of growth media, and plants. Depending on the type of plants and the waterproof membrane specified, an irrigation system and a root barrier also may be provided. Vegetated roofs reduce the peak rate and volume of stormwater runoff through interception of rainfall and evapotranspiration. Vegetated roofs improve water quality by capturing and filtering airborne depositional pollutants and by plant uptake of dissolved pollutants. Additionally, a vegetated roof provides reductions in energy use for heating and cooling, improvements in air quality, and aesthetic benefits. Vegetated roofs are classified as extensive or intensive systems based on the depth of the growth media and function of the roof.

6-1310.1A(1) Extensive systems are shallow systems, having a growth media depth of 2-6 inches, a low unit weight, low construction cost, low plant diversity, and minimal maintenance requirements. Extensive systems are constructed when the primary purpose is to achieve environmental benefits and typically are only accessible for maintenance and inspection.

6-1310.1A(2) Intensive systems have a growth media depth of 6 inches or greater, a greater unit weight, increased design sophistication and construction costs, increased plant diversity, greater water holding capacity, and increased maintenance requirements compared to extensive systems. Intensive systems often are accessible and provide an amenity for occupants of the building.

6-1310.1B Vegetated roofs shall conform to Virginia Stormwater Design Specification No. 5 Vegetated Roof (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1310.1C Post-development hydrology. For hydrologic computations using the Rational Method, the runoff coefficient “C” values for vegetated roofs in Table 6.5 shall be used. For hydrologic computations using Natural Resource Conservation Service (NRCS) methods, see § 6-0802.

6-1310.2 Feasibility and Limitations.

6-1310.2A Vegetated roofs may be used on non-residential buildings (commercial, industrial, and institutional uses), parking structures, multi-family residential buildings including condominiums and apartments, and mixed-use buildings with a residential component.

6-1310.2B Vegetated roofs may not be used on single family detached or attached units for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1310.2C Vegetated roofs may not be used on single family detached units in nonbonded subdivisions to satisfy the BMP requirements of the Stormwater Management Ordinance.

6-1310.2D Vegetated roofs must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved.

6-1310.2E Intensive systems may not be constructed on roofs with slopes greater than 10 percent. Extensive systems may not be constructed on roofs with slopes greater than 25%.

6-1310.3 Design of Vegetated Roofs.

6-1310.3A Vegetated Roof Components. Vegetated roofs typically consist of the structural components of the roof, a waterproof membrane, a root barrier (if required), a protective layer, a drainage layer, filter fabric, a layer of growth media, and plants. Vegetated roofs may also include an optional thermal insulation layer, a leak detection system, and an irrigation system. Specifications for the optional components of vegetated roofs are not provided herein but should meet any applicable Virginia USBC requirements. Variations on the vegetated roof system designs in the typical details and schematics in Virginia Stormwater Design Specification No. 5 Vegetated Roof (Latest version referenced in the VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements of § 6-1310 *et seq*.

6-1310.3B Extensive vegetated roof systems shall have a minimum growth media depth of 2 inches and a maximum growth media depth of 6 inches. Intensive vegetated roof systems shall have a minimum growth media depth of 6 inches. A maximum growth media depth is not specified for intensive vegetated roof systems. Unless needed to accommodate small trees or large shrubs, the growth media depth should not be greater than 12 inches. Intensive vegetated roof systems may include subareas with different growth media depths to accommodate different types of plants.

6-1310.3C The drainage layer below the growth media shall be designed to convey stormwater to the roof downspouts, conductors, and leaders without backing water up into the growth media. Roof areas draining to an individual roof drain may not exceed 4,300 square feet unless internal drainage conduits are provided. Internal drainage conduits shall be designed to convey the 10-year storm.

6-1310.3D Roof drains and emergency overflow measures shall be sized in accordance with the Virginia Uniform Statewide Building Code (USBC).

6-1310.3E Vegetated roofs shall have a minimum slope of 2 percent to provide for adequate drainage. The slope of extensive systems shall not be greater than 25 percent. The slope of intensive systems shall not be greater than 10 percent. Extensive systems with slopes equal to or greater than 17 percent will require supplemental slope stabilization measures (e.g., raised grids) to hold the growth media and plants in place.

6-1310.3F Access to vegetated roofs for maintenance and inspection shall be provided unless waived by the Director. Access shall be provided by an interior stairway through a penthouse or by an alternating tread device with a roof hatch or trap door not less than 16 square feet in area and having a minimum dimension of 24 inches, or by a terrace door with a minimum clear opening width of 32 inches. The access requirement may be waived by the Director for roofs no greater than 12 feet above finished grade and less than 1000 square feet in area.

6-1310.3G Provisions for the safety of maintenance and inspection workers (e.g., parapets, railings, secured rings for safety harnesses, etc.) shall be incorporated in the design of all roofs.

6-1310.3H A vegetation-free zone is recommended along the perimeter of the roof and around all roof penetrations to act as a fire break and to facilitate maintenance and inspection. This zone should be a minimum of 24 inches in width along the perimeter of the roof and a minimum of 12 inches around all roof penetrations. The width of the vegetation-free zone around the perimeter of the roof may be reduced from 24 inches to 12 inches where application of the 24-inch requirement would result in a reduction of the roof area available for greening of greater than 15 percent.

6-1310.3I Measures for irrigation shall be provided to ensure plant viability during long periods of drought unless waived by the Director. At a minimum, a hose bib shall be provided for manual irrigation. If automated irrigation is provided, the additional dead load shall be incorporated in the roof system design. The requirement to provide measures for irrigation may be waived by the Director for roofs no greater than 12 feet above finished grade and less than 1,000 square feet in area.

6-1310.3J ASTM Standards. The following ASTM standards should be used in the design of vegetated roofs.

6-1310.3J(1) ASTM E2396 Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems.

6-1310.3J(2) ASTM E2397 Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems

6-1310.3J(3) ASTM E2398 Standard Test Method for Water Capture and Media Retention of Geo-composite Drain Layers for Green Roof Systems.

6-1310.3J(4) ASTM E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems.
6-1310.3J(5) ASTM E2400 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.

6-1310.4 Specifications of vegetated roof components.

6-1310.4A Waterproof membrane. The waterproof membrane that separates the drainage system and growth media from the structural components of the roof can consist of several different systems including modified bitumen, rubberized asphalt, polyvinyl chloride (PVC), thermoplastic polyolephin (TPO), chlorosulfonated polyethylene (CSPE), and ethylene propylene diene monomer (EPDM) systems. Membranes impregnated with pesticides or herbicides are not allowed. Waterproofing must meet Virginia USBC requirements.

6-1310.4B Root barrier. A PVC, polypropelene, or polyethelene membrane ≥ 30 mil thick hot-air welded at the seams or approved equivalent is required to protect modified bitumen and rubberized asphalt waterproofing from root penetration. A root barrier is not required for PVC, EPDM, or CSPE membranes. Root barriers that have been impregnated with pesticides, metals or other chemicals that could leach into stormwater runoff are not allowed.

6-1310.4C Protective layer. A perforation resistant protective layer to protect the waterproofing and root barrier (if required) from damage is optional. A protective layer is typically is provided for systems that use granular drainage media or do not use root barriers. The protective layer shall be a polypropylene non-woven needled fabric with a density (ASTM D3776) ≥ 6 oz./yard^2.

6-1310.4D Drainage layer. The drainage layer shall be a single or composite system capable of conveying stormwater that drains through the growth media. Drainage layers may be a granular drainage media, synthetic geocomposite, or synthetic mat and may include internal drain pipes.

6-1310.4D(1) Granular drainage media shall be a non-carbonate mineral aggregate meeting the requirements listed in Table 6.33.

Table 6.33 Granular Drainage Media Specifications

Saturated Water Permeability (ASTM E2396)	≥ 25 in./min.
Total Organic Matter, by Wet Combustion (MSA)	≤ 1 %
Abrasion Resistance (ASTM C131)	≤ 25 % loss
Soundness (ASTM C88)	≤ 5 % loss
Porosity (ASTM C29)	≥ 25 %
pH	6.5 – 8.0
Grain-size Distribution (ASTM C136)	
Passing US #8 sieve	≤ 1%
Passing 1/4 in. sieve	≤ 30%
Passing 3/8 in. sieve	≥ 80%

6-1310.4D(2) For non-grid systems, a drainage system consisting of deformed polyethylene sheet with a transmissivity (ASTM D4716) greater than or equal to 24 gallons per minute per foot of width.

6-1310.4E Filter fabric. Filter fabric shall be a non-woven, root penetrable, needled, polypropylene geotextile meeting the requirements of Virginia Stormwater Design Specification No. 5 Vegetated Roof (Latest version referenced in the VSMP Regulations). Heat-set or heat-calendared fabrics are not permitted.

6-1310.4F Growth media. Growth media shall be a mineral and organic mixture that provides sufficient nutrients and water holding capacity to support the proposed plant materials. Growth media shall meet the requirements of Virginia Stormwater Design Specification No. 5 Vegetated Roof (Latest version referenced in the VSMP Regulations). The growth media shall be tested for organic content to demonstrate compliance with Level 1 or Level 2 design criteria using standard test methods.

6-1310.4G Plants.

6-1310.4G(1) The planting plan and specifications shall be prepared by a certified landscape architect, horticulturist, or other individual who is knowledgeable about the environmental tolerance and ecological functions and impacts of plant species.

6-1310.4G(2) Plant materials selected shall be shallow rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost. Plant materials for extensive systems may include mosses, sedums, herbaceous plants, and grasses. Plant materials for intensive systems may include mosses, sedums, herbaceous plants, grasses, shrubs and small trees. Invasive species that may disrupt or harm native plant communities shall not be used. The acceptability of proposed

plant materials will be determined by the Director. Guidance on the use and selection of plants for vegetated roofs is available from Urban Forest Management.

6-1310.4G(3) Plants may be installed by vegetation mats, plugs, potted plants, sprigs, or direct seeding.

6-1310.4G(4) The planting plan shall be designed to achieve 90 percent coverage within two years of installation.

6-1310.4G(5) Measures for irrigation shall be provided in accordance with § 6-1310.3I.

6-1310.5 Construction Requirements.

6-1310.5A The owner shall provide for inspection during construction of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets, certifications from the material suppliers, and test results of the organic content of the growing media required under § 6-1310.4F shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1310.5B Foot and equipment traffic on the roof shall be minimized. Traffic over the waterproof membrane must be strictly controlled until the protective layer and drainage layer are installed.

6-1310.5C The organic and mineral components of the growth media shall be thoroughly mixed prior to installation. It is preferable that the components of the growth media be mixed at a batch facility prior to delivery to the site. The media shall be moistened, as necessary, to prevent separation during installation.

6-1310.5D The growth media shall be soaked at a rate of 30 gallons per 100 square feet and allowed to drain thoroughly before planting.

6-1310.5E Erosion Control. A bio-degradable jute mesh with an aperture of 0.375-1.0 inch and a tensile strength (ASTM D4632) $\geq$ 20 pounds or approved equivalent shall be provided when establishing plants from sprigs and/or seed.

6-1310.5F Plant installation shall occur during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1310.5G Shrubs and potted plants must be hardened off adequately prior to planting.

6-1310.5H The roof should be checked for leakage, slippage of membranes and soil erosion after planting.

6-1310.5I Plantings must be well established prior to release of the conservation deposit. The conservation deposit will be held for a minimum of one year after installation of the plantings and shall only be released if the 90 percent coverage required by § 6-1310.4G(4) is achieved. If ninety percent coverage is not achieved, the area shall be replanted to achieve the minimum required coverage and the conservation deposit held for an additional year.

6-1310.6 Plan Submission Requirements.

6-1310.6A Plan view(s) showing facility dimensions, planting plan, layout for internal drains (if provided as part of the drainage layer), roof access, walkways, roof penetrations, and setbacks from roof lines.

6-1310.6B Cross section of proposed roof system showing the waterproof membrane, root barrier, protection layer (if provided), drainage layer, filter fabric, soil media depth, and emergency overflow system.

6-1310.6C Specifications for the waterproof membrane, root barrier (if provided), protection layer, drainage layer, filter fabric, and soil media.

6-1310.6D Plant list specifying species, size, and number of proposed plants, seeding rates, planting procedures, and specifications for erosion control.

6-1310.6E Construction requirements, sequence, and procedures including a list of certifications required to be provided to the County.

6-1310.6F Roof area in square feet that is vegetated.

6-1310.6G Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 5.

6-1310.6H A note shall be placed on the cover sheet stating that the site plan includes a vegetated roof on the proposed building to meet stormwater and water quality control requirements and that construction of the vegetated roof is required with the building. The note shall also state that the building plans shall include a statement signed and sealed by the licensed professional submitting the building design that:

6-1310.6H(1) The vegetated roof design on the building plans is in conformance with the vegetated roof design on the approved site plan;

6-1310.6H(2) Additional requirements for all items such as roof membranes, drains, irrigation systems, and safety rails shall comply with the requirements of the Virginia USBC;

6-1310.6H(3) Access to the vegetated roof has been provided in accordance with Public Facilities Manual § 6-1310.3F;

6-1310.6H(4) Provisions for the safety of maintenance and inspection workers have been incorporated in the design of the vegetated roof in accordance with Public Facilities Manual § 6-1310.3G; and

6-1310.6H(5) Manual or automated irrigation has been provided in accordance with Public Facilities Manual § 6-1310.3I.

6-1311 Reforestation (116-14-PFM)

6-1311.1 General.

6-1311.1A Site reforestation involves planting trees on existing turf or barren ground at a development site with the explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapotranspiration rates, and enhance soil infiltration rates. Forest ecosystems reduce the peak rate and volume of stormwater runoff through interception of rainfall by leaves and the forest duff layer, plant uptake and evapotranspiration, and infiltration into the soil. Forest ecosystems improve water quality by capturing and filtering airborne depositional pollutants, plant uptake of dissolved pollutants, and infiltration into the soil. Tree canopies provide energy conservation for buildings, screening, and other benefits in addition to stormwater management. Reforested areas may be used to meet the tree cover requirements of §12-0000 *et seq*. and Chapter 122 of the County Code. Ten-year canopy credit equivalent to the square footage of the area will be given for reforested areas that have been planted, and are established in accordance with the provisions of this section.

6-1311.1B Post-development hydrology. A runoff coefficient "C" for reforested areas found in Table 6.5 shall be used for hydrologic computations using the Rational Method. The Curve Number "CN" for use with Natural Resources Conservation Service methods shall be based upon woods in good condition and the underlying Hydrologic Soil Group.

6-1311.1C Reforestation shall conform to Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Appendix 4A) [Latest version referenced in the VSMP Regulations], except as modified herein.

6-1311.2 Feasibility and Limitations.

6-1311.2A In residential areas, reforested areas must be located on homeowner association (or "common") property and may not be located on individual buildable single family detached or attached residential lots, or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance. The Director may approve the use of reforestation on individual buildable single-family detached lots for subdivisions creating no more than seven lots where it can be demonstrated that the requirement is not practical or desirable due to constraints imposed by the dimensions or topography of the property. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure establishment and protection of the reforested area.

6-1311.2B Reforested areas may be located on individual residential lots in nonbonded subdivisions to satisfy the BMP requirements of the Stormwater Management Ordinance. Designers should carefully consider the impact of the required easement on future use of the property.

6-1311.2C In order to maximize the infiltration capacity, structure, and biota of the existing soil profile below the amended soil layer, areas to be reforested shall not be graded as part of the site development. The only land disturbance allowed is that which is necessary to amend the soils and install plantings.

6-1311.3 Maintenance.

6-1311.3A Reforested areas shall be privately managed and maintained.

6-1311.3B Reforested areas shall be placed in restrictive easements that include limited provisions for management practices necessary to assure the establishment of a healthy forest ecosystem.

6-1311.3C Reforested areas shall be posted with permanent signs designating the area as a Conservation Area. Signs shall state that the area has been reforested as a Low Impact Development practice and no disturbance or cutting of vegetation is allowed. Signs must be a minimum of 8 inches by 10 inches mounted on posts at a height of 4 feet to 6 feet and placed at approximately 150-foot intervals along the perimeter of the reforested area. See Plate 81-6.

6-1311.4 Design of Reforested Areas.

6-1311.4A Reforestation plans and specifications shall be prepared by a certified landscape architect, horticulturist, or other individual who is knowledgeable about the environmental tolerance, ecological functions, and impacts of plant species.

6-1311.4B Except as noted below, reforested areas shall have a minimum contiguous area of 5,000 square feet, be generally regular in shape, and have a minimum width of 35 feet. The Director may approve areas less than 5,000 square feet in size or with minimum widths less than 35 feet provided such areas are contiguous to existing naturally vegetated areas that are preserved with restrictive easements or other long-term protective mechanisms or that are in uses associated with long-term preservation.

6-1311.4C Reforested areas shall be designed to replicate adjacent forest communities using similar percentages of major indicator species or species that can adapt to abiotic conditions present in the area to be reforested. If there is no adjacent forest community to mimic, the area may be planted with pioneer species, such as Virginia pine, black locust, eastern red cedar, red maple, and persimmon.

6-1311.4D Reforested areas shall consist of a mixture of overstory trees, understory trees, and shrubs. Generally, overstory trees correspond to Category 3 or 4 trees and understory trees correspond to Category 1 or 2 trees as listed in Table 12.17 in §12-0000 *et seq*. At least 25 percent of the area shall be planted with trees from nursery stock. For nursery stock, deciduous trees must be a minimum of 1-inch caliper and evergreen trees must be a minimum of 6 feet in height. For areas planted with nursery stock, the density of overstory trees shall be a minimum of

100 trees per acre and the density of understory trees shall be a minimum of 200 trees per acre. Nursery stock may be replaced by transplanted material as approved by the Director. For areas planted with bareroot seedlings (See § 12-0705.5B), the density of the trees shall be double that required for nursery stock. The density of shrubs shall be a minimum of 400 plants per acre. Shrubs must be a minimum of 18 inches in height.

6-1311.4E To curtail the spread of disease or insect infestation in a plant species, no more than 70 percent of the trees, seedlings, and shrubs required to be planted shall be of one genus. In addition, no more than 35 percent of the deciduous trees shall be of a single species and no more than 35 percent of the evergreen trees shall be of a single species. Seedlings shall be randomly mixed and placed approximately 8-10 feet apart in a random pattern with shrubs placed surrounding seedlings. Additional guidance on appropriate species for soils and groundwater conditions can be found in § 12-0000.

6-1311.4F Tree planting credit may be given for existing trees within the planting area. A planting credit of one 1-inch caliper nursery stock overstory tree shall be given for each 150 square feet of existing overstory tree canopy and a planting credit of one 1-inch caliper nursery stock understory tree shall be given for each 75 square feet of existing understory tree canopy.

6-1311.4G Compacted soils will limit root growth and establishment of the forest ecosystem. Subsoiling (tilling) and soil amendments are required to relieve soil compaction and restore soil function in previously disturbed soils except as noted below.

6-1311.4G(1) The depth of subsoiling, the amount of compost to be incorporated, and the incorporation depth shall be determined in accordance with Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations).

6-1311.4G(2) Testing of the *in situ* soils for bulk density, pH, salts, and soil nutrients to a depth of 15 inches is required to determine if further soil amendments are needed. A minimum of one test for bulk density, pH, salts, and soil nutrients shall be performed per 5,000 square feet.

6-1311.4G(3) Subsoiling and soil amendments are not required if the *in situ* bulk density of the existing soil, as measured by the sand cone test (ASTM D1556) or nuclear gauge (ASTM D6938), is less than the value in Table 6.38 for the corresponding soil type or compaction, as measured by the cone penetration test (ASTM D3441), is less than 300 lb./square inch in the top 15 inches of soil. A minimum of one density measurement or test shall be performed per 1,000 square feet.

6-1311.4G(4) Testing of *in situ* soils to determine compaction is not required if soils will be amended at pre-approved rates in accordance with § 6-1311.4G(1).

Table 6.38 Bulk Densities That May Affect Root Growth[1]

Soil Texture	lb./ft^3
Sands, loamy sands	105.50
Sandy loams, loams	101.76
Sandy clay loams, loams, clay loams	99.88
Silts, silt loams	99.88
Silt loams, silty clay loams	96.76
Sandy clays, silty clays, some clay loams (35- 45% clay)	93.02
Clays (>.45% clay)	86.77

[1] From "Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications," USDA 2003

6-1311.5 Subsoiling and Soil Amendment Specifications.

6-1311.5A Compost. See Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations) for required compost specifications.

6-1311.5B Mulch. Mulch shall consist of wood chips, bark chips, or shredded bark that has been aged for a minimum of 4 months.

6-1311.6 Construction.

6-1311.6A See Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations) for the basic construction sequence for the soil amendments.

6-1311.6B The topsoil layer shall have a minimum depth as determined under § 6-1311.4G except for areas within the dripline of existing trees in or adjacent to the area to be reforested, where subsoiling may adversely impact existing tree roots. Compacted soils within the dripline of existing trees shall be addressed by the use of mulch. The mulch shall consist of a minimum of 3 inches of organic mulch that shall be placed on the topsoil layer at final grade. Mulch beds must be kept free of any grass, weeds, vines and any other plant or condition that might hinder the establishment of the tree canopy.

6-1311.6C After incorporation of the soil amendments, water thoroughly and allow soil to settle for one week.

6-1311.6D Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.

6-1311.6E A test pit shall be dug to verify the depth of mulch, amended soil, and scarification. A rod penetrometer should be used to establish the depth of uncompacted soil at one location per 10,000 square feet. The results of these tests shall be included in the inspection report.

6-1311.6F Planting should occur as soon as feasible after the soil has been amended.

6-1311.6G Planting procedures for trees, shrubs and seedlings shall be in conformance with § 12-0705.

6-1311.6H Planting of the reforested area should be done with minimal mechanical disturbance to the existing trees and shrubs to be preserved and given credit per § 6-1311.4F. The planting should be done by hand or mechanical auger.

6-1311.6I After planting, mulch planting beds with 2 inches of organic mulch. Alternatively, a native seed mixture combined with appropriate stabilization measures may be used. Installation of the above stabilization measures shall be in accordance with the "Virginia Erosion and Sediment Control Handbook," 3rd edition, 1992.

6-1311.6J Plantings must be well established prior to release of the conservation deposit. The conservation deposit will be held for a minimum of two years after the initial installation of the plantings. Ninety percent or more of the minimum number of nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released. Sixty-seven percent or more of the initial tree seedling density required by the approved plan shall be viable at the time the conservation deposit is released. If these minimum percentages are not met at the time of inspection, additional nursery stock trees, nursery stock shrubs, and seedlings shall be planted at densities necessary to achieve the required minimum percentages of viability of the initial plantings based on the observed mortality rates. For example, if the plan called for 500 seedlings to be planted, a minimum of 335 seedlings (67 percent) must be viable more than two years after installation. If 250 seedlings were viable (a deficit of 85 viable plants) at the time of inspection (2.5 years after installation), 170 replacement seedlings would need to be planted, based on the observed mortality rate (50 percent), prior to release of the conservation deposit. Replacement seedlings shall be selected such that the resulting mixture of surviving and replacement plants will generally achieve the mixture of understory trees and overstory trees shown on the approved plan as determined by the Director.

6-1311.6K The owner shall provide for inspection during installation of the soil amendments and planting by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the installation was performed in accordance with the approved plans. The licensed professional's certification along with an inspection report shall be provided to DPWES for review prior to bond release. This report shall include observed survival rates of plantings, replacement plantings installed, material delivery tickets, certifications from material suppliers, and the above field tests (§ 6-1311.6D). For projects requiring as-built plans,

the required inspection report and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required report and supporting documents shall be submitted with the RUP or non-RUP request.

6-1311.7 Plan Submission Requirements.

6-1311.7A Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed, and spacing of proposed plants within the reforested area.

6-1311.7B Reforested areas shall be delineated on the plan sheets with the note: "Reforestation Area. This area is being replanted for Low Impact Development credit. No disturbance other than that necessary to implement the planting plan allowed."

6-1311.7C Construction specifications for soil amendments (if provided) and planting procedures.

6-1311.7D *In situ* soil test results (see § 6-1311.4G).

6-1312 Rooftop (Impervious Surface) Disconnection (116-14-PFM)

6-1312.1 General.

6-1312.1A Rooftop (impervious surface) disconnection manages runoff close to its source by intercepting, infiltrating, filtering, treating or reusing it as it moves from the impervious surface to the drainage system. Two types of disconnection are included in the state design specifications: (1) simple disconnection, whereby rooftops or on-lot impervious surfaces are directed to pervious areas, and (2) disconnection leading to an alternative runoff reduction practice(s) adjacent to the roof. Alternative practices can use less space than simple disconnection and can enhance runoff reduction rates. Applicable practices include:

6-1312.1A(1) Soil compost amended filter path (§ 6-1315);

6-1312.1A(2) Infiltration by micro-infiltration practice (§ 6-1303);

6-1312.1A(3) Filtration by rain gardens or micro-bioretention (§ 6-1307);

6-1312.1A(4) Storage and reuse with a cistern or other vessel (§ 6-1316);

6-1312.1A(5) Storage and release in a stormwater planter (§ 6-1307).

6-1312.1B Rooftop Disconnections shall conform to Virginia Stormwater Design Specification No. 1 (Rooftop Disconnection (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1312.2 Feasibility and Limitations.

6-1312.2A Simple Rooftop Disconnection. Because of the constraints that would be placed on property owners' use of their land, difficulties in post-construction monitoring and enforcement, and the availability of more effective practices better suited to the County's urban nature, simple rooftop disconnection is not allowed without approval from the Director on a case by case basis. Designers seeking credit for sheet flow practices are directed to § 6-1313 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space.

6-1312.2.B Rooftop disconnection leading to alternative runoff reduction practices. Rooftop disconnection leading to alternative runoff reduction practices will be allowed based on the applicability of and limitations on the type of alternative practice utilized. The use of rooftop disconnection leading to alternative runoff reduction practices generally will provide greater runoff reduction and take up less space than simple runoff reduction.

6-1312.2.C The impervious area treated by simple rooftop disconnection or a soil compost amended filter path is limited to 1,000 square feet.

6-1312.3 Maintenance.

6-1312.3A Rooftop disconnections must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved.

6-1312.3B The flow path for simple rooftop disconnections must be placed in an easement that prohibits grading and conversion to impervious surfaces.

6-1312.4 Design.

6-1312.4A Rooftop disconnections shall conform to Virginia Stormwater Design Specification No. 1 (Rooftop Disconnection (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1312.4B See § 6-1300 *et seq*. for design of the alternative runoff reduction practices listed in § 6-1312.1A that may be employed with rooftop disconnection.

6-1312.5 Plan Submission Requirements.

6-1312.5A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1312.5B Areas of the flow path for simple rooftop disconnection shall be delineated by easements on the plan sheets with the note: "Sheet flow area for simple rooftop disconnection. This area is being used for BMP credit."

6-1312.5C Profile showing the flow path of the rooftop disconnection beginning at the peak of the roof and the slope of the pervious portion of the flow path.

6-1312.5D Plan submissions must include all plan submission requirements for any alternative runoff reduction practice utilized.

6-1313 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space (116-14-PFM)

6-1313.1 General.

6-1313.1A Filter strips are vegetated areas that treat sheet flow delivered from adjacent impervious and managed turf areas by slowing runoff velocities and allowing sediment and attached pollutants to settle and/or be filtered by the vegetation. The two types of filter strips are designed Vegetated Filter Strips and Conserved Open Space. The design, installation, and management of these design variants are different. In both instances, stormwater must enter the vegetated filter strip or conserved open space as sheet flow.

6-1313.1B Vegetated filter strips and conserved open space shall conform to Virginia Stormwater Design Specification No. 2 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space (Latest version referenced in the VSMP Regulations) except as modified herein.

6-1313.2 Feasibility and Limitations.

6-1313.2A In residential areas, vegetated filter strips and conserved open space must be located on homeowner association (or "common") property and may not be located on individual buildable single family detached or attached residential lots, or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1313.2B Vegetated filter strips and conserved open space may be located on individual residential lots in nonbonded subdivisions to satisfy the BMP requirements of the Stormwater Management Ordinance. Designers should carefully consider the impact of the required easement on future use of the property

6-1313.2C Vegetated filter strips and conserved open space may only be used to treat flow that has not been concentrated. When the existing flow at a site is concentrated, a vegetated swale or other suitable practice should be used instead of a vegetated filter strip or conserved open space.

6-1313.3 Maintenance.

6-1313.3A Vegetated filter strips and conserved open space shall be privately managed and maintained.

6-1313.3B Vegetated filter strips and conserved open space shall be placed in restrictive easements that include limited provisions for management practices necessary to assure the establishment of a healthy forest ecosystem or vegetated filter strip. Vegetated filter strips also require private maintenance agreements.

6-1313.3C Maintenance access must be provided for all vegetated filter strips and conserved open space not located on individual buildable single family detached lots in accordance with

§ 6-1306 except that the access way may have a grass surface rather than an all-weather surface. For vegetated filter strips and conserved open space located on individual buildable single family detached lots, maintenance access shall be considered as an integral part of the design and designated on the plan.

6-1313.3D Vegetated filter strips and conserved open space shall be posted with permanent signs designating the area as a Conservation Area. Signs for conserved open space shall state that the area is a Conservation Area and no disturbance or cutting of vegetation is allowed. Signs for vegetated filter strips shall state the area is a Conservation Area and no disturbance is allowed except for required mowing. Signs must be a minimum of 8 inches by 10 inches mounted on posts at a height of 4 feet to 6 feet and placed at approximately 150-foot intervals along the perimeter of the area. See Plate 81-6.

6-1313.4 Design of Vegetated Filter Strips and Conserved Open Space.

6-1313.4A The width of vegetated filter strips and conserved open space areas shall be determined in accordance with Virginia Stormwater Design Specification No. 2 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space (Latest version referenced in the VSMP Regulations). Where the sheet flow to be treated originates from both pervious and impervious areas, the design shall be based on the requirements for sheet flow from impervious areas.

6-1313.4B The design of engineered level spreaders must include a bypass structure that diverts the design storm to the level spreader and bypasses larger storm events around the vegetated filter strip or conserved open space through a channel or other adequate conveyance.

6-1313.4C Subsoiling (tilling) and soil amendments are required to relieve soil compaction and restore soil function in all previously disturbed soils regardless of the hydrologic soil group except as noted below.

6-1313.4C(1) The depth of subsoiling, the amount of compost to be incorporated, and the incorporation depth shall be determined in accordance with Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations).

6-1313.4C(2) Testing of the *in situ* soils for bulk density, pH, salts, and soil nutrients to a depth of 15 inches is required to determine if further soil amendments are needed. A minimum of one test for bulk density, pH, salts, and soil nutrients shall be performed per 5,000 square feet.

6-1313.4C(3) Subsoiling and soil amendments are not required if the *in situ* bulk density of the existing soil, as measured by the sand cone test (ASTM D1556) or nuclear gauge (ASTM D6938), is less than the value in Table 6.38 for the corresponding soil type or compaction, as measured by the cone penetration test (ASTM D3441), is less than 300 lb./square inch in the top 15 inches of soil. A minimum of one density measurement or test shall be performed per 1,000 square feet.

6-1313.4C(4) Testing of *in situ* soils to determine compaction is not required if soils will be amended at pre-approved rates in accordance with § 6-1313.4B(1).

6-1313.5 Subsoiling and Soil Amendment Specifications.

6-1313.5A Compost. See Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations) for required compost specifications.

6-1313.5B Mulch. Mulch shall consist of wood chips, bark chips, or shredded bark that has been aged for a minimum of 4 months.

6-1313.6 Vegetated Filter Strip Planting Plans.

6-1313.6A Planting plans are required for all vegetated filter strips.

6-1313.6B Planting plans and specifications for vegetated filter strips shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0515.

6-1313.6C A mixture of grasses and herbaceous plants with a high density of fibrous roots planted at a density sufficient to achieve 90% coverage after the second growing season is required. The use of shrubs and trees is optional. The acceptability of proposed plant materials will be determined by the Director. Guidance on the use and selection of plants for vegetated swales is available from Urban Forest Management.

6-1313.6D All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1313.6E Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size. Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1313.6F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1313.7 Construction.

6-1313.7A See Virginia Stormwater Design Specification No. 2 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space (Latest version referenced in the VSMP Regulations) for the basic construction sequence for vegetated filter strips and conserved open space and Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations) for the basic construction sequence for the soil amendments.

6-1313.7B The topsoil layer shall have a minimum depth as determined under § 6-1313.4B except for areas within the dripline of existing trees in or adjacent to the area to be vegetated, where subsoiling may adversely impact existing tree roots. Compacted soils within the dripline of existing trees shall be addressed by the use of mulch. The mulch shall consist of a minimum of 3 inches of organic mulch that shall be placed on the topsoil layer at final grade. Mulch beds must be kept free of any grass, weeds, vines and any other plant or condition that might hinder the establishment of the tree canopy.

6-1313.7C After incorporation of the soil amendments, water thoroughly and allow soil to settle for one week.

6-1313.7D Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.

6-1313.7E A test pit shall be dug to verify the depth of amended soil and scarification. A rod penetrometer should be used to establish the depth of uncompacted soil at one location per 10,000 square feet. The results of these tests shall be included in the inspection report.

6-1313.7F Planting should occur as soon as feasible after the soil has been amended.

6-1313.7G Planting procedures for trees, shrubs and seedlings shall be in conformance with § 12-0705.

6-1313.7H Plantings must be well established prior to release of the conservation deposit. The conservation deposit will be held for a minimum of two years after the initial installation of the plantings. Ninety percent coverage is required at the time the conservation deposit is released.

6-1313.7I The owner shall provide for inspection during installation of the soil amendments and planting by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the installation was performed in accordance with the approved plans. The licensed professional's certification along with an inspection report shall be provided to DPWES for review prior to bond release. This report shall include observed survival rates of plantings, replacement plantings installed, material delivery tickets, certifications from material suppliers, and the above field tests (§ 6-1313.6E). For projects requiring as-built plans, the required inspection report and supporting documents shall be submitted with or incorporated

in the as-built plans. For projects that do not require as-built plans, the required report and supporting documents shall be submitted with the RUP or non-RUP request.

6-1313.8 Plan Submission Requirements.

6-1313.8A Plan view(s) of the vegetated filter strip or conserved open space and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1313.8B Profile view(s) of the vegetated filter strip or conserved open space and appurtenant structures showing the slope of the first 10 feet of the filter and the overall slope of the filter.

6-1313.8C Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed, and spacing of proposed plants within the reforested area.

6-1313.8D Areas of conserved open space shall be delineated on the plan sheets with the note: "Conservation Area. No disturbance other than that necessary for forest management allowed."

6-1313.8E Construction specifications for soil amendments (if provided) and planting procedures.

6-1313.8F *In situ* soil test results (See § 6-1313.4G).

6-1314 Soil Compost Amendment (116-14-PFM)

6-1314.1 General.

6-1314.1A Soil compost amendment is a practice applied after construction, to deeply till compacted soils and restore their porosity by amending them with compost. These soil amendments can reduce the generation of runoff from compacted urban lawns and also may be used to enhance the runoff reduction performance of downspout disconnections, grass channels, and filter strips. The following specifications cover areas to be revegetated with turf grass. The use of soil compost amendments for areas to be reforested is covered in § 6-1311 *et seq*.

6-1314.1B Soil Compost Amendment shall conform to Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1314.2 Feasibility and Limitations.

6-1314.2A In residential areas, areas of compost amended soils must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance except as noted herein. The Director may approve the use of compost amended soils on individual buildable single-family detached lots for subdivisions creating no more than seven lots where it can be demonstrated that the requirement is not practical or desirable due to constraints imposed by the dimensions or topography of the property and where adequate provisions for maintenance are provided. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities.

6-1314.2B Compost amended soils may be located on individual single-family detached residential lots that are not part of a bonded subdivision to satisfy the BMP requirements of the Stormwater Management Ordinance for construction on the lot.

6-1314.2C Notwithstanding the above, soil compost amendments may be used to restore the porosity of compacted soils on residential subdivision lots. These areas can then be treated as forest/open space in the runoff reduction calculation. However, a loss of 30% of the treated area over time is assumed to compensate for future conversions or disturbance of the area. The existence and purpose of the amended soils shall be disclosed as part of the chain of title to all future homeowners (e.g., individual members of a homeowners' association) responsible for maintenance of the facilities. Such areas of compost amended soils shall not be subject to the requirement that the areas be placed in an easement in § 6-1314.3.

6-1314.2D Setbacks. There are no setback requirements for compost amended soils. However, designers should consider the constraints placed on prospective property owners and avoid

requesting credit for areas that are likely to be needed for future construction (e.g., decks and patios).

6-1314.3 Maintenance.

6-1314.3A Areas of compost amended soils shall be privately managed and maintained. Areas of compost amended soils may not be located in County storm drainage easements or sanitary sewer easements for BMP credit or runoff reduction credit. The above does not preclude the use of compost amended soils by the County within existing County drainage easements or on County-owned property.

6-1314.3B Areas of compost amended soils shall be placed in restrictive easements that preclude conversion of the area to impervious surfaces or compaction.

6-1314.4 Design Criteria.

6-1314.4A Plans and specifications for areas of compost amended soils shall be prepared by a certified landscape architect, horticulturist, or other individual who is knowledgeable about the process of amending soil with compost to relieve compaction and the establishment of turf grass.

6-1314.4B Compacted soils will limit root growth and establishment of a dense turf cover. Subsoiling (tilling) and soil amendments are required to relieve soil compaction and restore soil function in previously disturbed soils except as noted below.

6-1314.4B(1) The depth of subsoiling, the amount of compost to be incorporated, and the incorporation depth shall be determined in accordance with Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations).

6-1314.4B(2) Testing of the *in situ* soils for bulk density, pH, salts, and soil nutrients to a depth of 15 inches is required to determine if further soil amendments are needed. A minimum of one test for bulk density, pH, salts, and soil nutrients shall be performed per 5,000 square feet.

6-1314.4B(3) Subsoiling and soil amendments are not required if the *in situ* bulk density of the existing soil, as measured by the sand cone test (ASTM D1556) or nuclear gauge (ASTM D6938), is less than the value in Table 6.38 for the corresponding soil type or compaction, as measured by the cone penetration test (ASTM D3441), is less than 300 lb./square inch in the top 15 inches of soil. A minimum of one density measurement or test shall be performed per 1,000 square feet.

6-1314.4B(4) Testing of *in situ* soils § 6-1314.4B(3) to determine compaction is not required if soils will be amended at pre-approved rates in accordance with § 6-1314.4B(1).

6-1314.5 Specifications. See Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Version 1.8, March 1, 2011) for required compost specifications.

6-1314.6 Construction.

6-1314.6A See Virginia Stormwater Design Specification No. 4 Soil Compost Amendment (Latest version referenced in the VSMP Regulations) for the basic construction sequence for the soil amendments.

6-1314.6B The topsoil layer shall have a minimum depth as determined under § 6-1314.4G except for areas within the dripline of existing trees in or adjacent to the area to be amended with compost, where subsoiling may adversely impact existing tree roots. Compacted soils within the dripline of existing trees shall be addressed by the use of mulch. The mulch shall consist of a minimum of 3 inches of organic mulch that shall be placed on the topsoil layer at final grade. Mulched areas must be kept free of any grass, weeds, vines and any other plant or condition that might hinder the establishment of the tree canopy.

6-1314.6C After incorporation of the soil amendments, water thoroughly and allow soil to settle for one week.

6-1314.6D Rake beds to smooth and remove surface rocks larger than 2 inches in diameter.

6-1314.6E A test pit shall be dug to verify the depth of amended soil and scarification. A rod penetrometer should be used to establish the depth of uncompacted soil at one location per 10,000 square feet. The results of these tests shall be included in the inspection report.

6-1314.6F Turf grass may be established by seeding or laying sod.

6-1314.6G Turf must be well established prior to release of the conservation deposit. The conservation deposit will be held for a minimum of two years after the initial installation of the plantings. Ninety percent coverage must be achieved at the time the conservation deposit is released.

6-1314.6H The owner shall provide for inspection during installation of the soil amendments and planting by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the installation was performed in accordance with the approved plans. The licensed professional's certification along with an inspection report shall be provided to DPWES for review prior to bond release. This report shall include observed survival rates of plantings, replacement plantings installed, material delivery tickets, certifications from material suppliers, and the above field tests (§ 6-1314.6E). For projects requiring as-built plans, the required inspection report and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required report and supporting documents shall be submitted with the RUP or non-RUP request.

6-1314.7 Plan Submission Requirements.

6-1314.7A Areas of compost amended soils for BMP credit shall be delineated by easements on the plan sheets with the note: "Area of Compost Amended Soils. Soil in this area is being amended for BMP credit." Areas of compost amended soils to be treated as forest/open space in the runoff reduction calculation shall be delineated on the plan sheets with the note: "Area of Compost Amended Soils. Soil in this area is being amended to return it to a more functional hydrologic condition. Seventy percent of the area may be treated as forest/open space in the runoff reduction calculation."

6-1314.7B Construction specifications for soil amendments and planting procedures.

6-1314.7C *In situ* soil test results (See § 6-1314.4B).

6-1315 Rainwater Harvesting (116-14-PFM)

6-1315.1 General.

6-1315.1A Rainwater harvesting systems (RWHS) intercept, store, and use rainfall. Rainwater that falls on a collection surface is conveyed to a storage tank where it can later be used for non-potable water uses, and/or directed to a secondary BMP for treatment or infiltration.

6-1315.1B Rainwater harvesting can be combined with a secondary, down-gradient runoff reduction practice to enhance runoff volume reduction rates and provide treatment of overflow or drawdown of the storage tank during periods of reduced demand.

6-1315.1C Rainwater Harvesting systems shall conform to Virginia Stormwater Design Specification No. 6 Rainwater Harvesting (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1315.2 Feasibility and Limitations.

6-1315.2A1 Rainwater harvesting may be used for commercial, industrial, or multi-family residential uses to supply all or a portion of non-potable water demand.

6-1315.2B Non-potable uses may include, but are not limited to, water closets, urinals, irrigation, mechanical equipment and hose connections to perform operations, such as vehicle washing and lawn maintenance. Other applications may be used as approved by the Director.

6-1315.2C Rainwater harvesting systems may not be located in single family attached or detached residential developments for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1315.2D The owner of a RWHS is responsible for its on-going operation and maintenance. A private maintenance agreement must be executed before the construction plan is approved.

6-1316.3 Design of Rainwater Harvesting Systems.

6-1315.3A A rainwater harvesting system begins at the point of collection and terminates as waste after the water collected has been used in non-potable fixtures and outlets, industrial applications, or used for irrigation or other approved purposes. The parts of the RWHS include, but are not limited to: a) the collection surface; b) collection surface diversion (a.k.a roof washer, first-flush diverter); c) gutters, downspouts and/or collection piping; d) filtration and/or treatment appropriate for the intended application; e) storage tank (cistern); f) pump(s); g) distribution piping system; and h) a bypass or overflow. A RWHS may also incorporate meters, controls, automated systems for rainfall detection and soil moisture monitoring, a makeup water supply, and other components depending on the intended use.

6-1315.3B Rainwater harvesting systems shall conform to the Virginia Uniform Statewide Building Code (USBC).

6-1315.3C Acceptable sources of rainwater for harvesting and reuse include those collection surfaces and sources permitted by the USBC.

6-1315.3D Collection of water from managed turf, vehicular parking or pedestrian surfaces is prohibited except where the water is used exclusively for landscape irrigation.

6-1315.3E The design and placement of rainwater storage tanks must comply with applicable provisions of the Fairfax County Zoning Ordinance, this section, and any other applicable federal, state, or county codes.

6-1315.3F Underground chambers used exclusively for RWHS storage, are not subject to the requirements of § 6-0303.6 and the access door requirements of § 6-1306.3H.

6-1315.3G Stormwater credit for rainwater harvesting and reuse must be determined using a continuous simulation model for sizing the rainwater storage tank. The Virginia Cistern Design Spreadsheet or an alternative computer simulation model approved by the Director shall be used to quantify the runoff reduction volume credit for input into the Runoff Reduction Compliance Spreadsheet.

6-1315.3H The volume in the tank available for runoff reduction only applies to the useful storage volume that is available to receive stormwater inflow and must account for unused water remaining in the tank, “dead” storage below the pump cutoff elevation, storage above the overflow, freeboard, or an air gap above the maximum storage level. Freeboard volume above the maximum storage level must provide sufficient hydraulic head for proper function of the overflow, or a minimum five percent (5%) of the tank volume, whichever is greater.

6-1315.3I Local historical daily rainfall records shall be used to model daily precipitation for design of the RWHS. A multi-year series, such as the 30-year daily records in the Virginia Cistern Design Spreadsheet, shall be used.

6-1315.3J Daily demand (reuse) shall be based on calculations provided by the project architect and/or MEP engineer. For preliminary design, interior and exterior reuse can be estimated. Plan submittals shall include an itemized list or table of demand assumptions and calculations that support the daily reuse assumed for the design simulation.

6-1315.3K Daily demand assumptions shall appropriately account for fluctuations in reuse due to seasonal demand, day of the week (weekend vs. workday demand), or intermittent uses.

6-1315.3L If for any reason the designed dedicated end use becomes unavailable because of some change, an approved alternative end use or properly designed secondary BMP shall be installed to maintain stormwater credit for the RWHS.

6-1315.3M If a secondary or makeup water supply is used to supplement the RWHS, backup supply should be connected post-tank to the distribution system and should not occur in the tank. Connections must be protected from backflow in accordance with the USBC.

6-1315.3N An overflow or pre-tank diverter mechanism shall be included in RWHS designed to manage an individual storm event or multiple storms in succession that exceed the capacity of the tank.

6-1315.3O Overland relief must be provided in the form of a fail-safe bypass or overflow that ensures that if a complete failure of storm sewer system occurs, no building will be flooded or damaged by the design flow.

6-1315.3P RWH systems and downstream BMPs must discharge to an adequate channel.

6-1315.3Q Rainwater harvesting tanks may be oversized to provide additional stormwater detention volume. Tanks shall be modeled assuming that the Treatment Volume is full. Supporting calculations shall include routing of the 1-year, 2-year, and 10-year storms, outfall to an adequate channel, and provision for overland relief.

6-1315.3R Access to the RWHS shall be provided for inspection and maintenance. Access opening(s) shall be provided in the storage tank in accordance with USBC. Where applicable, access to storage tanks shall consider confined space entry requirements.

6-1315.4 Specifications.

To ensure proper system installation and function, applicable codes, these guidelines, and any applicable manufacturer's installation and maintenance instructions must be followed. Engineered systems shall be installed per plans and specifications of the engineer of record.

6-1315.5 Construction.

6-1316.5A Permits for installation of a RWHS can vary depending on the type and location of storage tank(s) being installed, system components, and intended use of the harvested rainwater. The applicant shall be responsible for obtaining necessary permits prior to construction. Required permits may include, but are not limited to: site permits, building permit(s) for footings, foundations, enclosures, vaults or roof structures; plumbing permit; and an electrical permit for the pump(s) and electrical controls.

6-1315.6 Plan Submittals.

6-1315.6A The site plan and/or stormwater management plan shall include, as a minimum, the following:

6-1315.6A(1) A concise narrative describing the stormwater management strategy, describing how the RWHS fits into the overall plan, and stating all assumptions made in the design and the purpose(s) for which the harvested rainwater will be used.

6-1315.6A(2) Show the location(s) of the RWHS on the site, a plan of the rainwater collection area including a roof plan of the building(s) that will be used to capture rainwater, showing slope direction and roof material. The plan shall include location of downspout leaders from the rooftops being used to capture rainwater.

6-1315.6A(3) Plan and profile view of the storm drain pipe layout between the building downspouts and the tank, if applicable, including materials, diameters, slopes and lengths.

6-1315.6A(4) Overflow location, filter path, and if applicable, the secondary runoff reduction practice.

6-1315.6B RWHS construction details and specifications shall be submitted and shall include sufficient detail to construct the primary components of the RWHS including, as a minimum, the following:

6-1315.6B(1) The collection surface including area, dimensions, type of surface material, pitch and slope direction, and type and location of rainwater collection points.

6-1315.6B(2) The collection and conveyance system including the specified materials, slopes and diameters of gutters and downspouts.

6-1315.6B(3) Pre-screen and first-flush diverter including the specific filter performance specification and filter efficiency curves. Runoff estimates from the rooftop area captured for the 1-inch storm should be compared to filter efficiencies for the 1-inch storm. It is assumed that the first flush diversion is included in filter efficiency curves. A minimum of 95% filter efficiency should be met for the treatment volume credit.

6-1315.6B(4) Storage tank type, material, and dimensions in a scalable detail and cross-section illustrating the incremental volumes specified for: (a) the low water cut-off volume level; (b) the storage volume associated with the Treatment Volume credit; (c) the storage volume associated with the Channel Protection Volume (if applicable); (d) the storage volume associated with the Flood Protection Volume (if applicable); and (e) the overflow freeboard volume.

6-1315.6B(5) Distribution system.

6-1315.6B(6) The inverts of the orifice outlet, the emergency overflows, and, if applicable, the receiving secondary runoff reduction practice or on-site infiltration facility.

6-1315.5C Plans shall be accompanied by supporting calculations and documentation that include, as a minimum, the following:

6-1315.5C(1) A drainage area map delineating the collection surface area (square feet) to be captured and indicating the 1-inch storm, and design storm peak discharge values on the plan.

6-1315.5C(2) Calculations showing that the collection and conveyance system, at its specified size and slope, will convey the design storm(s).

6-1315.5C(3) A print-out of the “Input” tab, as modeled, from the Virginia Cistern Design Spreadsheet or Director-approved simulation model.

6-1315.5C(4) A print-out of the “Results - Treatment Volume Credit” tab, as modeled, from the Virginia Cistern Design Spreadsheet or Director-approved simulation model.

6-1315.5C(5) A tabulation of the daily demand assumptions used to size the storage tank and determine runoff reduction credit accounting for fluctuations in reuse due to seasonal demand, day of the week, or intermittent uses.

6-1315.6C(6) Design spreadsheet and computations for adequate outfall or a secondary BMP, if applicable, at the point of discharge.

6-1316 Wet Swale (116-14-PFM)

6-1316.1 General.

6-1316.1A Wet swales are a cross between a wetland and a swale and provide runoff filtering and treatment within the conveyance system. These linear wetland cells often intercept shallow groundwater to maintain a wetland plant community. The saturated soil and wetland vegetation provide an ideal environment for gravitational settling, biological uptake, and microbial activity. On-line or off-line cells are formed within the channel to create saturated soil or shallow standing water conditions (typically less than 6 inches deep). A regenerative stormwater conveyance (RSC) system is a modification of a wet swale that is used to bring stormwater down steep grades through a series of step pools. RSC systems are used primarily to address channel erosion and outfall issues.

6-1316.1B Wet Swales shall conform to Virginia Stormwater Design Specification No. 11 Wet Swale (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1316.2 Feasibility and Limitations.

6-1316.2A In residential areas, wet swales and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1316.2B Wet swales may be located in the VDOT right-of-way with specific approval from VDOT.

6-1316.2C Setbacks. Wet swales shall meet the setback requirements for bioretention facilities in § 6-1307 *et seq*. In addition, vegetated swales shall be set back a minimum of 2 feet from property lines except where swales are located in the right-of-way.

6-1316.2D Wet swales shall not be located in the vicinity of loading docks, vehicle maintenance areas, or outdoor storage areas, where there is the potential for high concentrations of hydrocarbons, toxics, or heavy metals in stormwater runoff.

6-1316.2E The maximum drainage area to a wet swale shall be 2 acres. The maximum impervious area draining to a wet swale shall be 1 acre.

6-1316.2F Wet swales typically are designed as online conveyance systems but may be used offline as pre-treatment for other types of BMPs.

6-1316.2G The use of regenerative conveyance systems is subject to review and approval by the Director on a case by case basis.

6-1316.3 Maintenance.

6-1316.3A Wet swales and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Wet swales may not be located in County storm drainage easements. The above does not preclude the use of wet swales by the County within existing County drainage easements or on County-owned property.

6-1316.3B Maintenance access must be provided for all wet swales in accordance with § 6-1306 except that the access way may have a grass surface rather than an all-weather surface.

6-1316.3C Wet swales shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area that includes permanent pools of water, there may be additional ponding of water after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the length of the wet swale on alternating sides with a minimum of one sign for each swale. See Plate 81-6.

6-1316.4 Design Criteria.

6-1316.4A Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 11 Wet Swale (Latest version referenced in the VSMP Regulations).

6-1316.4B Check dams shall be provided along the length of the swale to provide storage of the treatment volume and to reduce the effective slope. The maximum height of check dams shall be 1.5 feet. Check dams shall be located and sized such that the ponded water does not reach the toe of the next upstream check dam or create a tailwater condition on incoming pipes. The length of the channel segment over which water is ponded is a function of the slope of the swale and the height of the check dam. See § 6-1308.4 *et seq*. for additional details on the design of check dams.

6-1316.4C The outfall of all wet swales must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1316.4D Variations of the wet swale designs in the typical details and schematics of wet swales in Virginia Stormwater Design Specification No. 11 Wet Swale (Latest version referenced in the VSMP Regulations) may be approved by the Director provided the facility meets all of the requirements in § 6-1317 *et seq*.

6-1316.5 Materials Specifications.

6-1316.5A Check dams. Check dams may be constructed of non-erosive material such as wood, gabions, rip-rap, or concrete. Earthen berms or bio-logs also may be used to create check dams.

Whatever material is used, check dams shall be designed to prevent erosion where the check dams intersect the channel side walls. Check dams shall be anchored into the swale wall a minimum of 2 feet on each side with the toe protected by a suitable non-erodible material (e.g., stone). A notch or depression shall be placed in the top of the check dam to allow the 2-year flow to pass without coming into contact with the check dam abutments.

6-1316.6 Wet Swale Planting Plans.

6-1316.6A Planting plans are required for all wet swales.

6-1316.6B Planting plans and specifications for wet swales shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0515.

6-1316.6C A mixture of shrubs, perennial herbaceous plants, and grasses with a high density of fibrous roots is required. The use of trees is optional. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation, retard and withstand stormwater flows, and filter pollutants. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant materials will be determined by the Director. Guidance on the use and selection of plants for vegetated swales is available from Urban Forest Management.

6-1316.6D All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1316.6E Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size. Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1316.6F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1316.7 Construction.

6-1316.7A The owner shall provide for inspection during construction of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of inspections shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1316.7B Wet swales shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan.

6-1316.7C Fill for earthen check dams shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to 12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Compaction equipment shall not be allowed within the facility on the soil bed. The top of the check dam shall be constructed level at the design elevation.

6-1316.7D Plant material shall be installed per § 12-0705.

6-1316.7E Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1316.7F All areas surrounding the facility that are graded or denuded during construction of the facility and are to be planted with turf grass shall be sodded.

6-1316.7G Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 11 Wet Swale (Latest version referenced in the VSMP Regulations).

6-1316.8 Plan Submission Requirements.

6-1316.8A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1316.8B Typical cross section(s) of the swale showing the following: dimensions of swale, groundwater table, and bedrock. Cross section(s) of the check dams.

6-1316.8C Profile showing the following: invert of the swale, groundwater table, bedrock, and check dams.

6-1316.8D Detail(s) of check dams.

6-1316.8E Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1316.8F Sizing computations for the facility including volume of storage, channel cross-section, and spacing of check dams required and provided.

6-1316.8G Hydrologic and hydraulic calculations for the swale.

6-1316.8H Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 11.

6-1316.8I A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1316.8J Construction and materials specifications.

6-1317 Filtering Practices (116-14-PFM)

6-1317.1 General.

6-1317.1A Stormwater filters are used to treat stormwater runoff from small, highly impervious sites. Stormwater filters capture, temporarily store, and treat stormwater runoff by passing it through an engineered filter media, collecting the filtered water in an underdrain, and then returning it back to the storm drainage system. The filter consists of two chambers: the first is devoted to settling, and the second serves as a filter bed consisting of a sand or organic filter media. Stormwater filters depend mainly on physical treatment mechanisms to remove pollutants from stormwater runoff, including gravitational settling in the sedimentation chamber, straining at the top of the filter bed, and filtration and adsorption onto the filter media. Microbial films often form on the surface of the filter bed, which can also enhance biological removal. Filters usually are designed only for water quality treatment.

6-1317.1B Stormwater filters can be classified into several broad categories:

6-1317.1B(1) Surface sand filters. The surface sand filter is designed with both the filter bed and sediment chamber located at ground level. Surface sand filters are normally designed to be off-line facilities, so that only the desired water quality or runoff reduction volume is directed to the filter for treatment. Surface sand filters can be designed as either non-structural systems with configurations similar to bioretention facilities or as structural systems using pre-cast or cast-in-place concrete chambers. The "Austin Sand Filter" design is an example of a surface sand filter.

6-1317.1B(2) Underground sand filters. The underground sand filter is designed with both the filter bed and sediment chamber in an underground vault and is often designed with an internal flow splitter or overflow device that bypasses runoff from larger stormwater events around the filter. Underground sand filters are expensive to construct, but they consume very little space and are well suited to ultra-urban areas. The "DC Sand Filter" design is an example of an underground sand filter.

6-1317.1B(3) Perimeter sand filters. The perimeter sand filter also is designed with both the filter bed and sediment chamber in an underground vault. However, in this design flow enters the system through grates or a curb inlet, usually at the edge of a parking lot. The perimeter sand filter is usually designed as an on-line practice (i.e., all flows enter the system), but larger events bypass treatment by entering an overflow chamber. One major advantage of the perimeter sand filter design is that it requires little hydraulic head and is therefore a good option for sites with low topographic relief. The "Delaware Sand Filter" design is an example of a perimeter sand filter.

6-1317.1C Stormwater filters shall conform to Virginia Stormwater Design Specification No. 12 Filtering Practices (Latest version referenced in the VSMP Regulations), except as modified herein. Additional guidance on the design of sand filters is provided in the "Northern Virginia

BMP Handbook Addendum; Sand Filtration Systems" (NVPDC/ESI, 1996) available online from the Northern Virginia Regional Commission.

6-1317.1D The requirements and specifications herein cover non-proprietary stormwater filters. Requirements and specifications for proprietary stormwater filters are in § 6-1322 *et seq*.

6-1317.2 Feasibility and Limitations.

6-1317.2A Stormwater filters are recommended for areas 1.5 acres or less and greater than 65% impervious.

6-1317.2B In residential areas, stormwater filters and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1317.2C Stormwater filters may be located in the VDOT right-of-way with specific approval from VDOT.

6-1317.2D Setbacks. Surface sand filters shall be set back a minimum of 2 feet from property lines.

6-1317.2E Stormwater filters may not be utilized in-line with the main conveyance system where the main conveyance system is maintained by the County or carries through drainage from adjoining properties.

6-1317.3 Maintenance.

6-1317.3A Stormwater filters and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Stormwater filters may not be located in County storm drainage easements. The above does not preclude the use of stormwater filters by the County within existing County drainage easements or on County-owned property.

6-1317.3B Maintenance access must be provided for all stormwater filters in accordance with § 6-1306. Access routes shall be depicted on plans for all facilities not located in parking lots or along streets.

6-1317.3C Stormwater filters with above ground ponding areas shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area, water may pond after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the filter area with a minimum of one sign for each facility. (See Plate 81-6.)

6-1317.3D Stormwater filters with below ground chambers shall be stenciled (or a plaque provided) on the inside of the box in a location clearly visible upon removal of the access manhole or door designating the stormwater filter as a water quality management facility. The stenciling or plaque shall state that the facility is a water quality management facility, water may pond after a storm, and the facility is not to be disturbed except for required maintenance.

6-1317.4 Design Criteria.

6-1317.4A Filter Area and Storage Volume. The required filter area and storage volume shall be determined in accordance with Virginia Stormwater Design Specification No. 12 Filtering Practices (Latest version referenced in the VSMP Regulations).

6-1317.4B For on-line facilities, the inlet must be designed to pass the peak flow rate for the 10-year storm. For off-line facilities, a flow splitter shall be used to capture the design storm (typically the treatment volume) and pass larger flows around the facility.

6-1317.4C For surface filters, the maximum surface storage depth from the top of the filter to the elevation of the overflow weir or drop inlet shall be 1 foot.

6-1317.4D Berms used to pond water in surface filters shall be a maximum of 2.0 feet in height measured from the downstream toe-of-slope to the top of the berm. The width of the top of the berm shall be a minimum of 2.0 feet. The side slopes of the berm shall be a maximum of 3:1. Berms and overflow weirs shall be sodded and pegged in accordance with the most recent edition of the "Virginia Erosion and Sediment Control." Facilities with berms that are equal to or less than 2.0 feet in height or excavated facilities will not be subject to the requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1317.4E The side slopes of the surface filter above ground shall be a maximum of 3:1. Where space permits, gentle side slopes (e.g., 5:1) are encouraged to blend the facility into the surrounding landscape. Side slopes of the facility excavated below ground may be as steep as the *in situ* soils will permit. All excavation must be performed in accordance with Virginia Occupational Safety and Health (VOSH) requirements. If the facility is located on problem soils, as defined in Section 107-2-2 (j) of the County Code, a professional authorized by the State shall specify the maximum acceptable slope.

6-1317.4F An outlet structure must be provided to convey the peak flow for the 10-year storm. The outlet structure may be a bypass pipe, drop inlet, or weir. A minimum freeboard of 6 inches shall be provided from the maximum elevation of the 10-year storm to the top of the facility.

6-1317.4G An emergency overflow weir shall be provided for all facilities with berms. The emergency overflow weir must have the capacity to pass the peak flow from the 100-year storm without overtopping the facility. If the facility design includes a weir in the berm to convey the peak flow for the 10-year storm, it also may be designed to function as the emergency overflow weir. The minimum weir length shall be 2 feet.

6-1317.4H The outfall of all outlet structures, emergency overflow weirs, and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1317.4I The depth between the bottom of the facility and groundwater table or bedrock shall be a minimum of 2 feet for surface filters as determined by field run soil borings.

6-1317.5 Specifications.

6-1317.5A Underdrains shall be PVC pipe conforming to the requirements of ASTM F758, Type PS 28 or ASTM F949; HDPE pipe conforming to the requirements AASHTO M252 or M 294, Type S; or approved equivalent pipe. Underdrains shall be perforated with four rows of 3/8-inch holes with a hole spacing of 3.25 ± 0.25 inches or a combination of hole size and spacing that provides a minimum inlet area ≥ 1.76 square inches per linear foot of pipe or be perforated with slots 0.125 inches in width that provides a minimum inlet area ≥ 1.5 square inches per linear foot of pipe.

6-1317.5B Filter fabric. Filter fabric shall be a needled, non-woven, polypropylene geotextile meeting the requirements listed in Virginia Stormwater Design Specification No. 12 Filtering Practices (Latest version referenced in the VSMP Regulations). Heat-set or heat-calendared fabrics are not permitted.

6-1317.6 Construction.

6-1317.6A The owner shall provide for inspection during construction of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the inspections required under 6-1317.6E shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1317.6B Stormwater filters shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan. The concrete box may be installed with the other elements of the storm drainage collection system provided that it is flushed of any accumulated sediments prior to installation of the underdrain, filter fabric and soil media components.

6-1317.6C Fill for the berm and overflow weir of non-structural filters shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to

at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Compaction equipment shall not be allowed within the facility on the soil bed. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1317.6D All areas surrounding the facility that are graded or denuded during construction of the facility and are to be planted with turf grass shall be sodded.

6-1317.6E The facility shall be inspected at 12-24 and 36-48 hours after a significant rainfall (0.5-1.0 inch) or artificial flooding to determine that the facility is draining properly. Results of the inspection shall be provided to DPWES prior to bond release.

6-1317.7 Plan Submission Requirements.

6-1317.7A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures including underdrains.

6-1317.7B Cross section of the facility showing the following: elevations and dimensions of the structure, inlet, outlet, underdrain, filter media, and underlying gravel layer, and filter fabric.

6-1317.7C Sizing computations for the facility including volume of storage and surface area of facility required and provided.

6-1317.7D Hydrologic calculations for the facility.

6-1317.7E Design calculations and specifications for all hydraulic structures including inlet structures and underdrain piping.

6-1317.7F A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1317.7G Construction and materials specifications.

6-1318 Constructed Wetlands (116-14-PFM)

6-1318.1 General.

6-1318.1A Constructed wetlands are shallow depressions that receive stormwater inputs for water quality treatment. Wetlands are typically less than 1 foot deep (although they have greater depths at the forebay and in micropools) and possess variable microtopography to promote dense and diverse wetland cover. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. Wetlands provide an ideal environment for gravitational settling, biological uptake, and microbial activity. Constructed wetlands are the final element in the roof-to-stream runoff reduction sequence. They should only be considered for use after all other upland runoff reduction opportunities have been exhausted and there is still a remaining water quality or channel protection volume to manage.

6-1318.1B Constructed Wetlands shall conform to Virginia Stormwater Design Specification No. 13 Constructed Wetlands (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1318.2 Feasibility and Limitations.

6-1318.2A Constructed wetlands are not permitted in residential developments unless there are no other reasonable options available for compliance with the water quality control (BMP) requirements. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities. When allowed in residential areas, constructed wetlands and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1318.2B Setbacks. Constructed wetlands shall meet the setback requirements of the Virginia Stormwater Design Specification No. 13 Constructed Wetlands (Latest version referenced in the VSMP Regulations).

6-1318.2C Trees within constructed wetlands may be used to meet the requirements of Chapter 122 of the County Code and § 12-0000 *et seq*. of the PFM.

6-1318.3 Maintenance.

6-1318.3A Constructed wetlands and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Constructed wetlands may not be located in County storm drainage easements. The above does not preclude the use of constructed wetlands by the County within existing County drainage easements or on County-owned property.

6-1318.3B Maintenance access must be provided for all constructed wetlands in accordance with § 6-1306. In addition, maintenance access stabilized to provide for passage of heavy equipment shall be provided for all sediment forebays.

6-1318.3C Constructed wetlands shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area that includes permanent pools of water, there may be additional ponding of water after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the wetland with a minimum of one sign for each facility. See Plate 81-6.

6-1318.3D An onsite area designated for sediment dewatering and disposal should be provided if feasible.

6-1318.4 Design Criteria.

6-1318.4A Constructed wetlands shall be designed and constructed in accordance with County standards for dam embankments, outlet structures including spillways, maintenance access, geotechnical testing, and signage. Constructed wetlands are treated as wet ponds for dam safety purposes and embankment design. Wherever any conflict exists between a County standard and the state specification, the County standard shall be used except for those design elements necessary to achieve the required pollutant removal.

6-1318.4B Sediment forebays shall be provided at all discharge points into the facility that account for more than 10% of the drainage area to the facility. Sediment forebays shall be excavated to the extent feasible. If sufficient volume cannot be created by excavation, a rock or gabion berm keyed into the sides of the pond no higher than 2 feet may be used.

6-1318.4C Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 13 Constructed Wetlands (Latest version referenced in the VSMP Regulations).

6-1318.4D Water Balance. Water balance computations are required for all facilities to determine their feasibility and minimum pool depths. Computation of the water balance and minimum pool depth shall be determined in accordance with Virginia Stormwater Design Specification No. 13 Constructed Wetlands (Latest version referenced in the VSMP Regulations).

6-1318.4E The outfall of all outlet structures, emergency overflow weirs, and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1318.4F In addition to any geotechnical testing required under § 6-1600 (Design and Construction of Dams and Impoundments), soils shall be tested in at least two locations within the planned wetland treatment areas to determine the depth to groundwater and bedrock and

potential infiltration losses. If potential infiltration losses are too large, an impermeable liner may be necessary.

6-1318.5 Specifications.

6-1318.5A See § 6-1600 *et seq*. for materials specifications for dam embankments, outlet structures, conduits, and spillways and § 6-1319.6 for plant materials.

6-1318.6 Wetland Planting Plans.

6-1318.6A Planting plans are required for all constructed wetlands.

6-1318.6B Planting plans and specifications for constructed wetlands shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0500.

6-1318.6C Depending on the wetland type and application, a mixture of trees, shrubs, and perennial herbaceous plants with a high density of fibrous roots is required. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant materials will be determined by the Director.

6-1318.6D All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1318.6E Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size. Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1318.6F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1318.7 Construction.

6-1318.7A The owner shall provide for inspection during construction of the facility by a licensed design professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1318.7B Constructed wetland sites shall be posted with signs during construction in accordance with § 6-1305.7F until the permanent signs required under 6-1318.3C have been installed.

6-1318.7C Constructed wetlands shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan.

6-1318.7D Construction shall meet all applicable requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1318.7E Fill for berms and overflow weirs not subject to the requirements of § 6-1600 *et seq*. shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Compaction equipment shall not be allowed within the facility on the soil bed. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1318.7F Plant material shall be installed per § 12-0705.

6-1318.7G Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1318.7H Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 13 Constructed Wetlands (Latest version referenced in the VSMP Regulations).

6-1318.8 Plan Submission Requirements.

6-1318.8A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1318.8B Cross section(s) of the facility showing the following: elevations and dimensions of berms, inlets, outlets, pipes, groundwater table, and bedrock.

6-1318.8C Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1318.8D Sizing computations for the facility including volume of storage and surface area of facility required and provided and a computation of the ratio of the shortest flow path to overall length of the facility.

6-1318.8E Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 13.

6-1318.8F Hydrologic calculations for the facility including computation of the water balance.

6-1318.8G Design calculations and specifications for all hydraulic structures including inlet structures, outlet structures, overflow weirs, and pipes.

6-1318.8H Soils analysis and testing results. Elevation of groundwater table and/or bedrock.

6-1318.8I A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1318.8J Construction and materials specifications.

6-1318.8K All plan submission requirements for dams and impoundments in § 6-1305.6 *et seq*. and § 6-1305.7 *et seq*.

6-1319 Wet Pond (116-14-PFM)

6-1319.1 General.

6-1319.1A A wet pond consists of a permanent pool of standing water that promotes a better environment for gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a sufficiently long residence time to allow numerous pollutant removal mechanisms to operate. Wet ponds can also provide detention above the permanent pool to help meet water quantity control requirements. Designers should note that a wet pond is the final element in the roof-to-stream runoff reduction sequence. Therefore, wet ponds should be considered only if there is remaining treatment volume or channel protection volume to manage after all other upland runoff reduction options have been considered and properly credited.

6-1319.1B Wet Ponds shall conform to Virginia Stormwater Design Specification No. 14 Wet Pond (Latest version referenced in the VSMP Regulations), except as modified herein.

6-1319.2 Feasibility and Limitations.

6-1319.2B Wet ponds are not permitted in residential developments unless they are regional ponds or there are no other reasonable options available for compliance with the water quality control (BMP) requirements. Such approval by the Director shall be in writing and shall specify such conditions deemed necessary to ensure the effectiveness, reliability, and maintenance of the proposed facilities. When allowed in residential areas, wet ponds and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1319.2C Setbacks. Wet ponds shall meet the setback requirements of the Virginia Stormwater Design Specification No. 14 Wet Pond (Latest version referenced in the VSMP Regulations).

6-1319.2D Trees planted around the perimeter of wet ponds may be used to meet the requirements of Chapter 122 of the County Code and § 12-0000 *et seq.* of the PFM.

6-1319.3 Maintenance.

6-1319.3A Except for regional ponds, wet ponds and their appurtenant structures must be privately maintained and a private maintenance agreement must be executed before the construction plan is approved. Nonregional wet ponds may not be located in County storm drainage easements. The above does not preclude the use of nonregional wet ponds by the County within existing County drainage easements or on County-owned property.

6-1319.3B Maintenance access must be provided for all wet ponds in accordance with § 6-1306. In addition, maintenance access stabilized to provide for passage of heavy equipment shall be provided for all sediment forebays.

6-1319.3C Wet ponds shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area that includes permanent pools of water, there may be additional ponding of water after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the wetland with a minimum of one sign for each facility. See Plate 81-6.

6-1319.3D An onsite area designated for sediment dewatering and disposal should be provided if feasible.

6-1319.4 Design Criteria.

6-1319.4A Wet ponds shall be designed and constructed in accordance with County standards for dam embankments, outlet structures including spillways, maintenance access, geotechnical testing, and signage. Wherever any conflict exists between a County standard and the state specification, the County standard shall be used except for those design elements necessary to achieve the required pollutant removal.

6-1319.4B Sediment forebays shall be provided at all discharge points into the facility that account for more than 10% of the drainage area to the facility. Sediment forebays shall be excavated to the extent feasible. If sufficient volume cannot be created by excavation, a rock or gabion berm keyed into the sides of the pond no higher than 2 feet may be used.

6-1319.4C Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 14 Wet Pond (Latest version referenced in the VSMP Regulations).

6-1319.4D The outfall of all outlet structures and spillways must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1319.5 Specifications.

6-1319.5A See § 6-1600 *et seq*. for materials specifications for dam embankments, outlet structures, conduits, and spillways and 6-1319.6 *et seq*. for plant materials.

6-1319.6 Planting Plans.

6-1319.6A Planting plans are required for all wet ponds.

6-1319.6B Planting plans and specifications for wet ponds shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0500.

6-1319.6C Depending on the type and application, a mixture of trees, shrubs, and perennial herbaceous plants with a high density of fibrous roots is required. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant materials will be determined by the Director.

6-1319.6D All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1319.6E Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size. Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1319.6F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1319.7 Construction.

6-1319.7A The owner shall provide for inspection during construction of the facility by a licensed design professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1319.7B Wet pond sites shall be posted with signs during construction in accordance with § 6-1305.7F until the permanent signs required under 6-1319.3C have been installed.

6-1319.7C Wet ponds shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan. If the pond site will be used for erosion and sediment control during construction of the development, the construction notes shall clearly indicate that the facility will be dewatered, dredged, and graded to design dimensions after the drainage area to the facility is stabilized.

6-1319.7D Construction shall meet all applicable requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1319.7E Fill for berms and overflow weirs not subject to the requirements of § 6-1600 *et seq.* shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1319.7F Plant material shall be installed per § 12-0705.

6-1319.7G Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1319.7H Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 14 Wet Pond (Latest version referenced in the VSMP Regulations)].

6-1319.8 Plan Submission Requirements.

6-1319.8A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1319.8B Cross section(s) of the facility showing the following: elevations and dimensions of berms, inlets, outlets, pipes, groundwater table, and bedrock.

6-1319.8C Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1319.8D Sizing computations for the facility including volume of storage and surface area of facility required and provided and a computation of the ratio of the shortest flow path to overall length of the facility.

6-1319.8E Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 14.

6-1319.8F Hydrologic calculations for the facility.

6-1319.8G Design calculations and specifications for all hydraulic structures including inlet structures, outlet structures, overflow weirs, and pipes.

6-1319.8H Soils analysis and testing results. Elevation of groundwater table and/or bedrock.

6-1319.8I A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1319.8J Construction and materials specifications.

6-1319.8K All plan submission requirements for dams and impoundments in § 6-1305.6 *et seq.* and § 6-1305.7 *et seq.*

6-1320 Extended Detention Pond (116-14-PFM)

6-1320.1 General.

6-1320.1A An extended detention pond relies on extended detention of stormwater runoff after each rain event. Extended detention ponds are designed for 24 hour (Level 1) or 36 hour (Level 2) detention of the treatment volume. An outlet structure restricts stormwater flow so it is temporarily stored within the basin. The temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on the banks of the receiving stream. Extended detention design differs from conventional detention design in that it is designed to achieve a minimum drawdown time, rather than a maximum peak rate of outflow (which is commonly used to design for channel protection or flood control and often detains flows for just a few minutes or hours). However, detention used for channel protection, may result in extended drawdown times. Therefore, designers are encouraged to evaluate the detention drawdown as compared to the extended detention requirements in order to meet both criteria. Extended detention ponds rely on gravitational settling as their primary pollutant removal mechanism. Consequently, they generally provide fair-to-good removal for particulate pollutants, but low or negligible removal for soluble pollutants, such as nitrate and soluble phosphorus. The use of extended detention alone generally results in the lowest overall pollutant removal rate of any single stormwater treatment option. Extended detention ponds include micropools at the outlet structure and sediment forebays with permanent pools to enhance performance and may incorporate additional deep pools or wetland cells.

6-1320.1B Extended Detention Ponds shall conform to Virginia Stormwater Design Specification No. 15 Extended Detention (ED) Pond [Latest version referenced in the VSMP Regulations], except as modified herein.

6-1320.2 Feasibility and Limitations.

6-1320.2A Extended detention ponds are not permitted in residential developments unless they are regional ponds or there are no other reasonable options available for compliance with the water quality control (BMP) requirements. When allowed in residential areas, extended detention ponds and their appurtenant structures must be located on homeowner association (or “common”) property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1320.2B Setbacks. Extended detention ponds shall meet the setback requirements of the Virginia Stormwater Design Specification No. 15 Extended Detention (ED) Pond [Latest version referenced in the VSMP Regulations].

6-1320.2C Trees planted around the perimeter of extended detention ponds may be used to meet the requirements of Chapter 122 of the County Code and § 12-0000 *et seq.* of the PFM.

6-1320.3 Maintenance.

6-1320.3A Extended detention ponds located in residentially zoned areas, including condominium developments, shall be within County storm drainage easements, and shall be maintained by DPWES. Extended detention ponds located in industrial, commercial, institutional, apartment developments and rental townhouses must be maintained by the property owner, and a Private Maintenance Agreement must be executed before the construction plan is approved.

6-1320.3B Maintenance access must be provided for all extended detention ponds in accordance with § 6-1306. In addition, maintenance access stabilized to provide for passage of heavy equipment shall be provided for all sediment forebays.

6-1320.3C Extended detention ponds shall be posted with permanent signs designating the area as a water quality management area. Signs shall state that the facility is a water quality management area that includes permanent pools of water, there may be additional ponding of water after a storm, and the area is not to be disturbed except for required maintenance. Signs shall be posted at approximately 150-foot intervals along the perimeter of the wetland with a minimum of one sign for each facility. See Plate 81-6.

6-1320.3D An onsite area designated for sediment dewatering and disposal should be provided if feasible.

6-1320.4 Design Criteria.

6-1320.4A Extended detention ponds shall be designed and constructed in accordance with County standards for dam embankments, outlet structures including spillways, maintenance access, geotechnical testing, and signage. Extended detention ponds are treated as wet ponds for dam safety purposes and embankment design because of the permanent ponding in the sediment forebay and micropool. Wherever any conflict exists between a County standard and the state specification, the County standard shall be used except for those design elements necessary to achieve the required pollutant removal.

6-1320.4B Sediment forebays shall be provided at all discharge points into the facility that account for more than 10% of the drainage area to the facility. Sediment forebays shall be excavated to the extent feasible. If sufficient volume cannot be created by excavation, a rock or gabion berm keyed into the sides of the pond no higher than 2 feet may be used.

6-1320.4C Treatment Volume. The required treatment volume shall be determined in accordance with Virginia Stormwater Design Specification No. 15 Extended Detention Pond (ED) [Latest version referenced in the VSMP Regulations].

6-1320.4D The outfall of all outlet structures and spillways must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1320.4E All facilities shall incorporate the installation of a concrete apron in front of the riser structure, a galvanized or painted steel BMP plate or a reverse slope pipe, and a galvanized or painted steel debris cage in general accordance with the typical details in Plates 3.07-1, 2, 3 & 4. The use of downturned elbows and half-round pipes as described in the state specifications is not permitted. Because the sediment forebay and the bottom of the pond are not intended to remain dry between storm events, a trickle ditch is not required.

6-1320.4F In addition to any geotechnical testing required under § 6-1600 (Design and Construction of Dams and Impoundments), soils shall be tested in at least two locations within the planned pond area to determine the depth to groundwater and bedrock and potential infiltration losses. If potential infiltration losses are too large, extended detention ponds with shallow marshes may not be feasible.

6-1320.5 Specifications.

6-1320.5A See § 6-1600 *et seq*. for materials specifications for dam embankments, outlet structures, conduits, and spillways and 6-1320.6 for plant materials.

6-1320.6 Planting Plans.

6-1320.6A Planting plans are required for all extended detention ponds.

6-1320.6B Planting plans and specifications for extended detention ponds shall be prepared by a certified landscape architect, horticulturist, or other qualified individual who has knowledge of the environmental tolerance, ecological functions, and ecological impacts of plant species. Planting plans shall be prepared in accordance with the requirements of § 12-0500.

6-1320.6C Depending on the type and application, a mixture of trees, shrubs, and perennial herbaceous plants with a high density of fibrous roots is required. Selected plants must be able to tolerate highly variable moisture conditions, generally dry with brief periods of inundation. Depending on site conditions, selected plants also must be able to tolerate exposure to wind and sun, as well as salt and toxins in runoff from roads, parking lots, and driveways. The use of native plant species is preferred. The acceptability of proposed plant materials will be determined by the Director.

6-1320.6D All plants shall conform to the latest version of American Standard for Nursery Stock published by the American Nursery and Landscape Association (ANSI Z60.1) for quality and sizing. Trees and shrubs shall be nursery grown unless otherwise approved and shall be healthy and vigorous, free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements as determined by the Director.

6-1320.6E Trees shall be a minimum of 1-inch caliper. Shrubs shall be a minimum of 2-gallon container size and herbaceous plants shall be a minimum of 6-inch diameter container size.

Variations in size may be approved by the Director, based on the requirements of the specific plants listed in the schedule.

6-1320.6F All plantings must be well established prior to release of the conservation deposit. Nursery stock trees and shrubs required by the approved plan shall be viable (healthy and capable of developing a trunk and branch structure typical for their species) at the time the conservation deposit is released.

6-1320.7 Construction Specifications.

6-1320.7A The owner shall provide for inspection during construction of the facility by a licensed design professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1320.7B Extended detention pond sites shall be posted with signs during construction in accordance with § 6-1305.7F until the permanent signs required under 6-1320.3C have been installed.

6-1320.7C Extended detention ponds shall be constructed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan. If the pond site will be used for erosion and sediment control during construction of the development, the construction notes shall clearly indicate that the facility will be dewatered, dredged, and graded to design dimensions after the drainage area to the facility is stabilized.

6-1320.7D Construction shall meet all applicable requirements of § 6-1600 (Design and Construction of Dams and Impoundments).

6-1320.7E Fill for berms and overflow weirs not subject to the requirements of § 6-1600 (Design and Construction of Dams and Impoundments) shall consist of clean material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches, or other deleterious material. Fill shall be placed in 8- to12-inch lifts and compacted to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. The top of the berm and the invert of the overflow weir shall be constructed level at the design elevation.

6-1320.7F Plant material shall be installed per § 12-0705.

6-1320.7G Planting shall take place after construction is completed and during the following periods: March 15 through June 15 and Sept. 15 through Nov. 15, unless otherwise approved by the Director.

6-1320.7H Additional guidelines for construction are provided in Virginia Stormwater Design Specification No. 15 Extended Detention (ED) Pond [Latest version referenced in the VSMP Regulations].

6-1320.8 Plan Submission Requirements.

6-1320.8A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures.

6-1320.8B Cross section(s) of the facility showing the following: elevations and dimensions of berms, inlets, outlets, pipes, groundwater table, and bedrock.

6-1320.8C Plant schedule and planting plan specifying species, quantity of each species, stock size, type of root stock to be installed and amount of tree cover claimed for each tree species or spacing of shrubs and perennials within facility. Planting plan shall be in conformance with § 12-0515.

6-1320.8D Sizing computations for the facility including volume of storage and surface area of facility required and provided and a computation of the ratio of the shortest flow path to overall length of the facility.

6-1320.8E Computations and other information demonstrating that the design meets level 1 or level 2 design criteria in Virginia Stormwater Design Specification No. 15.

6-1320.8F Hydrologic calculations for the facility.

6-1320.8G Design calculations and specifications for all hydraulic structures including inlet structures, outlet structures, overflow weirs, and pipes.

6-1320.8H Soils analysis and testing results. Elevation of groundwater table and/or bedrock.

6-1320.8I A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1320.8J Construction and materials specifications.

6-1320.8K All plan submission requirements for dams and impoundments in § 6-1305.6 *et seq.* and § 6-1305.7 *et seq.*

6-1321 Manufactured BMPs (116-14-PFM)

6-1321.1 General.

6-1321.1A Manufactured BMPs generally are proprietary stormwater treatment devices that utilize settling, filtration, absorptive or adsorptive materials, vortex separation, vegetative components, or other technology to reduce pollutants in stormwater runoff. Manufactured BMPs typically do not provide runoff reduction or water quantity control.

6-1321.1B Manufactured BMPs may be used to achieve water quality compliance provided they have been approved for use by the Virginia Department of Conservation and Recreation and have been approved by the Director in accordance with § 6-0400 *et seq*.

6-1321.1C Pollutant removal efficiencies for manufactured BMPs shall be as assigned by the Virginia Stormwater BMP Clearinghouse.

6-1321.2 Feasibility and Limitations.

6-1321.2A Individual manufactured BMPs will have different site constraints and limitations. Manufacturer's specifications, approvals by the Virginia Department of Conservation, and approvals by the Director should be consulted to ensure that manufactured BMPs are feasible for use on a specific site.

6-1321.2B Manufactured BMPs primarily are recommended to treat impervious areas.

6-1321.2C Manufactured BMPs may not be located in County storm drainage easements. The above does not preclude the use of manufactured BMPs by the County within existing County drainage easements or on County-owned property.

6-1321.2D In residential areas, manufactured BMPs and their appurtenant structures must be located on homeowner association (or "common") property and may not be located on individual buildable single-family attached or detached residential lots or any part thereof for the purpose of satisfying the detention, water quantity, or water quality control (BMP) requirements of the Stormwater Management Ordinance.

6-1321.2E Manufactured BMPs may be located in the VDOT right-of-way with specific approval from VDOT.

6-1321.2F Manufactured BMPs may not be located in the vicinity of loading docks, vehicle maintenance areas, or outdoor storage areas, where there is the potential for high concentrations of hydrocarbons, toxics, or heavy metals in stormwater runoff unless effective pre-treatment is provided to reduce the concentrations or the device is designed specifically to address these types of pollutants.

6-1321.2G Manufactured BMPs may not be utilized in-line with the main conveyance system where the main conveyance system is maintained by the County or carries through drainage from adjoining properties.

6-1321.3 Maintenance.

6-1321.3A Manufactured BMPs must be privately maintained and a Private Maintenance Agreement must be executed before the construction plan is approved.

6-1321.3B Maintenance access must be provided for all manufactured BMPs in accordance with § 6-1306. Maintenance access routes must be depicted on plans for all facilities not located in parking lots or along streets.

6-1321.3C Manufactured BMPs with below ground chambers shall be stenciled (or a plaque provided) on the inside of the box in a location clearly visible upon removal of the access manhole or door designating the manufactured BMP as a water quality management facility. The stenciling or plaque shall state that the facility is a water quality management facility, water may pond after a storm, and the facility is not to be disturbed except for required maintenance.

6-1321.4 Design Criteria.

6-1321.4A Manufactured BMPs shall be designed in accordance with the manufacturer's specifications as contained in the most recent design guidelines except as noted herein or as determined by the Director with his approval of the device.

6-1321.4B Manufactured BMPs shall be designed in accordance with all requirements developed by the Virginia Department of Conservation and Recreation and the County. Changes to manufacturer's specifications or variants of the original product design approved by the Director that may impact the device's hydraulic performance or phosphorus removal capability must be evaluated and approved by the Director prior to use.

6-1321.4C Manufactured BMPs shall be designed to treat an instantaneous flow rate of 0.7 cfs per acre without bypass or the minimum treatment volume required by Chapter 124 of the County Code.

6-1321.4D Individual manufactured BMPs may require pretreatment, or may be appropriate for use as pretreatment devices. Manufacturer's specifications should be consulted to determine the device-specific pretreatment requirements. Where the facility may be subject to significant exposure to leaf litter, grass clippings, trash and other debris, some form of pretreatment should be provided.

6-1321.4E For on-line facilities, the inlet must be designed to pass the peak flow rate for the 10-year storm. For off-line facilities, a flow splitter shall be used to capture the design storm (typically the treatment volume) and pass larger flows around the facility.

6-1321.4F The outfall of all outlet structures, bypass structures, and underdrains must be in conformance with the adequate drainage requirements of § 6-0200 *et seq*.

6-1321.4G Manufactured BMPs with below ground chambers shall be designed to resist flotation.

6-1321.5 Specifications.

6-1321.5A Materials shall be in accordance with the manufacturer's most recent specifications except as may be modified by the Director in approving use of the device under § 6-0400 *et seq*.

6-1321.5B Materials certifications from the manufacturer for filter media shall be submitted to the County prior to bond release. Materials certifications must be based on batch test results performed by the manufacturer as part of a quality control/quality assurance program.

6-1321.6 Construction.

6-1321.6A The owner shall provide for inspection during installation of the facility by a licensed professional. (In accordance with standard practice, the actual inspections may be performed by an individual under responsible charge of the licensed professional.) The licensed professional shall certify that the facility was constructed in accordance with the approved plans. The licensed professional's certification along with any material delivery tickets and certifications from the material suppliers and results of the inspections performed shall be submitted to the County prior to bond release. For projects requiring as-built plans, the required certification and supporting documents shall be submitted with or incorporated in the as-built plans. For projects that do not require as-built plans, the required certification and supporting documents shall be submitted with the RUP or non-RUP request.

6-1321.6B Manufactured BMPs shall be installed after the drainage area to the facility is completely stabilized. Erosion and sediment controls for construction of the facility shall be installed as specified in the erosion and sediment control plan. Chambers may be installed with the other elements of the storm drainage collection system provided that they are flushed of any accumulated sediments prior to installation of the internal components.

6-1321.7 Plan Submission Requirements.

6-1321.7A Plan view(s) of the facility and appurtenant structures with topography at a contour interval of no more than one foot and spot elevations throughout the facility showing all hydraulic structures including underdrains.

6-1321.7B Cross section of the facility showing the following: elevations and dimensions of the structure, inlet, outlet, underdrain, and internal components.

6-1321.7C Sizing computations for the facility including volume of storage and surface area of facility required and provided.

6-1321.7D Hydrologic calculations for the facility.

6-1321.7E Design calculations and specifications for all hydraulic structures including inlet structures and underdrain piping.

6-1321.7F A discussion of the outfalls from the facility is to be included in the outfall narrative.

6-1321.7G Construction and materials specifications.

6-1400 FLOODPLAIN

6-1401 Requirements

6-1401.1 In areas of streambeds subject to inundation with 70 acres or more of watershed, floodplain water surface elevations shall be computed in order that floodplain easements may be established.

6-1401.2 Where open drainage swales exist and drainage improvements are not provided, a drainage study and storm drainage easement to cover the 100-year drainageway must be provided on watersheds less than 70 acres.

6-1402 Flows

6-1402.1 All floodplains shall be calculated for a quantity of runoff based on the 100-year design storm.

6-1402.2 Flows in floodplains shall be determined by the methods discussed in § 6-0800 et seq.

6-1403 Methods and Guidelines for Calculations (Plate 45-6)

6-1403.1 Water surface elevations may be determined by the Standard Step Method which is expressed as:

$$B = \left(Z_2 + d_2 + V_2^2/2g\right) - \left(Z_1 + d_1 + V_1^2/2g - H_L\right)$$

$$V = \frac{Q}{A} = \frac{1.49}{n} r^{2/3} S^{1/2}$$

$$H_L = 1/2\left(S_1 + S_2\right)L = 1/2\left\|\frac{\left(n_1 v_1\right)^2}{2.208 r_1^{4/3}} + \frac{\left(n_2 v_2\right)^2}{2.208 r_2^{4/3}}\right\| L$$

6-1403.2 With exception of the term B, above terms are defined on Plate 45-6.

6-1403.3 The term B is the balance of energy between the two sections which shall be 0.2 feet + or -.

6-1403.4 The method is a trial and error procedure throughout most of the floodplain. General guidelines to performing calculations are as follows:

6-1403.4A Select floodplain cross-sections

6-1403.4A(1) (61-98-PFM) These sections shall be selected based on the topography and any existing and/or proposed hydraulic control sections. Floodplain cross-sections shall be developed from field run data or aerial spot elevations in accordance with methods described in the "Flood Insurance Study Guidelines and Specifications for Study Contractors" (Federal Emergency Management Agency, January 1995). Elevation data for all hydraulic structures and buildings in or adjoining the floodplain shall be collected by field survey. Areas of the channel which are underwater shall be field surveyed unless permission is granted in advance by the Director to use the water surface as the assumed channel bottom. Upon written request, permission to use the water surface as the assumed channel bottom may be granted by the Director where the assumption will not affect the Director's ability to administer the floodplain regulations. Topography between the cross-sections shall be at 2-feet contour intervals and may be developed by field or aerial methods. Aerial survey methods shall meet the "American Society of Photogrammetry and Remote Sensing Accuracy Standards for Large-Scale Maps" (ASPRS, 1990).

6-1403.4A(2) Cross-sections are needed at floodplain contractions, expansions, sharp changes in invert slope, and where abrupt changes in channel roughness occurs.

6-1403.4A(3) Special care shall be taken to include the effects of all major constrictions (such as culvert crossings under roads, etc.) in the computations.

6-1403.4A(4) Distance along the baseline between sections shall not exceed 300 feet. Locations of cross-sections are subject to approval of the Director, therefore, cross-sections selected shall be coordinated.

6-1403.4B Cross-sections shall be as nearly perpendicular to floodplain flow as possible. The baseline shall be located as close as possible to the center of the flood area.

6-1403.4C The roughness coefficients, (n), for the floodplain shall be obtained from DPWES. The designer may be permitted to use different values of roughness coefficients for the center of the stream and the overflow banks of each cross-section.

6-1403.4D If the floodplain study is being prepared for a particular site or property, the floodplain shall extend downstream a minimum of 300 feet from the lower property line or to a control section. The floodplain shall extend a minimum of 300 feet upstream from the upper property line.

6-1403.4E When the floodplain study is prepared in accordance with the provisions of Parts 6 and 9 of Article 2 of the Zoning Ordinance, then, consideration of the effects of any proposed use shall be based on the assumption that there will be an equal degree of encroachment by others extending for a significant reach on both sides of the stream. This combined effect must not have an adverse effect (normally construed to include no rise in water surface elevation) upon the adopted 100-year floodplain.

6-1404 Water Surface Calculations

6-1404.1 Water surface calculations shall begin where the energy and hydraulic gradient are known or can readily be obtained.

6-1404.2 Calculations shall generally be performed in an upstream direction since floodplains are usually subcritical flow through the entire floodplain.

6-1404.3 Once the water surface is established at a cross-section, the water surface in the next cross-section is assumed, the total energy (distance to the EGL) is calculated, and then the energy balance between the two cross-sections is computed.

6-1404.4 If the energy balance does not meet the required accuracy, then assume another water surface elevation and repeat calculations.

6-1404.5 When the energy balance meets the required accuracy, the water surface elevation is established and calculations may proceed between the next two cross-sections.

6-1405 Floodplain Easement

6-1405.1 All floodplains, or portions of floodplains, that pass through a project site shall have a floodplain easement. This easement shall be shown on the plats and plans and shall be designated as a "Floodplain and Storm Drainage Easement." The following note also must be clearly shown: "No use shall be made of, nor shall any improvements be made in, the floodplain easement without specific authorization from Fairfax County."

6-1405.2 The easement shall be placed around the water limits as established by the floodplain calculations. This easement shall be tied to the site boundaries in such a manner that the easement may be established at the site.

6-1405.3 The floodplain easements shall be placed on the record plat, the site construction drawings and floodplain study. However, only the record plat is required to have the metes and bounds of the easements and the boundary tie information.

6-1500 ON-SITE MAJOR STORM DRAINAGE SYSTEM

6-1501 Guidelines for Major Drainage System. Major and minor storm drainage systems are defined in § 6-0100 *et seq*.

6-1501.1 For most developments, the on-site major storm drainage system is the natural backup system and therefore consists of the less obvious drainage-ways.

6-1501.1A It is desirable that the major system provide drainage relief such that no buildings will be flooded with a 100-year design flow, even if the minor system should fail due to blocking.

6-1501.1B If a minor drainage system is available, the major system shall be designed to carry the runoff in excess of the capacity of the minor system.

6-1501.2 Guidelines for design of the on-site major drainage system are as follows:

6-1501.2A Areas shall be graded in such a manner and/or buildings located or constructed in such a manner that if a complete failure of storm sewer system occurs, no building will be flooded by the design flow.

6-1501.2B Key areas to watch are sump areas, relatively flat areas and areas where buildings are located below streets and/or parking lots.

6-1501.2C The 100-year frequency storm shall be used to compute the runoff for the major drainage system.

6-1501.2D For the first trial, the same time of concentration values that were used in designing the minor drainage system shall be used and the minor system shall be assumed to be completely inoperable. If no building will be flooded based on these assumptions, then the analysis may be considered complete.

6-1501.2E If buildings will be flooded based on the assumptions used in § 6-1501.2D, then the designer should perform more precise hydrologic and hydraulic computations. He shall design the minor system, overland relief swales, and/or surface storage in such a way that no building will be damaged by flooding.

6-1501.2F The minor storm drainage system normally should not be oversized as a design for the major system. The major drainage system should be in the form of grading of the area and/or locating and constructing buildings in such a manner that overland relief swales and/or surface storage will accomplish the objective. In some instances where a sump condition exists, the design engineer may desire to locate storm sewer openings and structures below the overland relief elevation.

6-1502 Major Drainage System Design Calculation

6-1502.1 In general, the design guidelines described in § 6-1500 *et seq*. are intended to result in a functional analysis rather than a numerical analysis.

6-1502.2 Design engineers shall indicate on the project drainage plans, the location and approximate extent of the overland relief path and areas that may be affected by surface storage for a 100-year design storm. Overlaying arrows, shading or other suitable see-through graphics are suggested for this purpose.

6-1502.3 Any calculations that may have been necessary in order to arrive at the major system shall be submitted.

6-1503 Overlot Grading in Residential Areas

6-1503.1 Grading plans for construction of dwellings shall show proposed grading necessary to ascertain adequate drainage and to show that overland relief will be provided.

6-1503.2 Compliance with the grading plan shall be required to the extent that zoning yard requirements are maintained, adequate drainage is provided and the limit of clearing is honored.

6-1503.3 (27-89-PFM) In residential areas, on lots of 36,000 square feet or less, where a developer creates cut or fill slopes 3:1 or steeper, with unbroken vertical heights of 4 feet or greater, such slopes shall be stabilized with a ground cover selected by the developer from the following list: English Ivy, Ajuga, Crown Vetch, Pachysandra, Periwinkle, Euonymus, Creeping Juniper or other, as approved by the Director. Since ground covers normally require two years for establishment, the following apply:

6-1503.3A Interim ground protection that will not inhibit development of the ground cover must be provided and be effective before RUP is issued. This protection may be a temporary grass cover or a permanent mulch providing that it does not interfere with growth of the ground cover.

6-1503.3B Because of the establishment time, the conservation deposit approved by the County posted prior to plan approval (subdivision or individual lot grading plan) shall include an amount equal to the estimated cost of seeding or sprigging with the selected ground cover all areas which qualify for such cover. The deposit shall not be released until all slopes scheduled for ground cover are covered to the satisfaction of the Director.

6-1503.3C If the first purchaser of a residential lot of 36,000 square feet or less requests, in writing, that the above types of ground cover not be provided on the lot, and accepts the maintenance responsibility therefore, the Director may authorize this exception.

6-1503.3D The alternate selected by the buyer, either grass or permanent hardwood bark mulch, must be completely established/installed before a RUP can be issued.

6-1503.4 On residential lots exceeding 36,000 square feet, the ground stabilization to be provided on all disturbed areas regardless of slope shall normally be a permanent variety of grass unless otherwise agreed to in writing between the buyer and the developer.

6-1503.5 For all industrial and commercial areas, the ground stabilization to be provided for all disturbed areas regardless of degree of slope shall normally be a permanent grass; except that mulches and ground covers may be accepted with specific approval of the Director.

6-1503.6 For all slopes in VDOT rights-of-way, regardless of zoning, the ground stabilization shall be a permanent grass acceptable to VDOT unless otherwise specifically approved by VDOT.

6-1503.7 (27-89-PFM) Regardless of location, no mulch or vegetation stabilized slopes steeper than 2H:1V shall be approved for vertical heights greater than 4 feet without intervening retaining walls or 4-foot wide benches. The Director may specify which option shall be provided, or may require a combination of the two. The Director's written authorization under this section must be obtained.

6-1600 DESIGN AND CONSTRUCTION OF DAMS AND IMPOUNDMENTS
(46-94-PFM)

6-1601 Virginia Dam Safety Regulations

6-1601.1 (84-04-PFM) Construction of impoundments with a dam height of 25 feet or greater and with an impoundment capacity of 15 acre-feet or more, and impoundments with a dam height of 6 feet or greater and with an impoundment capacity of 50 acre-feet or more, requires compliance with the Virginia requirements set forth in the Virginia Soil and Water Conservation Board's Impounding Structure Regulations (VR 625-01-00), dated Feb. 1, 1989, as revised under 4VAC 50-20-30, effective July 1, 2002. Definitions of "dam height" and "impoundment capacity" per the Virginia Dam Safety Regulations are as follows: "Dam Height" means the structural height of an impounding structure, and is the vertical distance from the natural stream bed or watercourse measured at the downstream toe of the impounding structure to the top of the impounding structure; "Impoundment Capacity" means the volume in acre-feet that is capable of being impounded at the top of the impounding structure.

6-1601.2 Permits for construction and operation of these dams are issued by the Virginia Soil and Water Conservation Board.

6-1601.3 A copy of any state-approved design also must be submitted to the Director in order to receive Director approval for grading and/or construction plans. Grading or construction plans must also include an erosion and sediment control plan in accordance with the provisions in § 11-0000 (Erosion and Sediment Control) *et seq.*

6-1602 County Dam Safety Regulations

6-1602.1 The Director shall require compliance with the procedures and criteria set forth in § 6-1602 through § 6-1608 for the design and construction of new dams and the rehabilitation of existing dams in the County that are not under the jurisdiction of a federal agency or Virginia. The rehabilitation of a feature of a dam or related facilities which would require construction or grading plan approval shall conform to the criteria and procedures which apply to that particular feature. However, where the rehabilitation of the feature would bring into question the safety or functional capability of another feature(s), as determined by the Director, that feature(s) shall also be rehabilitated to comply with the criteria and procedures. Rehabilitation means restoring the dam and/or appurtenant structures to the original or a superior functional condition affecting the design, construction, operation and/or performance, in a manner requiring the prior submission to the County of a construction or grading plan.

6-1602.2 These guidelines and standards are intended to ensure public safety and welfare. Dams are complex structures which must be designed and constructed taking into account specific site conditions, the characteristics of the construction materials, the particular functions of the dam and the hazards associated with the particular site. No written document can cover all design and construction problems that may be confronted by the design engineer. The acceptability of the

design and the adequacy of the plans and specifications will be made on a case-by-case basis. The primary responsibility for the proper design of the dam and appurtenant structures shall continue to be that of the design engineer.

6-1602.3 The County will regulate all dams except existing or proposed dams owned, operated, and maintained by the federal government or Virginia.

6-1602.4 All dams formed by highway embankments are also subject to the following additional procedures and criteria:

6-1602.4A VDOT special design considerations for permanently impounding water upstream of highway embankments.

6-1602.4B VDOT approval and acceptance must be secured for these impoundments.

6-1602.5 (88-05-PFM) VDOT will consider accepting subdivision streets for maintenance that occupy dams when the dam criteria outlined in the VDOT Subdivision Street Requirements are met. A roadway will be considered to occupy a dam if any part of the fill for the roadway and the fill for the dam overlap or if the area between the two embankments is filled in so that the downstream face of the dam is obscured or if a closed drainage facility from a dam extends under a roadway fill.

6-1602.6 (88-05-PFM) For privately maintained dams, a Private Maintenance Agreement shall be executed with the County by the owner of the dam and recorded among the land records of the County prior to construction plan approval.

6-1602.7 (88-05-PFM) A storm drainage easement shall be provided sufficient to convey the maximum emergency spillway flow downstream to an adequate drainage system (see § 6-0200). The intent of this provision is to restrict future development within the area immediately downstream from the spillway that will be inundated based on the appropriate spillway design flood.

6-1602.8 (88-05-PFM) Dams regulated by the County shall be designed by a Professional Engineer licensed in Virginia with experience and expertise in the fields of hydrology, hydraulics and geotechnical engineering.

6-1602.9 (88-05-PFM) The owner of the dam shall comply with the requirements of § 6-1607 related to the construction, inspection, and as-built certification of dams regulated by the County.

6-1603 Hydrologic Design Criteria for Dams Regulated by the County

6-1603.1 The emergency spillway shall be designed to safely pass or store the spillway design flood (SDF) without overtopping the dam. In addition, a freeboard shall be established in accordance with the criteria set forth below:

6-1603.1A (122-16-PFM) The SDF shall be determined based on a spillway design storm determined from Plates 46-6, 47A-6, and 47B-6. The spillway design storm total rainfall amount shall also be determined from Plate 46-6. The minimum storm duration shall be 24-hour. A storm hyetograph shall be constructed using the NOAA_C, 24-hour duration, rainfall distribution shown in Plates 47A-6, 47B-6, and 48-6. Once the spillway design storm hyetograph is constructed, the SDF hydrograph shall be determined using standard NRCS unit hydrograph techniques.

6-1603.1B (57-96-PFM) A freeboard above the water-surface elevation resulting from the SDF shall be determined based on a freeboard hydrograph (FBH) developed using the next highest storm (i.e., total rainfall amount) from Plate 46-6. The storm duration and storm distribution for the FBH shall be the same as that used for the SDF. The top of dam elevation should be designed at or above the water-surface elevation resulting from routing the FBH. For Class A, B and C reservoirs (see Plate 64-6, the minimum freeboard shall be no less than 2 feet above the SDF elevation. For Class D reservoirs with drainage areas less than 20 acres, the minimum freeboard shall be no less than 1 foot above the SDF elevation; however, the Director may require more freeboard if there is potential for downstream property damage or personal injury.

6-1603.1C The SDF and FBH shall be routed through the impoundment assuming that no storage is available below the emergency spillway crest and that the principal spillway is inoperative or clogged.

6-1603.2 An emergency spillway separate from the principal spillway should be provided. The Director may allow a combined principal/emergency spillway if existing conditions (such as the necessity to cut through rock) dictate. When a vegetated overland emergency spillway is proposed, the frequency of use for the emergency spillway shall be limited based on the following hydrologic criteria:

6-1603.2A For dry impoundments having drainage areas less than 70 acres, dam heights less than or equal to 15 feet and impoundment capacities less than or equal to 25 acre-feet, the principal spillway shall convey the entire 10-year flood and the emergency spillway crest shall be set at or above the 10-year flood elevation.

6-1603.2B For all other dry impoundments, the emergency spillway crest shall be set at or above the 25-year flood elevation and the principal spillway shall convey the entire 25-year flood.

6-1603.2C For wet impoundments having drainage areas less than 70 acres, dam heights less than or equal to 15 feet and impoundment capacities less than or equal to 25 acre-feet, the

emergency spillway crest shall be set at or above the 25-year flood elevation and the principal spillway shall convey the entire 25-year flood.

6-1603.2D For all other wet impoundments, the emergency spillway crest shall be set at or above the 50-year flood elevation and the principal spillway shall convey the entire 50-year flood.

6-1603.2E (122-16-PFM) The 10-, 25-, and 50-year recurrence interval floods mentioned in § 6-1603.2A thru § 6-1603.2D shall be developed as hydrographs using a minimum 24-hour storm duration, rainfall amounts from Table 6.19, storm distribution from Plates 47A-6 and 47B-6, and standard NRCS unit hydrograph techniques for converting the rainfall hyetograph to a runoff hydrograph.

6-1603.3 When two or more dams are positioned in a series, the following criteria shall apply:

6-1603.3A Upper dam. The hydrologic design criteria for the design of the upper dam in a system of dams in series shall be the same as, or more stringent than, those for the dams downstream, if failure of the upper dam could contribute to failure of the lower dam.

6-1603.3B Lower dam(s). For the design of a lower dam in a system of dams in a series, hydrographs shall be developed for the areas controlled by the upper dams based on the same hydrologic criteria as the lower dam(s). The hydrographs shall be routed through the spillways of the upstream dams and the outflows routed to the lower dam where they are combined with the hydrograph from the intermediate uncontrolled drainage area. The combined emergency spillway hydrograph and the combined freeboard hydrograph shall be used to determine the size of the emergency spillway and the height of dam at the lower site. If upon routing a hydrograph through the upper dam, the dam is overtopped or its safety is a concern, as determined by the Director, it shall be considered breached. For design of the lower dam, the breach hydrograph shall be routed downstream to the lower dam and combined with the uncontrolled area hydrograph. The breach hydrograph shall be determined as described in § 6-1603.4B through § 6-1603.4D.

6-1603.4 As a part of the overall dam design, the engineer shall determine the segment of the stream valley downstream from the dam that would experience an increased flood depth resulting from a potential dam failure. This analysis may be waived by the Director for those dams having drainage areas less than 70 acres, dam heights less than 15 feet and impoundment capacities less than 25 acre-feet. However, the Director can require that a dam breach analysis be performed for any size impoundment if there is any concern as to the potential hazard that the impoundment presents to downstream properties. The following procedure shall be used to perform the dam breach analysis:

6-1603.4A Initially, a dam breach analysis assuming failure due to internal erosion (piping) shall be performed. The reservoir level will be assumed to be at the crest of the emergency spillway for this analysis. This type of analysis is sometimes referred to as a “sunny day” breach since pond inflow is assumed to be equal to zero. The resulting dam breach hydrograph shall be routed

downstream of the dam to a point where the dam break flood depth has attenuated to a depth less than the 100-year flood elevation.

6-1603.4B After performing the “sunny day” dam breach analysis, a dam overtopping breach analysis shall be performed. The storm amount from the chart in Plate 46-6 which overtops the proposed dam shall be the basis of analysis. After determining the overtopping storm from the chart in Plate 46-6, a dam breach hydrograph shall be developed assuming that the dam fails at the time of maximum water-surface elevation in the reservoir. This dam breach hydrograph shall be routed downstream to a point where the dam break flood depth has attenuated to within 1 foot or less than the flood depth that would be experienced without the dam.

6-1603.4C Methods used by the Corps of Engineers, the Soil Conservation Service, or the National Weather Service for computing the outflow hydrograph resulting from a dam failure, or other methods approved by the Director, may be used for this analysis.

6-1603.4D The following guidelines are offered for performing dam break analysis for earth dams when failure results from overtopping and when using methods that require assumptions regarding the dam breach shape and time to failure. Analysis using the HEC-1 computer program is recommended when simulating a failure due to overtopping.

6-1603.4D(1) Breach Width (the width at the bottom of the breach when breach is at maximum size): The ultimate breach width for an earth dam can vary greatly; however, the breach width should be between 1/2 the dam height and 4 times the dam height. A breach width ranging from two to three times the dam height may be used in most situations. The breach width can be a function of reservoir volume. For instance, for two dams having the same height and section but exceedingly different impoundment capacities, the dam having the smaller capacity would normally have the smaller breach width. The ultimate breach width will also be limited by the size of the natural stream valley where the dam is located.

6-1603.4D(2) Side Slope of Breach (Z=horizontal to one vertical): $0 < Z < 1$.

6-1603.4D(3) Failure Time (TF). Failure time will vary dependent on dam section, embankment material, and impoundment size. For typical dam embankments with minimum required top widths, a failure time based on an erosion rate of 2 feet/minute may be used.

6-1603.4D(4) Pool Elevation at Which Failure Begins (FAILELEV): Failure typically begins at a depth of 1 foot to 5 feet above the dam top. However, for the purposes of the dam break analysis, failure shall be assumed to begin at the maximum pool elevation achieved during the overtopping flood.

6-1603.4E If the dam break analysis shows a potential for flooding of structures, the engineer shall increase the spillway capacity in excess of the requirements shown in Plate 46-6, at least to the point where there is no potential flooding of structures, or reduce the dam height to a level which results in no increase in flooding of structures.

6-1603.4F If the dam break analysis shows no increase in flood depths, the spillway capacity may be reduced to a level where flood depths start to increase. In such a case, the engineer must provide computations and a narrative on the plans supporting the reduced SDF and FBH criteria. The minimum acceptable SDF shall be the 100-year flood. Any reduction of the SDF and FBH criteria will require the explicit approval of the Director.

6-1604 Design Guidelines for Spillways

6-1604.1 Drop Inlet Spillways. Drop inlet spillways generally consist of a riser structure located in the reservoir area connected to a pipe or box culvert (outlet conduit) which extends through the dam embankment. Drop inlet spillways should be designed such that full flow is established in the outlet conduit and riser at as low a head over the riser crest as practical (see § 6-1604.1B), and to operate without excessive surging, noise, vibration , or vortex action at any stage. This requires that the riser have a larger cross-sectional area than the outlet conduit. The following procedures should be used for computation of the discharge rating curve for a drop inlet spillway.

6-1604.1A The following general equations are for flow determination at various locations throughout a drop inlet spillway.

6-1604.1A(1) Weir flow (rectangular cross section):

$$Q = CLH_w^{3/2}$$

Where:
Q = discharge (cfs)
C = weir flow coefficient, typically set at 3.0 but may vary with head and weir shape
L = weir length (ft.)
H_w = energy head above spillway crest (ft.)

This equation is applicable for the initial stages of flow over the riser crest as well as initial stages of flow into rectangular ports along the riser column.

6-1604.1A(2) Orifice flow:

$$Q = CA(2gH_o)^{1/2}$$

Where:
Q = discharge, cfs
C = orifice coefficient, typically set at 0.6 for sharp edged orifices but may vary depending on orifice geometry
A = flow area ($ft^{2)}$
g = acceleration of gravity (32.2 ft./sec²)
H_o = energy head above centroid of opening (ft.)

This equation is applicable for flow through openings on the spillway riser which are totally submerged and no longer operating under weir flow.

6-1604.1A(3) (57-96-PFM) Outlet conduit pipe flow. The outlet conduit should be designed to flow full with control occurring at the outlet. In most cases, the following equation can be used to determine the energy loss through a principal spillway conduit operating under outlet control:

$H = (1 + k_e + k_b + 29\, n^2 L / R^{4/3})\, V^2 / 2g$

Where:
H = head loss (ft.)
$k_e + k_b$ = entrance and bend loss coefficients, typically set at 0.7, but may vary depending on entrance and bend geometry
n = Manning's roughness coefficient, typically set at 0.013 for concrete
L = conduit length (ft.)
R = hydraulic radius of conduit (ft.)
V = flow velocity in conduit (fps)
g = acceleration of gravity (32.2 ft./sec²)

In some cases, particularly if the outlet conduit is set at a steep slope, full flow will not occur in the pipe conduit and control may occur at the junction between the outlet conduit and the riser. Calculation of a rating curve with the control at this location can be estimated by assuming orifice flow into the outlet conduit and using the orifice equation or by using FHWA inlet control nomographs. It should be understood that the inlet control nomographs are not truly representative of this type of flow situation and should be used with the understanding that they were developed to predict flow through highway culverts operating under inlet control. However, depending on the size relationship between the riser and outlet conduit, the inlet control nomograph may provide a reasonable estimate.

6-1604.1B The drop inlet spillway shall be designed so that full flow is established prior to the occurrence of orifice flow at the riser top. Therefore, for any Q, the water surface elevation associated with orifice flow at the riser top must be less than the water surface elevation resulting from either weir flow at the riser rim or full flow in the outlet conduit. A design that results in full flow occurring at as low a head over the riser top as practical is superior. In most cases, drop inlet spillways should be designed such that full flow is established in both the outlet conduit and riser. This type of design will discourage excessive surging, noise and vibration during operation. The engineer designing the spillway should avoid situations where the outlet conduit flows part full and control occurs at the junction of the riser and outlet conduit.

6-1604.1C Riser structures shall be designed with a factor of safety against flotation equal to or greater than 1.3 under any flooding condition. In addition to this criteria, riser structures in wet ponds shall also have a factor of safety against flotation equal to or greater than 1.5 at the normal pool elevation. When the riser is situated in the embankment, the buoyant weight of submerged fill over the footing projection may be considered.

6-1604.2 Vegetated Emergency Spillways. A vegetated emergency spillway is an open channel spillway located adjacent to a dam embankment for the purpose of conveying excess flood flows safely past a dam. They are excavated in natural earth and shall not be located on any portion of the dam embankment fill. Vegetated emergency spillways generally consist of an inlet channel, control section, and exit channel as shown in Plates 49-6, 50-6 and 51-6. Subcritical flow exists in the inlet channel and supercritical flow usually exists in the exit channel. The overland emergency

spillway is designed to convey a predetermined emergency spillway design flood without excessive velocities and a predetermined freeboard storm without overtopping the dam embankment.

6-1604.2A Procedures for Vegetated Emergency Spillway Layout:

6-1604.2A(1) The inlet channel should be level for a minimum distance of 20 feet to 30 feet upstream of the control section.

6-1604.2A(2) The level part of the inlet channel should be the same width as the exit channel.

6-1604.2A(3) Curvature in the inlet channel is acceptable; however, it shall only be introduced upstream of the level section and shall be tangent to the level section.

6-1604.2A(4) The centerline of the exit channel shall be straight and perpendicular to the control section to a point far enough below the earth dam embankment to ensure that any flow which might escape from the exit channel cannot damage the earth dam (see Plates 49-6 and 50-6).

6-1604.2B Hydraulic Design Procedures for Vegetated Emergency Spillways:

6-1604.2B(1) Vegetated emergency spillways shall be designed to convey the spillway design flood determined in accordance with § 6-1603.

6-1604.2B(2) If a control section is used, then the grade of the exit channel is to be sufficiently steep to ensure supercritical flow (see Plate 51-6).

6-1604.2B(3) A “Manning’s” roughness coefficient (n) of 0.04 is to be used for determining velocity and capacity in vegetated emergency spillways. Uniform flow may be assumed in the exit channel when the flow is supercritical; however, this assumption will be less accurate when the channel slope approaches or exceeds 10 percent. Where flow is subcritical, such as in the inlet channel, step backwater computations should be performed to determine the head loss between the control section and the reservoir pool when it is apparent that significant head loss may occur through the inlet channel. In cases where the inlet channel is very short and expands rapidly into the reservoir area, a step backwater analysis may not be required; the simple weir formula or direct calculation of critical depth may be used under these circumstances to estimate the energy head upstream of the control section.

6-1604.2B(4) Maximum permissible flow velocities for the SDF in vegetated emergency spillways should be determined in accordance with Plate 52-6.

6-1604.2B(5) The frequency of use of a vegetated emergency spillway should be limited in accordance with § 6-1603.2.

6-1604.3 Riprap Emergency Spillways. A riprap emergency spillway may be required when design velocities exceed those which are acceptable for vegetated emergency spillways.

6-1604.3A The layout of a riprap spillway shall be the same as that described for a vegetated emergency spillway in § 6-1604.2. The hydraulic design of a riprap spillway is similar to that of a vegetated spillway except that roughness coefficients and permissible velocities for riprap shall be used. Assuming dumped riprap placement and side slopes no steeper than 2H:1V, the following roughness coefficients and limiting velocities are applicable:

Table 6.39 Roughness Coefficients and Permissible Velocities for Riprap Spillways

Riprap Size	Mean Stone Diameter	Roughness Coefficient	Maximum Allowable Velocity
(VDOT Standard)	**ft.**	**Manning's "n"**	**fps**
Class I	1.1	0.040	10.0
Class II	1.6	0.043	11.5
Class III	2.2	0.045	13.0

6-1604.3B Riprap shall be placed at a depth equal to twice the mean stone diameter and the terminus of the riprap exit channel shall be keyed into the existing ground to a depth equal to four times the mean stone diameter. Riprap bedding shall meet VDOT standards and specifications. The frequency of use of a riprap spillway shall be limited similar to vegetated spillways by setting the crest elevation in accordance with § 6-1603.2.

6-1604.4 The combination of a drop inlet spillway and an overland emergency spillway (vegetated or riprap) is generally required. Standard riser types recommended for drop inlet spillways are shown in Plates 53-6, 54-6 and 55-6.

6-1604.5 Other types of spillways may be considered as alternatives to the drop inlet spillway and overland emergency spillway. Such other types of spillways include: straight drop (free overflow) spillway, ogee crest weirs, side channel spillways, and combined principal/emergency spillways. Topographic and other physical limitations will be considered in determining one type of spillway over another. In no case will an emergency overflow spillway be permitted on the dam embankment fill.

6-1604.6 Combined Principal and Emergency Spillways. As discussed in § 6-1604.4, an emergency spillway separate from the principal spillway is generally required. However, in some cases, it may not be practical to incorporate an overland emergency spillway at either dam abutment due to topographic limitations (e.g., abutments too steep), land use limitations (e.g., existing or proposed development), or some other factor (e.g., roadway embankments acting as dams). In these instances, subject to approval by the Director, a combined principal/emergency

spillway may be considered. A combined principal/emergency spillway is simply a single spillway structure which conveys both low flows (e.g., stormwater management functions) as well as extreme flows (e.g., spillway design flood). The combined spillway may take the form of a drop inlet spillway, a straight drop (free overfall) spillway, or some other spillway type. Plates 56-6 and 57-6 depict a combined principal/emergency drop inlet spillway when using a roadway embankment as a dam. A primary design consideration for a combined principal/emergency spillway, particularly when in the form of drop inlet spillways, is protection against clogging. Trash racks shall be designed in accordance with § 6-1604.8. When a drop inlet spillway is proposed as a combined principal/emergency spillway, the SDF and FBH determined in accordance with § 6-1603 shall be routed through the impoundment assuming that no storage is available below the riser crest or rim, and that all ports or orifices along the riser column are inoperative or clogged.

6-1604.7 Stilling Basins. A stilling basin should be incorporated at the downstream end of most spillway structures to help dissipate the high energy flow in the spillway and prevent excessive erosion downstream of the spillway. Stilling basins can take the form of riprap at the endwall of an outlet conduit of a drop inlet spillway or may consist of a sophisticated hydraulic jump basin with impact blocks. The type of stilling basin required is a function of the flow velocities associated with the spillway design flood and the amount of energy dissipation required. Riprap is the preferred form of stilling basin when it can be designed within the parameters and constraints outlined below.

6-1604.7A The following procedure shall be used for designing riprap-type energy dissipaters such as those typically placed downstream of outlet conduits discharging through dam embankments. All relevant computations shall be shown on the construction plans.

6-1604.7A(1) Determine the spillway design flood velocity at the outlet.

6-1604.7A(2) From Plate 58-6, determine the size of riprap required to withstand flow velocity.

6-1604.7A(3) If the riprap size selected can withstand the flow velocity in accordance with Plate 58-6, then the riprap should be placed in accordance with the detail in Plate 59-6. The depth of riprap placement should be two times D_{50} and the length of the riprap placement should be determined in accordance with the procedures outlined in FHWA HEC-14 Chapter XI, where the length of the basin is 15 times the anticipated depth of scour. However, in no case should the length of riprap be less than four times the height of the outlet conduit.

6-1604.7A(4) If the riprap size selected cannot withstand the flow velocity in accordance with Plate 58-6, then a riprap basin should be designed in accordance with the procedures outlined in FHWA HEC-14. In this case, the riprap basin is designed and shaped to reflect the depth of scour that will occur for the size riprap selected. Note that the detail in Plate 59-6 does not apply in this situation. Instead, the detail shown in Plate 60-6 (Figure XI-13 of FHWA HEC-14) should be used. It should also be noted that a culvert endwall incorporating wing wall flair should be avoided with this type of basin. Culvert end treatment should be limited to a headwall only and

the headwall should extend perpendicular to the pipe alignment. End treatment similar to the VDOT Standard EW-1 is preferred to the Standard EW-2.

6-1604.7A(5) For Froude Numbers greater than three, some other type of energy dissipator or stilling basin should be investigated such as impact basins or hydraulic jump basins.

6-1604.7A(6) For high tailwater stilling basins, the high velocity core of water emerging from the culvert may retain its jetlike character as it passes through the stilling basin, and be diffused in a manner similar to that of a concentrated jet diffusing in a large body of water. As a result, the scour hole will generally be shallower and longer. Therefore, additional riprap may be required for the channel downstream of the riprap stilling basin.

6-1604.7B Reference is made to the Federal Highway Administration (FHWA) publication HEC-14 for design information on several different types of stilling basins and energy dissipaters. Also, publications by the Soil Conservation Service, the Bureau of Reclamation, and the Army Corps of Engineers can be referenced for stilling basin design.

6-1604.8 Trash Racks and Debris Control Devices. Most spillways will be subject to some degree of trash and debris associated with incoming flows, and certain spillways are more susceptible than others to clogging as a result of debris. Prior to design of a debris control structure, an assessment of the anticipated debris problem shall be performed. The type and quantity of debris will be largely affected by upstream land use, soil erodibility, watershed size, and the type of stormwater management facility. Generally, debris control structures associated with wet ponds (permanent impoundments) will be designed to protect spillway structures from floating debris, including grass clippings, small limbs, trash, construction debris, logs and trees. Debris control structures associated with dry ponds will generally be designed to protect spillway structures from flowing debris as well as floating debris. Flowing debris may include silt, sand, gravel, trash, rock fragments, and construction debris; all of which may be transported as a bedload of the flood flow. The following design criteria shall be used:

6-1604.8A Trash racks for tops of drop inlet spillways should be designed to protect against clogging of the spillway under any operating level. The average velocity of flow through a clean trash rack should not exceed 2.5 fps for operation during the spillway design flood. Velocity can be computed on the basis of the net area of opening through that portion of the rack experiencing flow. This same criteria shall also apply to ports or openings along the side of a riser structure. Bar spacing should be no greater than one-half of the minimum conduit dimension in the drop inlet spillway, and, to discourage child access, bar spacings shall be no greater than 1 foot apart. The clear distance between bars shall generally not be less than 2 inches; however, one exception to this may be near the apex of the trash rack shown in Plate 53-6.

6-1604.8B Debris control devices for dry stormwater management ponds may be required for low level intakes at the pond bottom. In these situations, debris control structures such as those discussed in the FHWA publication entitled “Debris Control Structures (HEC No. 9)” should be considered where appropriate.

6-1604.8C Debris control devices for extended dry stormwater management facilities are required for the low flow orifice controlling the extended drawdown period. The preferred trash rack detail for those facilities is shown in Plate 61-6.

6-1604.8D In some cases, for both wet and dry stormwater management facilities, debris racks such as those discussed in FHWA HEC No. 9 may be required at major inflow locations to the stormwater management basin so that debris can be intercepted prior to entering the basin.

6-1604.8E Recommended debris control devices for riser structures are contained in Plates 53-6 through 55-6.

6-1604.9 Anti-Vortex Devices. All closed conduit spillways designed for pressure flow shall have adequate anti-vortex devices. Anti-vortex devices may take the form of a baffle or plate set on top of a riser, or a headwall set on one side of a riser. The NRCS 2-way covered riser (see example detail on Plate 55-6) has very reliable anti-vortex and debris control provisions inherent in the standard design. Example details for some recommended anti-vortex devices are shown on Plates 53-6 through 55-6.

6-1604.10 Drain Valves. Stormwater management facilities having permanent impoundments (i.e., wet ponds) shall be designed to allow draining the permanent pool to facilitate lake maintenance and sediment removal. The draining mechanism will usually consist of some type of valve or gate attached to the spillway structure. The following design guidelines for pond drains are provided:

6-1604.10A Pond drains shall be designed with sufficient capacity to pass a flood having a 1-year recurrence interval with limited ponding in the reservoir area such that sediment removal or other maintenance functions are not interrupted. The pond drain system may be no smaller than 8 inches in diameter.

6-1604.10B Pond drains shall be designed with adequate trash racks or debris control devices. Trash racks should generally be designed such that flow velocities through the rack are less than 2 fps. However, velocities of up to 5 fps may be allowed for racks that are easily accessible for cleaning. The spacing of trash rack bars shall depend on the size of the outlet conduit or valve and the type of valve or gate. When a pond drain consists of a small conduit with a valve control, closely spaced trash bars may be required to exclude small trash. When large conduits with sluice gates are used, the trash bars can be more widely spaced. In general, trash bars may be placed 3 inches to 6 inches apart and assembled in a grid pattern.

6-1604.10C In most cases, sluice gates are preferred over “in-line” type valves such as those used in water distribution systems (e.g., eccentric plug valves, knife gate valves, gate valves). Sluice gates are generally more appropriate for passing debris-laden flow, are generally less prone to clogging, and are usually easier to maintain. Standard sluice gate nomenclature is provided on Plate 62-6.

6-1604.10D An uncontrolled or rapid drawdown could induce problems such as slides in the saturated up-stream slope of the dam embankment or shoreline area. Therefore, the design of a pond drain system shall include operating instructions regarding draining the impoundment. Generally, drawdown rates shall not exceed 6 inches per day. For dam embankments or shoreline slopes of clay or silt, drawdown rates as slow as 1 foot per week may be required to ensure slope stability.

6-1604.11 Concrete Low Flow Channels (Trickle Ditches)

6-1604.11A When the pond storage area is left in a natural condition and in a conservation easement granted to the Board of Supervisors or Fairfax County Park Authority, a trickle ditch will be provided from the outlet riser to the limits of clearing and grading. This ditch shall be a minimum of 20 feet in length and transition from the outlet riser to the natural channel. A concrete or riprap approach shall be installed to direct the flow into the trickle ditch from the natural channel.

6-1604.11B Adequate drainage features shall be provided to enable excavated dry or extended dry pond bottoms to be readily maintained by heavy equipment. Springs or seeps shall be controlled and outfall to the drainage channel. A trickle ditch will normally be installed from a principal inlet to the outlet riser. A concrete or riprap approach shall be installed to direct the flow into the trickle ditch from the principal inlet. Special considerations with pond design should be given for unusual conditions such as extreme length of graded channel, or highly erosive or unstable soils.

6-1604.11C All trickle ditches shall conform to the design set forth in Plate 63-6. The design hydraulic capacity of the ditches shall be the greater of the low flow orifice or that of the minimum size ditch shown in Plate 63-6.

6-1605 Geotechnical Design Guidelines for Stormwater Management Reservoirs with Earthdams (107-11-PFM)

6-1605.1 Introduction

6-1605.1A Purpose and Scope. The purpose of these geotechnical guidelines is to provide minimum recommended procedures for exploration and minimum requirements for planning and designing stormwater management reservoirs with earthdams. The guidelines are intended to provide the basis for geotechnical design of these facilities. The designer is responsible for determining those aspects of the guidelines that are applicable to the specific facility being designed in addition to satisfying the minimum requirements as provided under § 6-1605 *et seq*. These guidelines are not intended for use in designing concrete or roller-compacted concrete dams.

6-1605.1B Facility Type. Three general types of facilities are acceptable: dry detention reservoirs, extended dry detention reservoirs and reservoirs with permanent pools. Plate 64-6 shows the minimum level of the geotechnical design guidelines associated with each type of facility.

6-1605.1C Dam Types. These guidelines are for design of earthfill embankment dams. Typically, these dams are designed as homogeneous dams with or without internal drainage. Zoned dams may be designed if the quality of the borrow material requires this approach. Typical embankment dam cross-sections are shown on Plates 65-6 and 66-6.

6-1605.2 Geotechnical Engineering Design Study

6-1605.2A Submission Requirements. Submission of geotechnical reports to DPWES are required for all reservoirs with permanent pools and for dry and extended dry detention reservoirs in Categories B and C as defined in Plate 64-6. This requirement may be waived by the Director provided the geotechnical aspects of the design are adequately addressed on the grading plans or construction plans.

6-1605.2B Geotechnical Engineer Qualifications. Geotechnical studies shall be performed under the direction of a qualified geotechnical engineer licensed as a Professional Engineer in the commonwealth of Virginia. The geotechnical engineer must have experience in the design and construction monitoring of dams of the size and scope covered by these guidelines.

6-1605.2C Study Content. The Geotechnical Engineering Design Study shall consist of: 1) field investigation; 2) laboratory testing; and 3) geotechnical engineering analysis. The study must provide the designer with adequate recommendations for the design of the dam, reservoir and appropriate structure.

6-1605.2C(1) (107-11-PFM) Field Investigation. The field investigation program shall be performed to explore the subsurface conditions for the proposed embankment dam, reservoir and

borrow area. The field investigation program must include: 1) review of available data; 2) field reconnaissance; and 3) subsurface exploration. Existing information such as topographic and geologic data should be reviewed. References such as soil maps, the soil properties available from the USDA-NRCS website, and any other sources of information should be reviewed. This review of available data should be followed by a field reconnaissance of the site of the dam and reservoir. The subsurface exploration program, consisting of test borings, test pits, or both, should be developed based on the complexity of the geologic and topographic features disclosed by the previous phases. Except when adequate measures are taken to restore the natural condition of excavations, test pits shall be in areas outside the alignment of the dam. At a minimum, three test borings shall be located along the dam alignment (centerline) and along the principal spillway profile at intervals not to exceed 100 feet. Additional borings shall be required at each major structure. Borings also shall be required throughout the ponding area at a density of at least one per acre (evenly distributed) with a minimum of two borings for ponding areas less than 2 acres. The ponding area shall be defined as that area inundated by the 2-year water surface elevation. The depth of borings shall extend to competent material or to a depth equal to the lesser of either the embankment height or the foundation width. The use of geophysical techniques, where applicable, is encouraged. The subsurface exploration program shall be designed and implemented to evaluate the foundations, abutments, reservoir area and embankment design and any other pertinent geological considerations. *In situ* testing, such as permeability tests, undisturbed sampling and installation of piezometers may be required depending upon the site conditions and anticipated designs.

6-1605.2C(2) Laboratory Testing. Laboratory tests to characterize the various borrow materials and foundation soils are required. At a minimum, an index property test shall be performed to properly classify soils in accordance with the Unified Soil Classification System. Shear strength, compressibility, and permeability testing may be required depending upon the size and complexity of the dam and the nature of the site subsurface conditions.

6-1605.2C(3) Geotechnical Engineering Study. After completion of the field investigation, associated testing and analysis, a report shall be prepared by the geotechnical engineer to present findings, recommendations and comments on items outlined in the design guidelines given in § 6-1605.2C(3) through § 6-1605.6. At a minimum, the report shall include:

6-1605.2C(3)(a) A site location map

6-1605.2C(3)(b) A boring/test pit location map

6-1605.2C(3)(c) A description of the site

6-1605.2C(3)(d) A description of the proposed dam

6-1605.2C(3)(e) Soil and rock strata descriptions to include boring/test pit logs and subsurface profiles

6-1605.2C(3)(f) Geologic characterization of soils and bedrock

6-1605.2C(3)(g) Summarization and discussion of laboratory test results

6-1605.2C(3)(h) Geotechnical engineering analysis and recommendations, including foundation preparation/treatment, design of interior drainage features and filters, geotechnical design of conduits/structures through embankment, embankment design including seepage and stability analysis, and important construction considerations

6-1605.2C(3)(i) A description of the subsurface exploration procedures utilized

6-1605.2C(3)(j) A description of laboratory test procedures utilized

6-1605.2C(3)(k) A description of any computer-aided stability analyses utilized

6-1605.2D This report shall be submitted with required construction plans to DPWES for review and approval. The recommendations in the approved report shall be incorporated into the construction plans as requirements to be fulfilled during construction. In addition, the geotechnical engineer shall review all applicable construction plans and provide a statement on the plans that the plans have been prepared in accordance with his recommendations.

6-1605.2E Special Cases:

6-1605.2E(1) Rehabilitation of Existing Dams and Retrofitting Existing Highway Embankments for Use as Dams. The following measures shall be taken when rehabilitating existing dams or when retrofitting existing highway embankments for use as dams for both wet and dry stormwater management facilities:

6-1605.2E(1)(a) A study shall be performed to thoroughly investigate the soils within the existing embankment, and, in the case of existing highway embankments, evaluate potential seepage through the bedding material of existing utilities in the embankment.

6-1605.2E(1)(b) A field investigation which should disclose such items as pervious layers which will allow excessive seepage and piping, inadequate clearing, grubbing and stripping of subgrade, highly variable compaction of materials and animal burrows.

6-1605.2E(1)(c) Sufficient laboratory and *in situ* testing should be performed to characterize the soils.

6-1605.2E(1)(d) Based upon the investigation and analysis, a report shall be prepared by the geotechnical engineer and submitted to the design engineer and DPWES along with construction plan submittal, presenting design recommendations as described in § 6-1605.2 *et seq*.

6-1605.2E(2) Raising Height of Existing Dam. A study must be performed to thoroughly investigate the soils of the existing embankment. Sufficient laboratory and *in situ* testing shall be performed to characterize the soils. Based upon the evaluation and required analysis, recommendations should be prepared to specify material and compaction requirements, acceptable slope, and benching when the method of addition of material to the downstream or upstream slopes is used. The evaluation shall include the consideration of the effect of additional surcharge loads imposed by the added materials, and the effect on any existing utility lines within the embankment. If a flood wall is proposed, the design should include maximum allowable bearing pressures, estimated settlement, footing cover, and lateral earth pressures for use in design. Based upon the investigation and analysis, a report shall be prepared by the geotechnical engineer and submitted to the design engineer and DPWES along with construction plan submittal, as described in § 6-1605.2

6-1605.3 Embankment Dam Foundations

6-1605.3A Clearing, Grubbing and Stripping. Clearing consists of the removal of all unwanted materials from the foundation area which may create any obstruction or other undesirable design or construction situation. Materials such as trees, bushes, fallen trees, boulders, rubble, garbage, buildings and similar debris must be removed from the foundation area. Grubbing is the removal of all unwanted materials which lie below the ground surface in the foundation area including stumps, roots, drain fields, abandoned utility lines, foundations, and other materials or buried structures. Stripping is the removal of topsoil, organic matter, excessively soft soil and any other deleterious materials. The limits of clearing, grubbing and stripping in the dam foundation and abutment area shall extend at least 10 feet beyond the toe of the slope of the dam embankment. Excavations in the dam foundation area shall be properly backfilled with embankment material as defined in § 6-1605.6A through § 6-1605.6F. The clearing limits for overland emergency spillways shall extend at least 10 feet beyond the top of the cut slope. Clearing limits for maintenance access roads shall extend at least 5 feet beyond the edge of pavement. Clearing in excess of the minimum limits outlined above is permitted when necessary; however, designers are encouraged to maintain the minimum clearing limits to the extent practical.

6-1605.3B Stream Diversion. The design of most dams should include the provision for streamflow diversion around or through the dam site during the construction period. Streamflow diversion can be accomplished by numerous acceptable means, including open channels, conduits, cofferdams and pumping. In most cases, stream diversion is accomplished in two phases. The first phase usually involves diversion of the stream into a man-made open channel which will convey drainage around the majority of the dam site. The second phase usually involves redirection of flow from the man-made diversion channel into a low flow conduit passing through the dam. At a minimum, the capacity of the diversion system shall be adequate to safely pass a 2-year recurrence flood. Designers are encouraged to increase capacity if it is likely that serious or costly damage may result if the capacity of the diversion system is exceeded. The diversion system shall be protected against erosion during the 2-year design storm through the use of appropriate channel linings, riprap drop structures or other suitable measures.

6-1605.3C Foundation Design (Treatment). The dam foundation includes the entire stream valley and abutments covered by the embankment. The objectives of foundation surface treatment are 1) embankment foundation bonding, 2) preventing piping of embankment material, 3) mitigating adverse impacts resulting from the presence of unsuitable foundation materials, and 4) preventing embankment cracking.

6-1605.3C(1) Foundation Suitability. The suitability of the foundation for support of the embankment is determined by the ability of the foundation to support the embankment (1) without detrimental settlement and associated embankment cracking, and (2) without excessive seepage which could cause excess loss of reservoir water or, in severe cases, piping and embankment failure. The suitability of the soils to support the embankment loading and control seepage should be determined during the geotechnical engineering design study and included in the report described in § 6-1605.2A through § 6-1605.2D.

6-1605.3C(1)(a) Compressibility. Soils which are highly compressible and which will cause excessive total and differential settlement, such as soft organic soils, should be undercut prior to embankment construction. Soils to be undercut must be identified and defined in the geotechnical engineering design study and the actual extent of undercut must be verified in the field by the geotechnical engineer during construction.

6-1605.3C(1)(b) Seepage. To determine how to control foundation seepage, both soil and rock properties should be considered depending upon the geology of the site and the hydraulic head. Within a zoned or a homogeneous embankment dam, a cutoff trench to rock or to an impervious soil stratum is usually employed to control seepage through the foundation. Partially penetrating cutoff trenches should not be used solely for the purpose of reducing seepage. Such trenches may, however, be employed for stability purposes. Alternative seepage control measures such as upstream synthetic membranes, a central diaphragm such as a soil bentonite or cement bentonite slurry wall, or an upstream impervious blanket, may also be used for seepage control, as described in § 6-1605.6.

6-1605.3C(2) Cutoff Trench. The width (w) of the cutoff trench should be equal to the height of the reservoir (h), less the depth below the ground surface to the impervious soil or rock Stratum (d) or W=h-d, with a minimum width of 8 feet. In order to obtain adequate compaction against the sides of a cutoff trench, the trench shall have sloping sides as described in § 6-1605.3C(3) and § 6-1605.3C(4).

6-1605.3C(3) Rock Foundations. Rock foundations require special treatment to provide a proper bond between the foundation and the embankment material as described below.

6-1605.3C(3)(a) Slopes. Rock slopes should not be greater than 0.5H:1V. All overhangs must be removed. Within the core zone or cutoff trench, slopes steeper than 0.5H:1V shall be excavated or treated with dental concrete if they are greater than 1 foot high. In other foundation areas, the height of slopes steeper than 0.5H:1V should not exceed 5 feet.

6-1605.3C(3)(b) Blasting. Generally, no blasting shall be permitted within 100 feet of the dam foundation and abutment area. If blasting must be performed, it shall be carried out under controlled conditions to reduce adverse effects on the rock foundation, such as overblasting and opening fractures. Blasting should be performed by a specialty contractor experienced in blasting techniques. Blasting procedures shall be submitted to the geotechnical engineer for review prior to use.

6-1605.3C(3)(c) Surface Cleaning. Within the cutoff trench area, the surface of the rock must be cleaned of all objectionable material by hand work, brooming, or by air or water jetting. Loose or unsuitable material must be removed from all cracks, seams or shear zones to a depth of three times the width of the feature up to 5 feet in depth, and as determined in the field in the case of wider features.

6-1605.3C(3)(d) Dental Concrete. Cracks which have been cleaned, areas into which it would be difficult to compact soil, and other uneven features such as overhangs and steep slopes, must be filled with dental concrete. Dental concrete shall have mix proportions to ensure a 28-day strength of at least 3,000 psi. The rock surface should be thoroughly cleaned and moistened prior to placement of dental concrete to ensure a proper bond. The surface of the dental concrete should be broom finished to assure proper bond with the overlying soil. A minimum curing time of 24 hours under curing conditions approved by the designer must be provided prior to placement of soil fill material.

6-1605.3C(3)(e) Slush Grouting. Slush grout consisting of “neat” cement and water, or cement, sand and water, should be used to fill small cracks. The maximum aggregate size should not exceed 1/3 the crack width. Grout shall be used within 30 minutes of mixing.

6-1605.3C(3)(f) Grout Curtain. Grouting of foundation rock may be required depending upon the site geology, fracture condition of the rock and the reservoir head conditions. Generally, the grout curtain should extend to a depth below the foundation and abutment level equal to the reservoir head above the location. Laterally, the curtain should extend at least to the end of the abutments. If grouting is required, a minimum double line grout curtain should be used. Primary grout hole spacing of 25 feet to 40 feet is typical with staggered hole locations between the two grout hole lines. The spacing between lines is typically 10 feet. Secondary grout holes should split the spacing between primary holes. The need for tertiary holes will depend upon the grout take from the secondary holes. Grout pressures will depend upon site conditions. Generally, grout pressures should not exceed 1 psi per foot of depth below the surface. A concrete grout cap should be employed if numerous fractures intersect the surface of the rock. Grout hole spacing and depth, grout mix design and consistency and grout pressures should be in accordance with current grouting practice design.

6-1605.3C(3)(g) Filters. The downstream surface of the cutoff trench shall be evaluated for the potential of piping of embankment material into the foundation soil or rock. Filters should be designed in accordance with the criteria included in § 6-1605.4.

6-1605.3C(3)(h) Earth Fill Placement. Earth fill placed within the cutoff trench and the remainder of the embankment must be placed and compacted according to the criteria included in § 6-1605.6F.

6-1605.3C(4) Soil Foundations. The following special conditions are applicable to the preparation of soil foundations to receive embankment materials.

6-1605.3C(4)(a) Excavation and Shaping. Surface irregularities should be removed to provide satisfactory foundation contours. Slopes should be sufficiently flat to prevent sloughing, but in no case greater than 1H:1V. Disturbed materials must be removed to a depth of at least 6 inches.

6-1605.3C(4)(b) Subgrade Preparation. The subgrade must be compacted to a depth of at least 6 inches to the required density standard as defined in § 6-1605.6 of these Design Standards. Fine-grained subgrades should be scarified to a depth of at least 6 inches prior to compacting. Coarse-grained subgrades generally should not be scarified. Proofrolling is usually performed to locate soft unsuitable surficial soils; however, proofrolling may not be feasible if soils are too soft for heavy equipment, or if a firm layer exists over a soft layer in which case proofrolling could cause deterioration of the subgrade.

6-1605.3C(4)(c) Foundation Dewatering. The foundation shall be dewatered to ensure that the surficial 6 inches of the subgrade to be compacted is not saturated and pumping of the subgrade does not occur under the weight of compaction equipment. Pumping from sumps, well points, or deep wells may be required for excavation of the cutoff trench.

6-1605.4 Embankment and Foundation Seepage Control. The control of seepage through its embankment is required for all dams. Leakage through a reasonably well-constructed embankment occurs from: 1) cracks due to shrinkage; 2) cracks due to differential settlement; and 3) cracks due to hydraulic fracturing in zones of reduced stress. Filters are effective in controlling erosion resulting from seepage. Seepage may be controlled with: 1) a downstream toe drain; 2) a downstream drainage blanket; or 3) a chimney drain along the downstream side of the core of a zoned embankment dam or within a homogeneous earth fill dam. Appropriately designed filters must be provided between the drainage materials and the soil foundation or embankment. An area of special concern is the control of seepage along conduits or structures penetrating the embankment. Cutoff collars or other protruding features should not be used solely for seepage control. Seepage along the conduit or structure through the embankment foundation and/or "impervious" zone should be controlled by the use of properly designed filters and drainage features in the downstream portion of the embankment.

6-1605.4A Filter, Drainage Layer and Toe Drain Design. Filters should be designed to prevent migration of fines from the foundation or embankment soils into the drainage layer. The filter should be designed for stabilizing migration of the soil into the filter as follows:

SOIL TYPE	FILTER CRITERIA
SILTS & CLAYS (> 85% Passing No. 200 sieve)	$D_{15F} / D_{85B} = < 9$
SANDY SILTS AND CLAYS SILTY AND CLAYEY SANDS (40 to 85% Passing No. 200 sieve)	$D_{15F} < 0.7$mm
SANDS AND SANDY GRAVELS (0 to 40% Passing No. 200 sieve)	$D_{15F} / D_{85B} = < 4$

6-1605.4A(1) (57-96-PFM) The filter should be designed for adequate permeability to drain the soil as follows: D_{15F}/D_{85B} less than or equal to 5

6-1605.4A(2) D_{15F} is the size of the filter material for which 15 percent is finer and D_{85B} is the size of the base material being drained for which 85 percent is finer.

6-1605.4A(3) The percentages of base material passing the No. 200 sieve pertains to the fraction excluding material retained on the No. 4 sieve. The drainage layer and toe drain piping system should be sufficiently porous and sized to accommodate the anticipated flow of water into the drainage system. The minimum design requirements for embankment and foundation seepage control design are set forth on Plate 64-6.

6-1605.4B Geosynthetics. Nonwoven geosynthetic fabrics and drainage nets with nonwoven geosynthetic fabric facings (geonets) may be used in place of sand filters to control seepage through earthfill embankments under restricted conditions. Restrictions are required due to the lack of data concerning the effectiveness of these products to transmit seepage without clogging over extended periods of time under steady seepage conditions.

6-1605.4B(1) Geosynthetic Fabrics and Geonets. These materials should not be used as filters under steady seepage conditions with greater than 6 feet of head. This applies to horizontal drainage blankets or drainage blankets surrounding the downstream portion of the principal spillway pipe, or as filters between the “impervious” fill of a cutoff trench and the downstream face of the cutoff trench. They may be used as filters surrounding drainage materials in downstream trench-type toe drains. They may also be used as filters under nonsteady seepage conditions, such as for dry and extended dry detention reservoirs.

6-1605.4B(2) Geosynthetic Design. The design should consider permeability and pore size in selecting geosynthetics for use as filters. Non-woven and woven geosynthetic fabrics may also be used for erosion control in place of graded filters beneath riprap on grout type mattresses. The design should consider permeability, pore size and hydraulic gradient in selecting a geosynthetic. Design procedures published by any federal agency (e.g., COE, NRCS) as well as those

recommended by the manufacturer of the geosynthetic are generally acceptable. Geosynthetics may be used for material separation.

6-1605.5 Design of Conduits/Structures through Embankments. Because the contact between the soil embankment, the foundation material and the embankment penetrating conduits is the most susceptible location for piping, special attention must be given to the design of any conduit penetrating a dam embankment. The number of these conduits shall be minimized, and whenever possible, utility conduits other than the principal spillway should be located outside of the dam embankment. All conduits penetrating dam embankments shall be designed in accordance with the following criteria:

6-1605.5A Conduit/Structure. Conduits and structures penetrating the embankment should have a reasonably smooth surface and should not have protrusions or indentations that will hinder compaction of embankment materials.

6-1605.5A(1) Shape. Cast-in-place conduits should be formed such that the side surfaces slope at 1H:10V to facilitate compaction of soil against the conduit in the impervious zone and the embankment upstream of the drainage blanket. Within the drainage blanket, vertical surfaces are acceptable. Where pipe is to be used as a conduit, a concrete cradle shall be provided such that the resulting surface of the conduit has a slope of 1H:10V up to the level of the spring line of the pipe. A standard concrete cradle detail is provided in Plate 67-6. Cradles on yielding foundations should be articulated. Cradle requirements depend upon dam classification as noted in Plate 64-6. The length of the cradle generally shall extend from the riser structure to the beginning of the seepage collection zone. Other structures penetrating the embankment, such as cast-in-place concrete sections of the dam, should also have battered side surfaces of 1H:10V upstream of the drainage layer.

6-1605.5A(2) Pipe. Principal spillway pipe shall be reinforced concrete pipe meeting the specifications of § 6-1607.1B(4). The minimum allowable pipe diameter shall be 18 inches.

6-1605.5A(3) Pipe Joints. Pipe joints shall be designed to remain watertight during the life of the structure under maximum anticipated hydrostatic head and maximum likely joint opening related to foundation settlement. Round rubber gaskets set in a groove are required for all precast concrete pipe conduits.

6-1605.5A(4) Rock Foundation Preparation. The surface of rock for support of the conduit/structure should be prepared as stated in § 6-1605.3C.

6-1605.5A(5) Backfill Below Rock Surface. Cast-in-place conduits/structures and pipes founded below the rock surface in trenches upstream of the drainage blanket should be backfilled with dental concrete to the surface of the rock as set forth in § 6-1605.3C. Alternatively, the structure may be cast against the surface of the rock within this zone. Nonstructural concrete backfill or casting the conduit/structure against the surface of the rock may also be used throughout the embankment section upstream of the drainage zone. When a pipe is used as a conduit, a concrete

cradle shall be provided. The cradle should be cast surrounding the pipe to the level of the spring line of the pipe. The cradle may be cast against the rock surface. Soil backfill as stated in § 6-1605.6F, may be used above the rock surface for all types of structures.

6-1605.5A(6) Soil Foundation Preparation. The soil subgrade for support of the conduit/structure should be prepared as set forth in § 6-1605.3C.

6-1605.5A(7) General Earthfill Requirements. Earthfill adjacent to conduits/structures should be placed so that lifts are at the same level on both sides of the conduit. In order to improve the quality of compaction adjacent to the conduit/structure, fill may be ramped away from the conduit/structure on a 6H:1V slope. Compaction equipment must be approved by the geotechnical engineer. Material quality, moisture content, lift thickness and compacted density should be the same as required for other similar portions of the embankment or impervious zone. Use of hand compaction is not recommended. When hand-type equipment is used, the maximum lift thickness shall not exceed 4 inches. General criteria for backfill soils are included in § 6-1605.6F.

6-1605.5B Seepage Control Along Embankment Conduits/Structures. The contact between the soil embankment and foundation material and conduits/structures which penetrate an embankment are the most likely locations for piping. This is due to the discontinuity formed by the contact and the difficulty in compacting soil in this zone. Collection and control of this seepage by filters and a drainage system is required. The seepage control system or drainage blanket provided for the conduit/structure should be contiguous with the drainage blanket placed within the embankment; otherwise a separate drainage system should be provided.

6-1605.5B(1) Drainage Blanket. The drainage blanket should completely surround the conduit/structure if supported on soil, or should extend above the rock surface of the conduit/structure cradle/foundation if supported on rock. In the case of a homogeneous dam, the drainage system should extend from the downstream toe to the downstream point one-third of the distance of the base width. In the case of a zoned dam, the drainage system should extend from the downstream side of the core to the downstream toe of the dam. If a drainage blanket is used, the conduit/structure filter should extend to the upstream edge of the blanket, or at a minimum, to the downstream point one-third the distance of the base width of the dam. The filter and drainage blanket should be designed in accordance with the criteria in § 6-1605.4A through § 6-1605.4B. The requirements to determine for the necessity of drainage blankets adjacent to conduits/structures are stated in Plate 64-6.

6-1605.6 Dam Embankment Design

6-1605.6A Geometry. Dam embankments typically are dams constructed as homogeneous (with or without internal drainage), zoned or diaphragm-type structures. Homogeneous dams without internal drainage are not permitted for reservoirs with permanent pools if the phreatic surface will intersect the downstream surface of the dam. Homogeneous dams without internal drainage may be permitted for reservoirs with permanent pools if justified by an approved seepage analysis. However, for dry detention or extended dry detention (BMP) reservoirs where a saturated

condition does not exist, a homogeneous dam without internal drainage may be appropriate. Thin diaphragms, such as soil bentonite slurry walls, may also be used within homogeneous sections to control seepage.

6-1605.6A(1) Height. The height of a dam embankment shall be based upon the freeboard (see § 6-1603), wave action and compensation for settlement, and the design capacity of the pond.

6-1605.6A(2) Crest. The crest of a dam embankment should be designed with the following considerations:

6-1605.6A(2)(a) Width. The minimum top width may be determined by the following equation, but shall not be less than 12 feet:

$$W = (H + 35) / 5$$

Where:
W = width of crest (ft.)
H = height of dam above downstream toe at stream bed (ft.)

6-1605.6A(2)(b) Drainage. Surface drainage should be provided by either crowning or sloping towards the upstream slope. The minimum slope is 2 percent.

6-1605.6A(2)(c) Camber. Camber is provided to maintain the height of the dam lost due to compression of the foundation soils or soils within the embankment. Camber will be based on the estimated total compression and will vary from the abutments to the center.

6-1605.6A(2)(d) Surfacing. A grass surface is permitted unless frequent vehicular traffic or foot travel is expected, in which case a gravel or bituminous surface shall be required to prevent erosion.

6-1605.6A(2)(e) Safety Requirements. Crests that are used for roadways within the state right-of-way shall be provided with guard rails or other safety devices in accordance with VDOT standards.

6-1605.6A(3) Nonlinear. Dam embankments should be linear. If a nonlinear section is proposed, the shape should be limited to concave upstream geometry.

6-1605.6B Zoning. Zoning, if required, should consist of impervious materials on the upstream side and pervious materials on the downstream side. If impervious material is scarce, then an impervious core or a thick blanket of impervious material on the upstream embankment face may be considered.

6-1605.6B(1) Impervious Core Thickness. The impervious core thickness design shall take into account tolerable seepage loss, minimum width which will permit proper construction, type of

material available for core and shells, and the design of proposed filters. Suggested minimum and maximum core sizes are set forth in Plate 68-6. The core sizes given in Plate 68-6 are suggested and other core thickness may be considered. However, dams with cores smaller than minimum Core Size A should be designed as a diaphragm-type and cores larger than Core B should be designed as homogeneous. Recommendations for the core should include material type, compaction, filter requirements, width, height and side slopes.

6-1605.6C Stability Analysis. The design of slopes for dam embankments depends on the materials used for construction, foundation conditions, height of the embankment, pool level and whether the embankment is for permanent storage (wet ponds) or detention (dry or extended dry detention ponds).

6-1605.6C(1) Slope Design by Material Type. Plate 69-6 states the maximum upstream and downstream slopes for dam embankments with various soil types in cases when detailed seepage and stability analyses are not required. The slopes in these tables are for stable foundations. If complicated foundation conditions exist or only poor quality construction materials are available, then a detailed stability analysis should be performed.

6-1605.6C(2) Stability Analysis. When required in accordance with Plate 64-6, slope stability analyses should be based on the criteria specified in NRCS TR-60. These analyses require determination of shear strength parameters developed for site specific conditions and materials to be used in construction of the dam. The County is located in seismic zone 2, and as such, dams must be designed for a seismic coefficient of 0.05. The factor of safety for the various conditions is calculated based on the factor of the shear strength available to the shear strength mobilized. Clear documentation of assumptions, conditions analyzed and not analyzed, and correlated shear strength parameters is required. Calculations must be submitted with the design to DPWES.

6-1605.6C(3) Raising Height of Existing Dam. Raising the height of an embankment dam may be performed by adding material to the upstream slope, downstream slope or both. Raising the height by adding material to the slopes should be constructed as an integral part of the existing embankment. Recommendations for material type, moisture content, compaction requirements and side slopes should be provided. Embankment slopes should be determined by seepage and stability analyses or be based upon material type depending upon the reservoir classification in Plate 64-6.

6-1605.6D Upstream Blankets. An upstream soil blanket consisting of material similar to the homogeneous dam may be used to reduce seepage through a pervious foundation if the material is sufficiently impervious. The thickness of the blanket will be influenced by acceptable seepage loss, permeability of blanket and foundation dam material, reservoir head, unsaturated or saturated foundation, and constructability. Blankets must be no less than 1.5-feet thick. An impervious upstream soil blanket may also be used for a homogeneous dam constructed of more pervious soils or with a zoned embankment. The thickness, material, and compaction requirements for soil blankets should be specified and migration of fines into the foundation must be evaluated. Where filters are required, they should be designed in accordance with § 6-1605.4A

through § 6-1605.4B. For synthetic liners, material type, subgrade preparation, bedding, seam preparation and overlap should be specified.

6-1605.6E Cutoff Trench. The cutoff trench shall be backfilled with relatively impervious material for homogeneous dams or the impervious core material for a zoned dam. Recommendations for backfill of the cutoff trench shall include soil type, moisture content and compaction requirements.

6-1605.6F Compacted Fill Requirements

6-1605.6F(1) Soil Type. The soil type shall be specified by use of the Unified Soil Classification System. Rock fill types shall be specified by maximum or minimum percent passing various sieve sizes and durability to resist deterioration from slaking or weathering.

6-1605.6F(2) Compaction. Compaction requirements should be specified. The requirements should include the percent of maximum dry density for the specified density standard, allowable range of moisture content, and maximum loose lift thickness. Dam embankment compaction to 95 percent of the maximum dry density in accordance with ASTM D-698 or AASHTO T-99 is considered a minimum standard. The allowable moisture content for compaction will vary depending on material type. Generally, the moisture content specified shall take into consideration the permeability of embankment material, the potential for expansion, shrinkage, and cracking, and shall permit uniform compaction to the project specification without any yielding of the fill surface. Fill must be placed in layers with a maximum thickness which will allow uniform density throughout the compacted layer. For materials with more than 5 percent passing the 200 sieve, the maximum loose thickness should generally be between 6 inches and 8 inches. Thicker loose lifts may be specified, but in no case shall the loose lift thickness exceed 12 inches. Lift thickness for open-graded stone or gravel may vary from 12 inches to 24 inches, with 12 inches being the minimum for hand equipment and 24 inches being the maximum for large vibrating rollers. Any layer of fine grained fill which becomes smooth under compaction or construction traffic should be scarified to a depth of 2 inches to allow adequate bond between layers. Initial lifts for the cutoff trench on rock foundations must be placed and compacted by methods that will assure adequate compaction without damaging the rock surface. This can be accomplished by making the initial lift thickness 150 percent of the specified normal lift thickness and then stripping the upper 50 percent after initial compaction and recompacting the lower portion to specification.

6-1606 Maintenance and Safety Design Requirements

6-1606.1 Safety Considerations. The following design considerations address safety concerns related to dams and impoundments. Principal safety concerns involve child access to various components of the stormwater management facility; therefore, design features should discourage child access. Safety features should also be consistent with the requirements of § 6-0303.

6-1606.1A Trash racks and other debris control structures shall be sized to prevent entry by children. Bar spacing on any debris control structure shall be no greater than 12 inches in any direction, with the preferred spacing being 6 inches.

6-1606.1B Fencing or other barriers shall be required around spillway structures having open or accessible drops in excess of 3 feet.

6-1606.1C Embankment and pond slopes generally should be no steeper than 3H:1V. For dam embankments exceeding 15 feet in height, a 6-feet to 10-feet wide bench should be provided at intervals of 10-feet to 15-feet in height, particularly if slopes are steeper than 3H:1V. Slopes steeper than 2.5H:1V shall not be permitted without approval by the Director.

6-1606.1D Shorelines along wet ponds in areas accessible to the public should incorporate a shallow bench 1- to 2-feet deep extending 5 feet to 10 feet from the shoreline.

6-1606.1E Safety signs shall be placed in areas near wet ponds and spillway structures.

6-1606.2 Maintenance Considerations. All dams shall be designed with the maintenance design considerations stated in § 6-1306. In addition, the following maintenance provisions shall also be considered in designing the dam.

6-1606.2A Sediment forebays should be considered at most stormwater management facilities having permanent pools (i.e., retention ponds). Sediment forebays should be located near major pond inflow locations and should have sufficient storage and depth to trap projected sediment over a 10- to 20-year period. On-site sediment disposal areas (decanting basins) should be considered near wet ponds to reduce or eliminate hauling and dumping costs to off-site disposal areas. Maintenance access shall be provided, including access to the sediment forebay. The maintenance access shall be stabilized to provide passage of heavy equipment.

6-1606.2B Low level drains, generally sluice gates, should be designed with rising stems, particularly when the stem is located in the reservoir area. Nonrising stems are not acceptable except in instances where the stem is easily accessible for frequent maintenance (cleaning and greasing).

6-1606.2C Internal drainage systems in dam embankments (e.g., drainage blankets, toe drains) should be designed such that the collection conduits (e.g., perforated PVC pipe) discharge

downstream of the dam at a location where access for observation is possible by maintenance personnel.

6-1606.2D Adequate erosion protection is required along the contact between the face of the embankment and the abutments. Runoff from rainfall concentrates in these areas and can reach erosive velocities depending on the gutter slope and dam height. Although a sod gutter will be satisfactory for most small dams, an evaluation should be made at each dam to determine if some type of gutter protection other than sod is required. For most dams, a riprap gutter is preferred rather than a paved concrete gutter.

6-1606.2E For permanent impoundments (wet ponds), the upstream face of a dam may be protected against wave erosion by placement of a layer of riprap over a layer of filter material. Riprap not smaller than VDOT Standard Class II is required for this purpose. Vegetative protection will usually be sufficient on the upstream face of smaller impoundments if the effective reservoir fetch is less than 500 feet and the dam embankment soils are not highly erosive.

6-1606.2F Trees, shrubs, or any other woody plants shall not be planted on the dam embankment or adjacent areas extending at least 10 feet beyond the embankment toe and abutment contacts.

6-1606.2G (76-02-PFM) Access shall be provided to all areas of an impoundment requiring observation or regular maintenance. These areas include the dam embankment, emergency spillway, lake shoreline, principal spillway outlet, stilling basin, toe drain, riser structure, extended drawdown device, and likely sediment accumulation areas. The schematic pond layouts shown in Plates 49-6, 50-6, 56-6 and 57-6 show typical maintenance access road locations. An access road detail is provided in Plate 70-6. A 20-foot cleared access easement shall be provided from the access entrance along the downstream side of the embankment toe to the outlet channel. Unauthorized vehicular access shall be controlled with a standard access road gate (see Plates 71-6 and 71A-6). The Director may allow the use of a cable barricade (see Plate 10-8) in lieu of a standards access road gate for ponds that control a watershed of less than 100 acres and where the cable barricade would be more compatible with the proposed development and would be sufficient to restrict unauthorized vehicular access to the pond.

6-1607 Minimum Required Construction Standards, Specifications and Inspection Requirements

6-1607.1 Construction Specifications for Category "D" Dams (see Plate 64-6). The minimum required construction specifications outlined below are intended for Category D dams, except where specific reference is made to Category A, B, and C dams. These specifications should be considered as minimum requirements with the understanding that more stringent specifications may be required dependent on individual site conditions as evaluated by the project geotechnical engineer and/or DPWES. Therefore, in all cases final construction specifications tailored to each individual project shall be included on the construction plans submitted to DPWES. In general, any construction items not addressed in the final dam construction specifications should adhere to VDOT standards and specifications. In all cases, the final dam construction specifications shall take precedence over VDOT specifications.

6-1607.1A Foundation and Abutment Preparation

6-1607.1A(1) Extent. The foundation and abutment area is defined to extend to a distance of 10 feet beyond all limits of the planned facilities.

6-1607.1A(2) Clearing, Grubbing and Stripping. The foundation and abutment area shall be cleared, grubbed and stripped of all vegetation, topsoil and/or organic soil and "any other unsuitable materials," as specified by the construction plans. "Other unsuitable materials" should be defined in the specification by the designer along with the estimated minimum depth of undercut where possible.

6-1607.1A(3) Control of Surface and Groundwater. The landowner and his contractor shall be responsible for removal and control of any surface water and groundwater which would adversely affect construction.

6-1607.1A(4) Subgrade Preparation and Approval. After clearing, grubbing, stripping and removing any other unsuitable materials, the subgrade shall be proofrolled with compaction equipment under the observation of a qualified engineer. The compaction equipment should be the heaviest possible equipment that will not cause disturbance of suitable subgrade soils. If, in the opinion of the Director or the engineer, excessively soft or unsuitable materials are disclosed, these unsuitable materials shall be removed and replaced with compacted fill. Where rock is exposed after stripping or undercutting, all loose rock material shall be removed prior to placing compacted fill. Rock subgrades shall be inspected and approved by the inspector or engineer prior to placement of fill.

6-1607.1B Conduits/Structures

6-1607.1B(1) Subgrade. After excavation for the planned conduit/structure, the subgrade should be inspected and approved by the engineer. Any soft or unsuitable soils shall be removed and replaced with compacted fill meeting the requirements in § 6-1607.1C.

6-1607.1B(2) Pipe Bedding (57-96-PFM). After approval of the subgrade, a concrete cradle shall be provided below the pipe for the distance specified on the construction plans (see Plate 64-6 for minimum requirements). The remaining downstream one-third of the pipe shall be bedded in accordance with Plate 18-10 or 19-10. The cradle and bedding should be placed to the spring line of the conduit.

6-1607.1B(3) Backfill. Backfill shall meet the same requirements set forth in § 6-1607.1C.

6-1607.1B(4) Pipe. Principal spillway pipe shall be reinforced concrete pipe which meets the following specifications:

6-1607.1B(4)(a) (68-00-PFM). For dams having permanent pools (wet ponds), reinforced concrete pressure pipe shall be used which meets AWWA specifications C300, C301, C302 or ASTM specification C361.

6-1607.1B(4)(b) For dams associated with dry or extended dry (BMP) detention facilities, reinforced concrete low head pressure pipe shall be used which meets ASTM specification C361.

6-1607.1B(4)(c) Reinforced concrete pipe strength shall be in accordance with VDOT Standard PC-1, with Class III being the minimum strength permitted.

6-1607.1B(5) Trash Racks. Trash rack members shall be A36 steel. When reinforcing bars are used as cage members, they shall be grade 60. All components shall be galvanized in accordance with VDOT Specification 241. Trash racks shall be attached to a concrete spillway structure with stainless steel anchor bolts.

6-1607.1C Earthwork

6-1607.1C(1) Compacted Fill. Compacted fill shall not be placed prior to performing the required foundation and abutment preparation, or on any frozen surface. Compacted fill shall extend to the fill limit lines and grades indicated by the approved construction plan. Compacted fill material shall be of the type classification symbol specified by the designer, or of a better quality material as defined by the Unified Soil Classification System. Also, restrictions on the liquid limits and plasticity index of the material may be included where applicable. Compacted fill shall consist of material free of organic matter, rubbish, frozen soil, snow, ice, particles with sizes larger than 3 inches or other deleterious material.

6-1607.1C(2) Compacted fill shall be placed in horizontal layers of 8 inches to 12 inches in loose thickness. Actual lift thickness will be specified on a case-by-case basis. The moisture content shall be controlled such that compaction is achieved without yielding of the surface. Each layer shall be uniformly compacted with suitable compaction equipment to at least 95 percent of Standard Proctor Maximum Density in accordance with ASTM D-698, AASHTO T-99, or VDOT specifications. Any layer of fine-grained fill which becomes smooth under compaction or

construction traffic should be scarified to a depth of 2 inches to allow adequate bonding between layers.

6-1607.1C(3) Compacted fill with a moisture content which will not permit compaction to the specified density standard shall be scarified dried or wetted as necessary to permit proper compaction.

6-1607.1C(4) Riprap. Rock fill at the embankment surface for the purpose of protecting the embankment against weathering, wave action, etc., shall consist of Class II riprap in accordance with VDOT specifications.

6-1607.1D Field Density Testing

6-1607.1D(1) Tests of the degree (percent) of compaction of the compacted fill shall be performed as part of the permittees' normal quality control program for construction of the dam. Tests will be made concurrently with the installation of the compacted fill and the contractor shall coordinate his work so that the testing can be accomplished. Should the results of the tests indicate that the specified degree of compaction is not obtained, the fill represented by such tests shall be reworked, sprinkled with water or scarified, dried as required and retested until the specified minimum degree of compaction is achieved.

6-1607.2 Construction Inspection Requirements

6-1607.2A Category A, B, or C Dams (defined in Plate 64-6). A qualified engineer as described in § 6-1605.2B of these design standards must observe foundation and abutment preparation, installation of cutoff trench, internal drainage system, outlet pipe or culverts, riser structure foundations, fill placement, and any other geotechnical-related items. The frequency of the observations and testing shall be adequate for the geotechnical engineer to state, in his professional opinion, that the specific items observed and tested were installed in accordance with the approved construction plans and specifications. Compaction in the field shall be monitored based on laboratory density test results. At least one field density test shall be conducted per 10,000 square feet of compacted area per lift with at least one test occurring every other lift. Additional tests must be performed if there is any change in material. The locations of tests are to be representative of the area under construction. Within 30 days following the completion of construction of the dam, an inspection report shall be provided to DPWES for review. As a minimum, these reports should state subgrade material and condition, grouting, fill material classification, in-place density and moisture content, location and elevation of tests performed, interior drainage material, filter type, location and conduit/structure grades.

6-1607.2B Category D Dams. The permittee shall be responsible for providing all quality control procedures necessary to ensure conformance with the approved plans and specifications. Within 30 days following the completion of construction of the dam, an inspection report shall be provided to DPWES for review. This report shall include all test results set forth in § 6-1607.2A.

6-1607.2C If there is any question as to the physical integrity of a constructed dam or stormwater management facility because of inadequate construction documentation, inadequate inspection reporting, or some other apparent inadequate condition, the Director may require a geotechnical engineering study after construction to verify that the facility has been constructed in accordance with § 6-0000 *et seq*.

6-1607.3 As-Built Requirements and Certification (Deleted by 119-15-PFM, See § 2-1300)

6-1608 Operation, Maintenance, and Inspection Guidelines

6-1608.1 A Private Maintenance Agreement with the Board of Supervisors shall be executed by the owner for all privately maintained stormwater management facilities prior to construction plan approval in accordance with § 6-0303.

6-1608.2 The following are general operation, maintenance, and inspection standards for all stormwater management facilities (including dams) not maintained by the County. The guidelines presented here are not intended to be all inclusive and specific facilities may require special measures not discussed here.

6-1608.3 Operation and Maintenance

6-1608.3A Embankment. The dam embankment should maintain a thick, healthy grass cover over the embankment which is free of trees and brush. This type of cover will assist in stabilizing the surfaces of the dam as well as increase the ease of inspecting the dam.

6-1608.3A(1) The embankment should be mowed periodically during the growing season with the last cutting occurring at the end of the growing season. The grass cover should not be cut to less than 6 inches to 8 inches in height.

6-1608.3A(2) If necessary, the embankment should be limed, fertilized and seeded in the fall after the growing season. The amount of lime and fertilizer should be based on soils test results. The type of seed shall be consistent with that originally specified on the construction plans.

6-1608.3A(3) All erosion gullies noted during the growing season should be backfilled with topsoil, reseeded and protected until revegetated.

6-1608.3A(4) All bare areas and pathways on the dam embankment should be properly seeded and protected to eliminate the potential for erosion.

6-1608.3A(5) All animal burrows should be backfilled and compacted. Measures should be taken to remove the animals from the area.

6-1608.3A(6) All trees, woody vegetation, and other deep-rooted growth, including stumps and associated root systems, are to be removed from the dam embankment and adjacent areas to at least 10 feet beyond the embankment toe and abutment contacts. The old root system should be removed and the excavated volume replaced and compacted with material in character with the surrounding area. All seedlings should be removed at the first opportunity. Similarly, any vine cover and brush should be removed from the dam embankment to allow for proper and complete dam inspection.

6-1608.3B Spillways

6-1608.3B(1) Spillway structures shall be cleared of debris periodically, and after any significant rainfall event if inspection reveals significant blockage.

6-1608.3B(2) During low water conditions, concrete spillway structures such as outlet conduits, risers, weir structures, etc., shall be inspected to determine if water is passing through any joints or other structure contacts. The condition of any concrete structure should be checked for cracks, spalling, and broken or loose sections. Any cracked or spalled areas should be cleaned and refilled with an appropriate patching concrete. Any extensive leakage, spalling or fractures should be inspected by a Professional Engineer and his recommendations followed.

6-1608.3B(3) Stilling basins and discharge channels shall be cleared of brush at least once per year.

6-1608.3B(4) Trash racks and locking mechanisms shall be inspected and tested periodically to make sure they are intact and operative.

6-1608.3B(5) Vegetated emergency spillway channels should be mowed at the time of embankment mowing. The grass in the emergency spillway should not be cut to less than 6 inches to 8 inches in height. The emergency spillway approach and discharge channels should be cleared of brush and trees periodically. After any flow has passed through the emergency spillway, the spillway crest (control section) and exit channel should be inspected for erosion. All erosion areas should be repaired and stabilized.

6-1608.3C Toe Drains, Low-Level Lakes, Drains and Sluice Gates

6-1608.3C(1) All sluice gates (or other types of gates or valves used to drain an impoundment) should be operated periodically to insure proper functioning. At those times, the gate and stem should be lubricated and all exposed metal shall be painted to protect it from corrosion.

6-1608.3C(2) Toe drains or other internal drainage outlets should be cleared of debris, brush, and silt at least once per year to allow and ensure the free flow of water.

6-1608.3D Additional Maintenance Items

6-1608.3D(1) The dam should be inspected periodically to ensure that motorcycle, ATV, and other vehicles are not operating on the dam embankment or emergency spillway.

6-1608.3D(2) The common areas and other access points to the dam should be inspected to ensure that plantings, fences or other obstructions are not placed such that access to the dam is impeded.

6-1608.4 Inspection

6-1608.4A At a minimum, an annual inspection (by a person with experience in dam inspection) should be performed following a mowing and brush removal operation. Important items to look for during an inspection include: any evidence of movement within the dam or at the abutments; seepage anywhere along the dam toe; excessive erosion or other damage to the embankment or emergency spillway; any growth of trees or underbrush in the dam embankment or in the emergency spillway; heavy pedestrian and/or vehicular traffic on the dam embankment or emergency spillway; animal burrows or wave action damage along the dam embankment; and, for any stormwater management facility where a portion of the upstream ponding area is left "natural" or in an undisturbed condition within a conservation easement, any disturbance within this area should be noted.

6-1608.4B The dam inspection checklist provided by the Virginia Division of Soil and Water Conservation in the publication entitled "Safety Evaluation of Small Dams" also should be used when making annual dam inspections.

6-1700 POLICY ON WHAT MAY BE DONE IN CHESAPEAKE BAY PRESERVATION AREAS (38-93-PFM)

6-1701 General Information

6-1701.1 (94-06-PFM) Certain areas of the County have been designated Chesapeake Bay Preservation Areas (CBPAs) and divided into Resource Protection Areas (RPAs) and Resource Management Areas (RMAs) that are subject to the criteria and requirements contained in Chapter 118 (Chesapeake Bay Preservation Ordinance) of the Code. RPAs are protected from most development because, left intact, they function to improve and protect water quality. RMAs are regulated to protect RPAs and water resources from degradation resulting from development and land disturbing activity.

6-1701.2 A map of CBPAs has been adopted by the Board. Where RPA and RMA boundaries on the adopted map differ from boundaries as determined on a site-specific basis from the text of Chapter 118 of the Code, the text shall govern.

6-1701.3 (79-03-PFM) The site-specific boundaries of the RPA shall be delineated on all preliminary plans, site plans, subdivision plans, grading plans, public improvement plans, record plats, and all other plans of development in accordance with Chapter 118 of the Code and subject to the approval of the Director.

6-1701.4 (94-06-PFM) (79-03-PFM) Chapter 118 of the Code requires that a reliable, site-specific evaluation shall be conducted to determine whether water bodies on or adjacent to development sites have perennial flow and that RPA boundaries shall be adjusted, as deemed necessary by the Director, on the site, based on this evaluation of the site. The evaluations performed by the Department of Public Work and Environmental Services that are the basis for the perennial streams depicted on the adopted map of CBPAs satisfy this requirement. Water bodies identified as perennial on the adopted map of CBPAs are presumed to be perennial and may only be reclassified as intermittent based on additional studies performed in accordance with this Article and Chapter 118 of the Code.

6-1702 Use Regulations in Chesapeake Bay Preservation Areas

6-1702.1 (79-03-PFM) Unless an exception is approved by the Exception Review Committee or the Board of Supervisors, as provided for in Chapter 118 of the Code, all newly proposed buildable subdivision lots in or adjacent to an RPA must contain sufficient area of land outside the RPA to allow development of the lot without encroachment upon the RPA.

6-1702.2 Land development and redevelopment may be allowed within an RPA if otherwise permitted by the Zoning Ordinance and subject to the requirements of the PFM and to the performance criteria of Chapter 118 of the Code, if it is water-dependent development as defined as § 118-1-6 of Chapter 118 of the Code, is considered to be redevelopment, is exempted, or for

which an exception allowing the land development is approved in accordance with Chapter 118 of the Code.

6-1702.3 (86-04-PFM) No part of any building lot in a cluster subdivision may extend into a Resource Protection Area, except as provided in Part 6 of Article 9 of the Zoning Ordinance for cluster subdivisions in the R-C, R-E and R-1 Districts and for cluster subdivision in the R-3 and R-4 Districts which have a minimum district size of 2 acres but less than 3.5 acres, and § 101-2-8 of the Code for cluster subdivisions in the R-2 District and cluster subdivisions in the R-3 and R-4 Districts which have a minimum district size of 3.5 acres or greater.

6-1702.4 All wetlands permits required by law shall be obtained prior to commencing land disturbing activities. No land disturbing activity shall commence until all such permits have been obtained by the applicant and evidence of such permits has been provided to the Director. For those activities regulated under general permits for which the issuing agencies do not normally provide written confirmation of permit issuance, a copy of the general permit(s) and a statement describing the proposed activity and certifying compliance with all applicable permit conditions will serve as the required evidence. Wetlands permits include both COE Permits and Virginia Water Protection Permits.

6-1703 Water Quality Impact Assessments (86-04-PFM)

6-1703.1 A Water Quality Impact Assessment (WQIA) is required for any development or redevelopment within an RPA unless waived by the Director or exempted under Chapter 118 of the Code.

6-1703.2 The Director shall require a WQIA for development or redevelopment within an RMA if the Director determines that such an assessment is necessary because of the unique characteristics of the site or because the intensity of the proposed development may cause significant impacts on the adjacent RPA.

6-1703.3 WQIAs, as required, shall be submitted to the Director for review in conjunction with the submission of a plan of development. Unless modified by the Director, a WQIA shall be performed in accordance with Chapter 118 of the Code.

6-1704 Guidelines for Determining Locations of Resource Protection Areas and Identifying Water Bodies With Perennial Flow (79-03-PFM)

6-1704.1 (94-06-PFM) Resource Protection Area (RPA) boundary delineation studies and the identification of water bodies with perennial flow shall be performed by the methods described herein or other acceptable methods as determined by the Director.

6-1704.2 The RPA shall include any land characterized by one or more of the following features:

6-1704.2A A tidal wetland;

6-1704.2B A tidal shore;

6-1704.2C A water body with perennial flow;

6-1704.2D A nontidal wetland connected by surface flow and contiguous to a tidal wetland or water body with perennial flow;

6-1704.2E A buffer area as follows:

6-1704.2F (1) (94-06-PFM) Any land within a major floodplain ("Major floodplain" means those land areas in and adjacent to streams and watercourses subject to continuous or periodic inundation from flood events with a 1 percent chance of occurrence in any given year (i.e., the 100-year flood frequency event) and having a drainage area equal to or greater than 360 acres.;

6-1704.2F(2) (94-06-PFM) Any land within 100 feet of a feature listed in § 6-1704.2A through § 6-1704.2D. The full buffer area shall be designated as the landward component of the RPA notwithstanding the presence of permitted uses, encroachments, and permitted vegetation clearing.

6-1704.3 Designation of the RPA components listed in § 6-1704.2A through § 6-1704.2D shall not be subject to modification unless based on reliable, site-specific information.

6-1704.4 (94-06-PFM) Water bodies with perennial flow shall be identified using a scientifically valid system of in-field indicators of perennial flow as determined by the Director. Acceptable methods include but are not limited to the perennial stream mapping protocol developed by the Department of Public Works and Environmental Services and methods determined by the Virginia Department of Conservation and Recreation, Division of Chesapeake Bay Local Assistance to be scientifically valid that are acceptable to the Director.

6-1704.4A (94-06-PFM) Water bodies identified as perennial on the adopted map of Chesapeake Bay Preservation Areas are based on field studies conducted by the Department of Public Works and Environmental Services using established protocols and shall only be reclassified as

intermittent based on observations of the absence of stream flow during normal or wetter than normal hydrologic conditions.

6-1704.4B (94-06-PFM) The weekly drought assessment under the U.S. Drought Monitor (NOAA et al) shall be used to determine the general hydrologic conditions at the time of observation. Observations of the absence of stream flow will not be accepted as definitive proof that a stream is intermittent if the weekly U.S. Drought Monitor classification is D0 (abnormally dry) or drier at any time during a period extending from 20 days prior to the date that the first set of observations required by § 6-1704.4D are made through 20 days after the date when the second set of observations required by § 6-1704.4D are made.

6-1704.4C (94-06-PFM) Water bodies not identified as perennial on the adopted map of Chesapeake Bay Preservation Areas may only be reclassified as perennial in conjunction with an amendment to the map by the Board of Supervisors.[1]

6-1704.4D (94-06-PFM) Observations of stream flow shall be made in accordance with the following:

6-1704.4D(1) (94-06-PFM) Unless modified by the Director (e.g., if access to off-site properties is denied or the final upstream limit of the perennial stream lies within the property and is greater than 150 feet from the downstream property line), observations of stream flow or lack thereof shall be made at intervals of 50 feet or less along the stream channel beginning a minimum of 150 feet downstream from the property line to a point a minimum of 150 feet above the terminus of the perennial stream as depicted on the adopted map of Chesapeake Bay Preservation Areas, at all control sections within the study reach, and at the nearest control section upstream and downstream from the property boundary. A control section is a culvert or other section with a hard bottom where flow would be readily visible.

6-1704.4D(2) (94-06-PFM) Two sets of observations at the above locations must be made a minimum of seven but no longer than thirty days apart.

6-1704.4D(3) (94-06-PFM) Observations shall be made at the true channel bottom which is located below the moveable bed material. Where the channel bed is armored, the presence of flow within the armoring layer must be checked.

6-1704.4D(4) (94-06-PFM) The Department of Public Works and Environmental Services (DPWES) shall be advised prior to or within three days of completion of the first set of observations of the property owner's intent to submit an RPA boundary delineation study to reclassify the stream from perennial to intermittent. DPWES will perform a field review as part of the evaluation of the reclassification study. DPWES will coordinate the field review with the 2nd visit to the site by the agent of the landowner whenever possible. Where there are visible pools of water within the channel that do not appear to be moving, dye tracing and tracing techniques in accordance with ASTM or USGS methods, or other methods and techniques, shall be utilized by DPWES to determine if water is flowing from pool to pool.

6-1704.5 Wetland determinations shall be performed using methods specified by the United States Army Corps of Engineers (USACE).

6-1704.6 RPA boundary delineation studies shall be sealed by a professional engineer, land surveyor, landscape architect, soil scientist, or wetland delineator certified or licensed to practice in the Commonwealth of Virginia. Any work performed by other firms or individuals not under the responsible charge of the licensed professional sealing the study shall be identified and sealed by that individual as appropriate.

6-1704.7 RPA boundary delineation studies shall be submitted on standard-size sheets of 24 inches x 36 inches or the metric equivalent at a scale of 1 inch = 50 feet or larger meeting the requirements of § 2-0201.2.

6-1704.8 (94-06-PFM) RPA boundary delineation studies to determine site-specific RPA boundaries shall include the following:

6-1704.8A Cover sheet with project name, County plan identification number, vicinity map, tax map reference, and fee computation;

6-1704.8B A narrative describing how the RPA boundary was established including a discussion of which components listed in § 6-1704.2 determine the RPA boundary and any wetlands shown on the plan that were determined not to be a component of the RPA (i.e., did not meet the requirement of § 6-1704.2D);

6-1704.8C Plan sheet(s) with 2-foot contour interval topography showing each individual component of the RPA overlain to create the final RPA boundary, the RPA boundary from the adopted Chesapeake Bay Preservation Area maps, locations of horizontal and vertical control points, and locations of points and transects used in the wetland determination. Topography shall be correlated to a USGS or County benchmark(s), based on NGVD29, which shall be referenced in the plan. Plan sheets shall include a north arrow in accordance with § 2-0212.3;

6-1704.8D Standard USACE data forms used in the wetland determination and any relevant correspondence from the USACE;

6-1704.8E (94-06-PFM) Source of the major floodplain boundary.

6-1704.9 (94-06-PFM) RPA boundary delineation studies to reclassify streams from perennial to intermittent shall include the following:

6-1704.9A (94-06-PFM) Cover sheet with project name, County plan identification number, vicinity map, tax map reference, and fee computation;

6-1704.9B (94-06-PFM) A narrative describing how, when, and where the observations were made, the weather conditions at the time the observations were made, and the study's final conclusion on whether the stream is perennial or intermittent;

6-1704.9C (94-06-PFM) Plan sheet(s) with 2-foot or 5-foot contour interval topography showing the RPA boundary from the adopted Chesapeake Bay Preservation Area maps, locations of points where observations were made with a key to the photographic documentation provided, the point at which the stream transitions from perennial to intermittent and the revised RPA boundary. Topography shall be correlated to a USGS or County benchmark(s), based on NGVD29, which shall be referenced in the plan. Alternatively, property and topographic information from the County's Geographic Information System may be used. Plan sheets shall include a north arrow in accordance with § 2-0212.3;

6-1704.9D (94-06-PFM) Meteorologic data. Daily precipitation, maximum and minimum temperature, and cloud cover from the nearest National Weather Service weather station for a period of 20 days preceding the date that the first set of observations were made through 20 days after the date when the second set of observations were made. The weekly U.S. Drought Monitor classification for a period of 20 days prior to the date that the first set of observations were made through 20 days after the date when the second set of observations were made. The County may use meteorologic data from local rain gauge stations closer to the site in evaluating the reclassification request;

6-1704.9E (94-06-PFM) Observations of streamflow. The date, time, name of the observer, weather conditions at the time of observation, and photographs looking upstream and downstream documenting each observation. Photographs shall capture the various stream features (e.g., pools, riffles, and runs) along the stream. Photographs of the stream shall be taken close enough to see the channel bed and banks, shall show the channel bottom and any armoring materials, and shall be unobstructed by vegetation. If a clear view cannot be obtained by relocating the point of observation, vegetation may be trimmed to obtain a clear view. Photographs of the channel shall include identifiable stationary landmarks in the field, so that the point of observation can be verified at a later date, if necessary. Identifiable landmarks include survey markers with identification, structural objects such as culverts, bridges, and nearby buildings, or unique natural features. Photographs must have a visible date stamp or certification by the observer of the date the photographs were taken.

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[1] (94-06-PFM) Any request to re-evaluate a stream segment for possible reclassification from intermittent to perennial should be made through the Board member in whose district the stream segment is located. The Department of Public Works and Environmental Services will re-evaluate the stream segment and provide a recommendation to the Board member.