VEGETATION
IN STORMWATER
BEST MANAGEMENT PRACTICES

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Maryland
Department of
the Environment

Contents

Introduction

The Maryland Department of the Environment (MDE) routinely receives inquiries related to vegetation within stormwater best management practices (BMP). MDE recognizes that vegetation plays a significant role in water quality improvement, and that it is an essential part of stormwater BMPs. This guidance memorandum expands on guidelines set forth in Appendix A, Landscaping Guidance for Stormwater BMPs, of the *2000 Maryland Stormwater Design Manual, Volumes I & II*. This memorandum includes a literature review, as well as findings from interviews with academic researchers, local nurseries, and municipal and county separate storm sewer system (MS4) permittees that are responsible for administering Maryland's stormwater management program. MDE has reviewed this information to create updated guidance set forth here regarding how stormwater vegetation should be chosen, installed, and maintained within BMPs in the State of Maryland.

The Maryland Stormwater Design Manual, Volumes I & II (2000, 2009), hereafter referred to as the Design Manual, serves as the guide for implementing stormwater management principles and practices in the State of Maryland. The Design Manual was created to serve as a guide for protecting the waters of the State from adverse impacts of urban stormwater runoff. It was updated in 2009 to reflect increased knowledge on how to mimic natural hydrology through site design and the use of small-scale practices for new development and existing development. Since the 2009 revision, Maryland Department of the Environment staff have continued to observe the design and implementation of stormwater BMPs throughout the State by local jurisdictions and agencies.

While the Design Manual outlines basic requirements and recommendations, it was created to serve as a starting point. In a series of seminars conducted by MDE in October 2013, the Department explained that the "use of innovative solutions to unique problems is encouraged on a case-by-case basis." This statement summarizes the philosophy of the Design Manual, which was intended be tailored to each administrator's needs beyond the general points listed.

The following memorandum provides clarification and additional information on various aspects of vegetation in stormwater BMPs. These recommendations were based on interviews with local government representatives, common questions received by MDE since the creation of the Design Manual, the experiences and lessons learned of local horticulture experts, and academic research. MDE intends that this information serve the stormwater community of Maryland in creating high quality BMPs, while minimizing maintenance effort, in an era when stormwater is managed increasingly through use of micro-scale practices to implement environmental site design (ESD) to the maximum extent practicable (MEP).

Summary of Recommendations

GENERAL GUIDANCE

• Install vegetation in BMPs that is best suited for the local conditions, considering:
  ○ Primary water quality goals of the site
  ○ Soil composition and climate, water level depth and duration
  ○ Available resources, e.g., plant availability at local nurseries
  ○ Use of the area surrounding the BMP, e.g., next to a road with high salt runoff, on school grounds with high foot traffic
  ○ Local concerns, e.g., deer grazing
• Coordination and communication at all steps, from design to construction to maintenance, increases efficiency and success, and improves timeliness of addressing issues that may be observed in the field.
• Employing or collaborating with knowledgeable, extensively trained experts, e.g., with a landscape architecture or horticultural background, improves results.
• Some training (classroom, in the field, or educational materials) should be provided for all staff that perform vegetation maintenance, including subcontractors.

SPECIES SELECTION
• Each local administrator is encouraged to develop a local list of acceptable plant species based on experience, local natural conditions, and administrator preferences, that is more specific than the information found in Appendix A of the *2000 Maryland Stormwater Design Manual*, *Volumes I & II*, hereafter referred to as the Design Manual. • As specified in the Design Manual, woody vegetation including trees and shrubs is prohibited on, or within 15 feet of the toe of slope of, any dam embankment that is designed and constructed according to the Natural Resources Conservation Service (NRCS) - Maryland (MD) 378 Standards and Specifications for Small Pond Design (MD-378). Trees must not block maintenance access, and must be a minimum of 25 feet away from perforated pipes and principal spillway structures (see Design Manual for full details). Ensure that roots will not impact underdrains or impervious liners.

SPECIES DIVERSITY

- A minimum of three species is recommended in all BMPs where vegetation is a component, including stormwater ponds and wetlands, infiltration practices, bioretention, open channels, and filter strips and buffers.
- Consider choosing a variety of species and including attractive species in BMPs that are located in public spaces to increase public acceptance and avoid a "vacant" or unkempt look.
- A variety of plant types are encouraged in bioretention and wetlands, including grasses, shrubs, and trees.
- Managed turf (e.g., regularly mown areas) does not reflect natural conditions and must be minimized.

SEEDS AND PLUGS

- The specific goals and restrictions of each site must be considered when making the choice between planting seeds, plugs, live woody cuttings, or a combination. Advantages exist with each type of planting.
- Regardless of which method is used to establish vegetation, take the appropriate care to ensure a high survival rate and minimize weed growth until plants are mature.
- Work with nurseries to obtain plants that have been grown outdoors during the season in which they will be planted, so that plants will not be shocked during transplant.

VEGETATIVE COVER

- 85% vegetation ground cover should be generally evenly distributed across the surface area of the BMP within three years of installation and maintained thereafter.
- The advice of a landscape architect or a landscape manual should be followed regarding plant spacing.
- Planting should be done generally between mid-March through June and mid-September through mid-October (i.e., spring and fall) to avoid temperature extremes and frost. Table B.5 in the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control provides recommended approximate planting dates for permanent cover in Maryland. Regardless of time of year, to prevent damage do not

plant in soil that is unsuitable to the plant, e.g., frozen, waterlogged, compacted, or in a drought.

- Vegetation should be planted at the time it is received to increase survival rate.
- Upon delivery, tickets should be checked to ensure they match the plant species, quantities, and sizes delivered. The plants should be checked to ensure they are the species listed on the approved plans or project specifications.
- The on-site contractor should verify that plants are in good condition when they arrive. Plants should have no obvious signs of damage, pests, or disease. This includes major leaf damage, a large portion of broken stems or branches, or an obvious infestation of insects. Leaves should not be wilted.
- Before installing plants, any weeds in pots or on root balls should be removed.

MULCH

- To prevent mulch migration or "floating mulch":
    - Mulch should be double or triple shredded hardwood because the shape (thin, fine, and stringy) binds more tightly and resists floating.
    - Mulch should be wetted thoroughly via irrigation when installed.
- Stone is acceptable to use as an alternative to prevent floating mulch. Stone should be light in color to maintain cooler water temperatures and avoid damaging any shallow roots. Stone mulch should never be used, regardless of color, in more temperature sensitive class III and IV watersheds because of its potential to raise water temperature. Stone may be angular in shape to provide extra resistance to movement, e.g., on slopes.
- Local administrators are encouraged to consider using low growing vegetation as an alternative ground cover to mulch, such as grasses, evergreens, ferns, or succulents, as growing conditions allow. Ground cover vegetation should be placed in addition to the other plants indicated on the plans and is not intended to replace them; i.e., a "managed turf grass" look should be avoided.

NON-NATIVE SPECIES, INVASIVE SPECIES, AND WEEDS

- Native species are strongly encouraged.
- Vines must never be planted and should be removed during maintenance.

- Invasive and noxious species are considered unacceptable in all BMPs and should be removed when they are identified.

MAINTENANCE AND MANAGEMENT

- Choose plants that are low maintenance and suited to the climate and site conditions.
- Choosing long-lived plants or perennials may reduce replacement cost. Consider avoiding plants that have shorter life expectancies, for example, some cultivars.
- Budget for eventual replacement regardless of which plants are selected.
- Innovative local solutions are encouraged where they meet the intent of the Design Manual and do not detract from the water quality benefits that BMPs provide. This may include planting in squares or bands to make weeds more obvious to maintenance personnel.
- To reduce confusion or disagreement over which entity is assigned to perform maintenance, formal agreements must contain clear and specific language regarding issues such as replacement of vegetation, length of maintenance agreement, and any assurance measures such as the withholding of bonds, deeds, or as-builts.
- If a homeowner's association is responsible for BMP maintenance, the association management documents and any associated fees should contain provisions to inspect and maintain the BMP as needed.
- Contractual agreements with plant providers must ensure that plants will be replaced if they fail within a certain period (e.g., during the first year).
- Create standard operating procedures for inspection and enforcement of vegetation guidelines so that any staff or contractual employee may easily follow them.
- If the original plants do not survive or volunteer species become established in the BMP, they may be kept in the BMP if not invasive or vines and if the administrator makes an effort to determine why the original plants failed and uses that information to improve future designs. MDE advises that volunteer species may grow aggressively and require more frequent maintenance.
- Pesticides (including insecticides and herbicides) must not be applied in drainage paths, including in stormwater BMPs and at outfalls. If administrators need guidance

in removing weeds, they may consult local horticultural companies, the Maryland Department of Natural Resources, or the University of Maryland Extension.

- Fertilizers should not be applied to vegetation during routine maintenance. BMPs are designed to capture nutrients in runoff and not be a source of nitrogen or phosphorus.

WORKING WITH HOMEOWNERS, THE PUBLIC, AND ONSITE STAFF

- Safety should be a primary consideration in designing and maintaining BMPs that are accessible to the public.
- Creating an attractive BMP improves homeowner acceptance for BMPs that are located in residential spaces or are otherwise highly visible to the public. This usually includes selecting a diverse variety of plants that have year-round aesthetic interest, such as flowers, berries, fruits, bright stems, leaves, or bark.
- Citizen education is a cost effective way to ensure that BMPs continue to function properly. It is also important to educate onsite staff at private businesses and on government properties where BMPs are present. Individuals that understand a BMP's function and any maintenance responsibilities they have are less likely to modify or remove it and are more likely to contact the program if issues arise.
- Financial investment by homeowners (e.g., through a rain garden cost-share or rebate program) can be an effective tool for success.

TRAINING

- Where possible, utilize knowledgeable individuals, preferably with a landscaping or gardening background, in all aspects of design, installation and maintenance. This may mean hiring a contractor for any or all of these steps.
- Provide training and/or educational material to staff who work with stormwater vegetation, including permanent staff and contractual employees.
- Resources are available from local nurseries, agriculture extension programs, neighboring jurisdictions, and other organizations, or materials may be developed in house or in conjunction with other agencies, organizations, or companies.

Recommendations

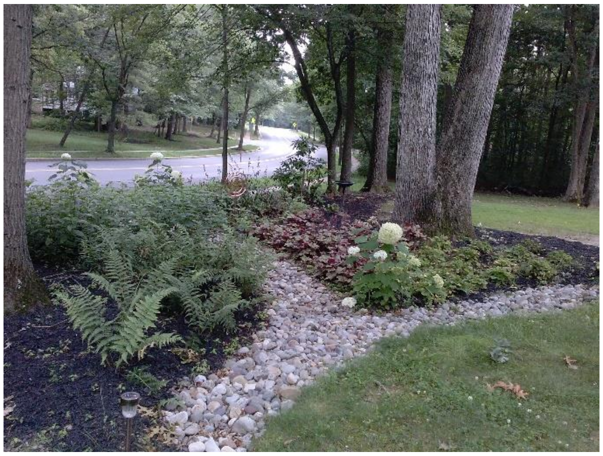
Recommendations for stormwater BMP vegetation are made here based on the findings of a literature review, observations made on recent visits by MDE with local administrators, and communication with current local government practitioners, academic researchers, and local plant nurseries. General guidance is provided below regarding species choice, including a discussion of native and invasive species. Guidance is also provided regarding plant diversity, minimum vegetation ground cover, the planting of seeds versus plugs or live cuttings, the use of mulch, soil composition, maintenance, working with homeowners, and staff training. These recommendations strive to provide flexibility through strategies that have been demonstrated to be successful on a local scale. MDE will continue to work with local government administrators to create innovative solutions and to share this knowledge across the State.

<u>General guidance</u>

Local government administrators are encouraged to develop solutions that match local conditions such as soil properties and topography, and that utilize locally available resources. Many aspects of the Design Manual were written to be less prescriptive, so that a program administrator's ability to establish thriving plants would not be limited. For example, the Appendix A list of acceptable species includes an extensive number of options. Because each site has unique characteristics, site-specific design is essential to ensure long-term vegetation survival and reduced cost and maintenance effort. Greater initial effort may be needed to assess each individual site to ensure that appropriate BMP vegetation has been selected. However, this extra effort greatly reduces the likelihood that resources will be spent on troubleshooting afterwards.

In addition to natural site characteristics, the planned use of the area surrounding the BMP must be taken into account when choosing vegetation. Species must be selected that support the priority functions of the site. For example, when situated in areas that are highly visible to the public, a key consideration is to plant vegetation that is aesthetically pleasing with features such as multi-season blooms. Public spaces should appear attractive and "finished", i.e., appear cared for, in a shorter amount of time to ensure public acceptance and support. In areas that require frequent mowing, large tough fruits such as from sweetgum trees *(Liquidambar styraciflua)* are problematic to machinery. Similarly, fruiting plants such as winterberry *(Ilex verticillata)* and serviceberry (*Amelanchier canadensis*) and sap producing plants such as cedars *(Juniperus spp.)* and white pine (*Pinus strobus*) are attractive but may create maintenance issues in parking lots by dropping fruits or sap onto the ground and cars. As another example, shorter plants may be preferred in residential areas and college campuses for public safety, and to ensure adequate visibility in medians and at intersections. See Figure 1 for examples of BMPs that have been well designed to suit their function and location, and Figure 2 for examples of BMPs that were less successful in attaining public acceptance.

Bioretention doubles as a meditation garden for medical center patients



Attractive rain gardens act as both a stormwater management feature and an educational tool for neighbors

A green roof that is visible to the public has a diversity of flowers pleasing to the eye

Bioretention and rooftop disconnect are designed to complement the architecture

Figure 1. Examples of BMPs that were designed to complement their surroundings.

Neighbors complained that the organic debris in this stream restoration looked unattractive

The debris storage in this residential dry well indicated that the resident did not understand the BMP's function to properly maintain it

Figure 2. Examples of BMPs that would benefit from additional public education or a redesign to suit the needs and preferences of residents.

Deer and geese grazing are a concern throughout the State. Regional nurseries have developed lists of species that are unpalatable to these animals and are not typically grazed, although plant selection alone will not solve instances where grazing is intense. Temporary or permanent plant protection may also be considered to shield from wildlife; this includes wire netting and fence. Fencing or tall, dense vegetation around the BMP perimeter are also options to discourage human foot traffic inside the BMP that would lead to soil compaction, erosion, and plant damage, e.g., on school yards or campuses.

Many local administrators have developed lists of species that have proven over the years to tolerate difficult roadside conditions such as runoff of salt and heavy metals. However, administrators should note that while strategies may be developed to improve vegetation success, there is a limit to the conditions that plants can tolerate, and vegetation has a low probability of surviving large amounts of pollutants such as salts or heavy metals. The Design Manual prohibits directing runoff from hotspots to stormwater BMPs. If there is an incident involving toxic runoff associated with a hotspot, proper steps should be taken to restore vegetation after any required remediation.

Coordination during design, construction, and maintenance will contribute to success. During the design phase, planners must verify which plants will be available from local vendors at the time of installation. During construction, on-site staff should install plants when they are received to increase survival rate, and to verify that plants have been installed according to the plan details. Clear agreements must be noted on approved plans to designate responsibility for maintenance and for replacement in the event of failure. Larger organizations should encourage coordination among their divisions to report observed issues to the appropriate staff member. Adding this simple step into standard procedures can make a significant impact when resources are limited.

MDE has observed that programs employing knowledgeable, more extensively trained staff exhibit higher quality, more successful stormwater facilities. Several of these administrators employ at least one staff member with a landscape architecture background. Other staff have a gardener background or collaborate with local Master Gardeners (as part of cooperative agriculture extension programs provided by USDA through land-grant colleges and universities) to select species and create plant layouts. Alternatively, some administrators subcontract all aspects of vegetation in order to maximize limited resources, minimize error, and entrust this responsibility to an organization that focuses strictly on vegetation. The most successful programs usually provide some training for all staff and contractors that perform vegetation maintenance.

Species selection

Appendix A of the Design Manual presents an extensive list of herbaceous and woody plants that are native to Maryland and potentially suitable for planting in stormwater BMPs located in the State. This section is intended to be a starting point for the selection of species on a case-by-case basis using more site specific information such as soil properties, site hydrology, and administrator preferences. High variability exists in topography, geology, and microclimate throughout the State. Each administrator therefore faces a unique set of constraints that in several instances have led to the development of a local list of approved plant species more restrictive than that found in Appendix A. Local lists are typically based on patterns of successes or failures that have caused the administrator to recommend or prohibit particular species. MDE encourages local agencies to develop additional guidance such as these where they see fit.

When trees are planted, guidance exists within Appendix A to prevent common issues. Trees are often discouraged or prohibited locally in BMPs because of the long-term challenges in ensuring that proper tree maintenance is performed and tree growth does not block or damage BMP structures such as pipes, liners, or underdrains. However, trees perform valuable water quality functions and may be considered where they align with the priorities and maintenance needs within a specific BMP. As specified in the Design Manual, woody vegetation including trees and shrubs is prohibited on, or within 15 feet of the toe of slope of, any dam embankment that is designed and constructed according to the Natural Resources Conservation Service (NRCS) - Maryland (MD) 378 Standards and Specifications for Small Pond Design (MD-378). Trees must not block maintenance access, and must be located a minimum of 25 feet away from perforated pipes and principal spillway structures to prevent roots or limbs from damaging structures (see Design Manual for full details). Vegetation on embankments must be no more than 10 inches tall. When situating dam embankments near property lines, it is critical that designers ensure adequate space to allow vegetation maintenance, such as removal of encroaching trees. This may be accomplished, for example, through creating a setback or requiring the establishment of an easement, as some local administrators have done. Local rules may be more stringent.

Species diversity

The Design Manual encourages a variety of plants, and states that a turf monoculture is not sufficient to meet water quality goals. Appendix A specifies that bioretention areas must have “diverse” plant cover.

Based on a literature review and field observations, MDE requires a minimum of three species in all BMPs that are designed to include vegetation, including stormwater ponds and wetlands, infiltration practices, filtering practices, and open channel practices. A greater number should be considered in facilities that are located in or near public spaces to increase public support. While grasses and non-woody vegetation may be preferred in infiltration practices and open channels, a variety of types of plants are encouraged in bioretention and submerged gravel wetlands, including grasses, shrubs and trees. For open channels and filter strips / stream buffers, administrators must continue to consult Table A.7 Common Grass Species for Open Channels in the Design Manual and the additional resources named in that table (i.e., the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control, and USDA Natural Resources Conservation Service Maryland Conservation Practice Standard No. 391, respectively).

Planting a BMP solely with turf grass opens the door for improper uses: the area may become a dumping ground for trash, a spot where plows dump snow piles, or a makeshift playground or dog park that eventually kills the vegetation. Including more plant types (including grasses, flowers, shrubs, and trees) prevents these scenarios by creating an "intentional" look, as opposed to appearing "vacant". For BMPs located in high visibility areas, public acceptance can be improved by including a variety of attractive plants that flower or fruit throughout the year (more information is provided in the section titled "Working with homeowners, the public, and onsite staff"). High diversity also provides increased wildlife habitat.

MDE further recommends that the mixture of species include fast-growing plants that quickly establish ground cover and slower growing plants that are longer lived. Local administrators may also find it beneficial to include in the mixture plants that are tolerant to the many types of stresses encountered in urban BMPs, including wind, salt, intermittent flooding, and chemicals.

Some administrators have found that maintaining a large number of species causes confusion among maintenance staff who may not have extensive training in identifying species that were planted versus those that were not. MDE recommends that administrators work to create bioretention facilities that include a diversity of plants while balancing the need to create BMPs that can be maintained long-term. The Training and Maintenance sections of this memorandum discuss strategies for success in those cases.

Seeds, plugs, and live cuttings

The Design Manual does not discuss in great detail the planting of seeds versus plugs (seedlings), whips (unbranched, container-grown tree seedlings), live stakes (woody cuttings that are dormant), or wattles (bundled together live branches). Each type of planting has advantages. The goals and limitations of each project must therefore be considered when making this choice. Seeds are less costly, which is often a significant concern. However, this does not provide immediate stabilization, and too much mulch or flooding may prevent germination. Other possible drawbacks include difficulty in distinguishing seedlings from weeds during maintenance, and potential out-competition by weeds.

Plugs achieve immediate results, which may be important in high visibility areas. Larger plugs have a greater survival rate than smaller plugs because of their more developed roots and leaves, but they are more expensive.

Live cuttings may be planted on their own or used to provide temporary structural support for other plants and to minimize erosion on banks. Cuttings should be planted immediately. They are simple to install but have special planting instructions from the supplier that must be followed, including timing of installation. A combination of seeds, plugs, and cuttings may balance a limited budget with other goals.

When sourcing from local nurseries, there is a risk that plants that were grown in ideal conditions, such as high quality soil and well regulated temperatures, may not survive when transferred to the site and may die from the shock of transplant. Failure can be avoided by working with nurseries to obtain plants that have been grown outdoors during the season in which they will be planted. Additionally, contracts with suppliers can be established to ensure that plants will be replaced if they fail. For example, an agreement can include a guarantee that a specified percentage of dead vegetation within a certain time period will trigger replacement.

Vegetative cover

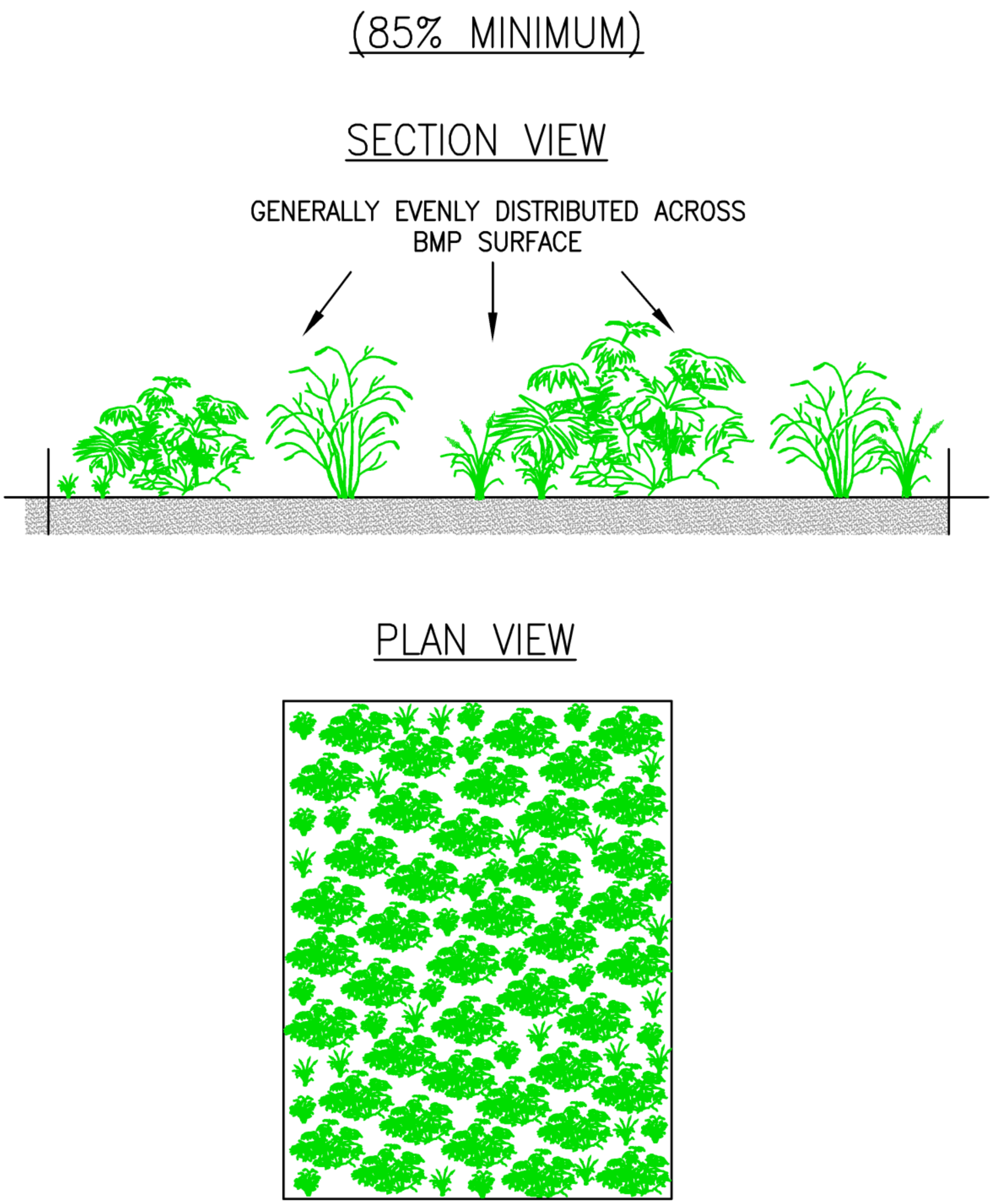
The Design Manual states that dense vegetative ground cover must be established in bioretention as quickly as possible to stabilize the area and prevent erosion. Multiple authorities including the MDE Wetlands and Waterways Program, as well as Virginia, Pennsylvania, and New Jersey, require or recommend a minimum percent cover of vegetation within a specified amount of time. The justification for such high coverage is to create more effective ground stabilization and pollutant filtering than sparse vegetation would be able to achieve. Based on a literature review, interviews, and field observations, MDE recommends 85% overall BMP vegetation ground cover that is generally evenly distributed across the surface area of the stormwater BMP. See Figure 3 for an illustration of 85% cover as viewed from above and an alternate section view of underneath the canopy. Overall vegetation ground cover shall be visually estimated as viewed from above and should include all types of existing vegetation (grass, shrub, and tree). When spacing vegetation, the advice of a landscape architect or a landscape manual should be followed. The minimum required coverage should be achieved within three years of BMP installation. In some cases, stone may be partially substituted in bioretention and rain gardens, as noted in the section discussing mulch.

Vegetation must be planted during a time of year that will maximize its chance of survival. Planting should be done generally between mid-March through June and mid-September through mid-October to avoid temperature extremes and frost. Table B.5 in the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control provides recommended approximate planting dates for permanent cover in Maryland. Designers may also refer to the updated 2012 Plant Hardiness Zone Map available on the USDA website and included as an appendix to this document. Regardless of time of year, to prevent damage, do not plant in soil that is unsuitable to the plant, e.g., frozen, waterlogged, compacted, or during a drought. Planting should be done in an appropriate season, but the administrator may create a mechanism to release part of a bond after only mulching the BMP if construction happens in extreme weather seasons; the remaining bond may be returned after planting within the BMP is successful.

Care must be taken to ensure that all vegetation is planted when it is received to prevent death or extensive damage. In this way, timely planting will prevent waste of resources. Plants should be installed as soon as possible after they are received, but should be planted no later than 1-2 days after delivery to increase the chance of survival. If it is not possible to plant immediately, vegetation should be stored in a cool and shaded location with roots covered to protect them from extreme temperature and direct sunlight. Roots should be kept moist; this usually means watering daily. Upon delivery, tickets should be checked to ensure they match the plant species, quantities, and sizes delivered. Additionally, the plants should be verified to ensure they are consistent with the species listed on the approved plans or project specifications. See *Construction Inspection of Stormwater Management Practices* (MDE, 2019) for further information on construction sequencing and inspection procedures.

While vegetation should be sourced from a knowledgeable nursery supplier that will ensure plants are in good condition and free of disease, the on-site contractor should verify that plants are in good condition when they arrive. Plants should have no obvious signs of damage, pests, or disease. This includes major leaf damage, a large portion of broken stems or branches, or an obvious infestation of insects. Leaves should not be wilted. Before installing plants, any weeds in pots or on root balls should be removed.

A mixture of grasses and woody vegetation will achieve more ground cover than the more common BMP design that includes mulch underneath a canopy of widely spaced shrubs and trees. Local administrators are encouraged to consider using low growing vegetation as an alternative ground cover to mulch, such as grasses, evergreens, ferns, or succulents, as growing conditions allow. This layer of vegetation may be seen as a “green mulch” that provides the functions of both vegetation and mulch, including preventing weed growth and erosion. Mowing should generally only be done to create access for maintenance and inspection and in cases where it will improve safety. This may require additional maintenance training to prevent cutting back or removing the wrong plants.



NOTES:

1. MINIMUM OF 3 SPECIES PER BMP.
2. OVERALL VEGETATION GROUND COVER MUST BE VISUALLY ESTIMATED AS VIEWED FROM ABOVE.

Figure 3. Illustrated example of percent cover.

The following information is intended to assist designers and plan reviewers in ensuring dense cover is established in vegetated BMPs. Horticulturists provide a recommended spacing for each species to accommodate roots and leaves, preventing overcrowding that may lead to plant death (see Figure 4 for an illustration of recommended plant spacing stated as inches on center).

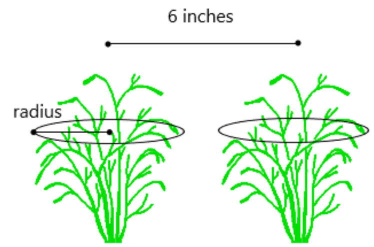


Figure 4. An illustration of planting six inches on center.

Typical plant spacing dimensions and surface areas for bioretention facilities were used to calculate an acceptable range of maximum planting densities, see Table 1.

		Total Area (square feet)				
Recommended Plant Spacing (inches on center)	**Individual Plant Spacing Area, A_i (sq. ft.)**	**100**	**250**	**500**	**750**	**1,000**
6	**0.2**	509	1,273	2,546	3,819	5,092
8	**0.3**	286	716	1,432	2,148	2,864
10	**0.5**	183	458	916	1,375	1,833
12	**0.7**	142	357	714	1,071	1,428
18	**1.7**	58	147	294	441	588
24	**3.1**	31	79	159	238	318
36	**7.0**	14	35	71	107	142

Table 1. Maximum number of plants that may be placed in a bioretention best management practice for a given minimum recommended plant spacing.

Table 1 assumes that all species placed in the area have the same recommended plant spacing. For example, when planting a species with a recommended spacing of 18 inches on center in a 250-square-foot area, the designer will need a maximum of 147 plants. Note that this may create 100% cover, depending on the spread of the species selected.

Equation 1 below provides a formula that allows designers to calculate the number of plants needed to achieve 85% cover based on the average plant spread:

$$\frac{\sum_1^n (X \times A_i)}{0.85} \geq A_f \ and \ \sum_1^n (X \times A_i) \ \leq A_f \qquad \text{(Equation 1)}$$

Where: n is the number of plant species;

X is the number of plants to install;

A_i is the average spread of each plant, calculated as πr^2 (sq. ft.); and

A_f is the total area of the filter bed (sq. ft.)

Because a minimum of three species is encouraged within all vegetated BMPs, Equation 1 can be expanded to calculate the number of plants needed for three species, each with a different recommended plant spacing. For example, a 500-square-foot bioretention is designed with three species that each has a different recommended plant spacing and average canopy spread.

$$\frac{\sum_1^n (X \times A_i)}{0.85} = \frac{(X_1 \times 19) + (X_2 \times 19) + (X_3 \times 38)}{0.85} = \ 500 \ sq.ft.$$

The designer decided to allocate 250 square feet to blueflag iris, 125 square feet to royal fern, and 125 square feet to swamp rose mallow. To calculate the number of plants needed, each species' section area is multiplied by 0.85 and then divided by the average spread of an individual plant's canopy:

$$\frac{(X_1 \times 19)}{0.85} = \ 250 \ sq.ft. \qquad \frac{(X_2 \times 19)}{0.85} = \ 125 \ sq.ft. \qquad \frac{(X_3 \times 38)}{0.85} = \ 125 \ sq.ft.$$

The results are shown in Table 2. Species may be planted in discrete sections or mixed throughout. Figure 5 illustrates the results from a plan view perspective.

Species	Average Plant Spread (inches)	Individual Plant Spacing Area (A_i) in sq. ft.	Total Filter Bed Area Covered (A_f) in sq. ft.	Number of Plants
Blueflag iris (*Iris versicolor*)	30	4.9	250	50
Royal fern (*Osmunda regalis var. spectabilis*)	30	4.9	125	25
Swamp rose mallow (*Hibiscus moscheutos*)	42	9.6	125	12
			500	89

Table 2. Example calculating the number of plants per species to create 85% cover within a 500-square-foot area.

Figure 5. Example illustration of a 500-square-foot bioretention with three species, with the number of plants required to create 85% cover as calculated using Equation 1. Species have been planted in discrete sections but may alternatively be mixed throughout the facility.

A simple grid may be used as a quick reference to estimate 85% cover, as shown in Figure 6.

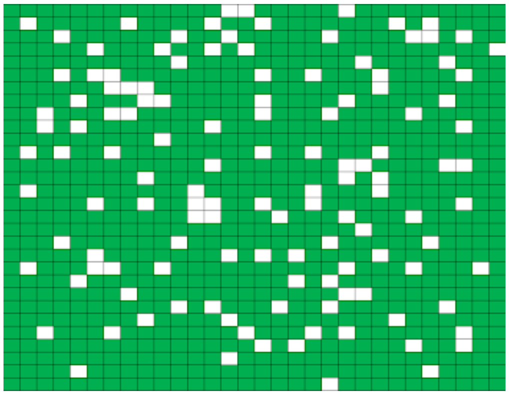


Figure 6. Example of a simple grid that may be used to estimate 85% cover within a best management practice. Green squares represent plant cover, and white squares represent bare or mulched area.

<u>Mulch</u>

Mulch has many benefits when used in bioretention, including maintaining soil moisture, decreasing surface sealing, preventing erosion, providing a microenvironment suitable for soil biota, and trapping finer sediments. However, displaced mulch can clog overflow structures and enter local waters, and the exposed underlying soil can erode. MDE has observed floating mulch in BMPs throughout the State of Maryland. Local program administrators have also reported instances of mulch floating in bioretention during ponding, and are seeking additional guidance on correcting this issue.

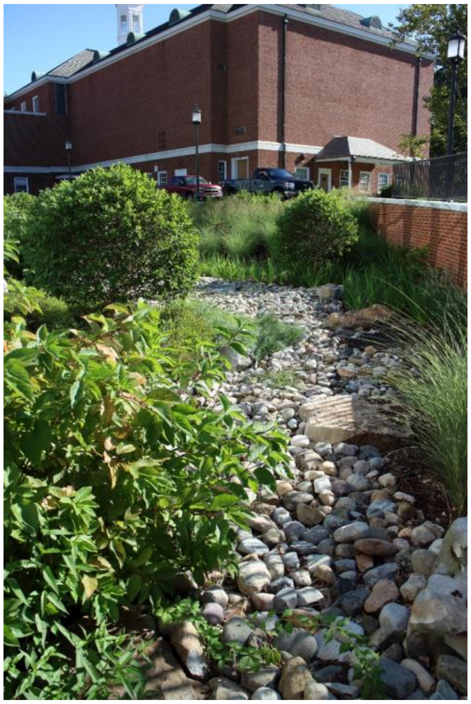
Where mulch is included in the design, MDE recommends using double or triple shredded hardwood mulches, which are thinner, finer, and stringier in shape. MDE further recommends that it be wetted thoroughly via irrigation when installed. Shredded hardwood mulch or chips should be applied to a maximum depth of 3 inches. Figure 7 shows a comparison of the more common single shredded mulch with the recommended triple shredded variety.

Single shredded hardwood bark mulch

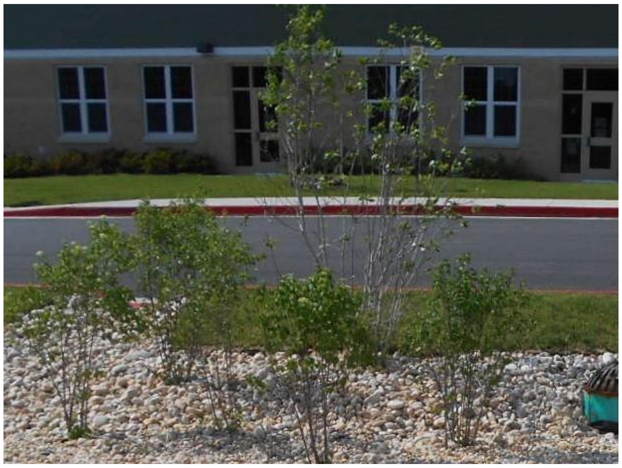
Triple-shredded hardwood bark mulch

Figure 7. Standard organic mulch versus type of mulch recommended to prevent the issue of "floating mulch".

MDE also encourages administrators to explore other solutions. Stone is acceptable to use as an alternative to prevent floating mulch. Stone should be light in color to maintain cooler water temperatures and avoid damaging any shallow roots. Stone mulch should never be used, regardless of color, in more temperature sensitive class III and IV watersheds because of its potential to raise water temperature. Stone may be angular in shape to provide extra resistance to movement, e.g., on slopes. Figure 8 shows examples of light colored stone that has been used in place of mulch.



Stone was designed to look like a stream bed in bioretention on this university campus



Stone prevents weed growth and erosion in this bioretention

Figure 8. Examples where stone was placed as an alternative to mulch.

Alternatively, BMP designs that include a layer of vegetation for ground cover minimize or eliminate the need for mulch. Plant cover reduces water velocity and helps to anchor mulch in place. Plants may also be preferable to mulch since organic mulch may be a source of nitrogen or phosphorus. An additional concern is that finely shredded mulch may form a compacted surface over time because its shape tends to form interlocking pieces, although this characteristic reduces floating. Administrators should consider adding an understory of vegetation or include short grasses in the planting scheme in place of mulch.

Non-native species, invasive species, and weeds

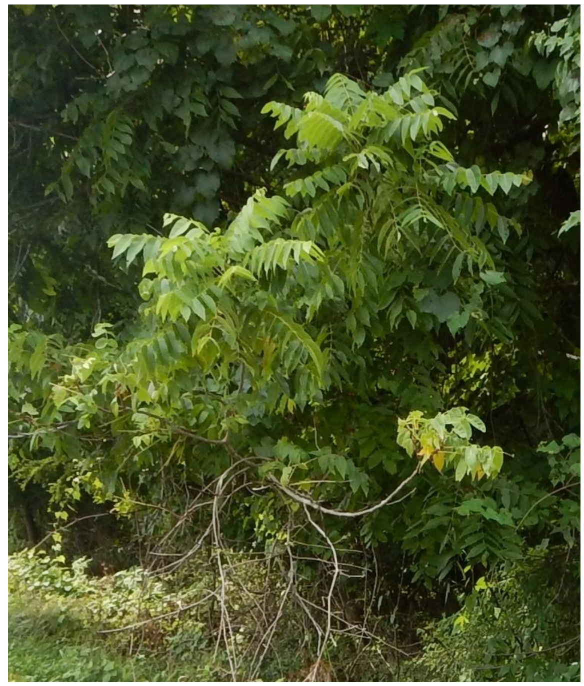
Several administrators currently use non-native species that have a local history of withstanding the more challenging conditions commonly found in stormwater BMPs, such as fluctuating water levels and road salt runoff. Non-natives are often used as temporary ground cover to exclude weeds (i.e., plants that were not part of the original plan), prevent soil erosion, and prepare soil while other species are germinating. Some non-native species may be suitable for planting although this decision is ultimately at the discretion of the local administrator.

In the Design Manual, native plants are encouraged in stormwater facilities. Because these species have evolved over time to survive in the region's conditions, they require less maintenance and replacement than exotic species that have adapted to other climates. Native species continue to be strongly encouraged. Maintenance should include removing all vines because they tend to spread quickly and become overgrown, as shown in Figure 9.

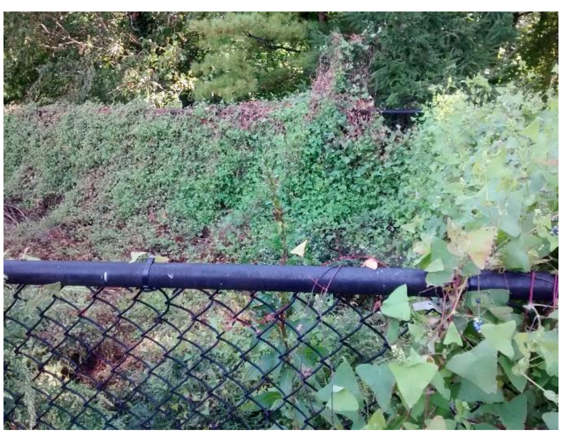
Figure 9. Although *Vitis spp.* (wild grape vine) is native to the area, it has an aggressive growth rate typical of a vine and can quickly become overgrown in a BMP, shown here growing on the edge of a property near a stormwater BMP.

Both the Maryland Department of Natural Resources and the Maryland Department of Agriculture have policies and strategies to manage and eliminate species that are classified as invasive or noxious. MDE considers these species unacceptable in all stormwater BMPs and should be removed as they are identified during inspections and maintenance. Figure 10 illustrates a few examples of invasive species commonly found in Maryland.

Sorghum halepense (Johnson grass)



Ailanthus altissima (tree of heaven)



Persicaria perfoliatum (mile-a-minute, tearthumb)

Phragmites australis (common reed)

Figure 10. Invasive species commonly found in or near Maryland stormwater BMPs.

Maintenance and management

Inadequate maintenance is a frequent issue for many possible reasons, including limited resources, a lack of knowledge, or miscommunication regarding maintenance responsibility. The simplest way to minimize maintenance effort is to choose plants that are low maintenance. This includes species that require minimal trimming and fertilizer, and plants that are well matched to the soil and climate. Plants that require little work are more likely to survive in the event of ownership transfers since their maintenance legacy is minimal. If new owners do not fully understand the function of a BMP or have limited resources to maintain it, vegetation that does not need a large amount of care has a greater chance of continuing to thrive. Seasonal staff who are not familiar with local facilities and who may not have extensive training will also be better able to manage low maintenance plants.

It is important to budget for eventual replacement regardless of which plants are selected, but choosing long-lived plants and perennials will extend the time until new plants must be purchased. Cultivars of native species may have shorter life spans, and varieties should be carefully chosen and replacement costs considered when budgeting. Similarly, germination may not occur if a mulch layer is placed over self-sowing annuals.

It is often not feasible to hire dedicated staff for vegetation maintenance, and seasonal staff may not have the horticultural background to enable them to easily distinguish weeds among diverse plants, and may inadvertently mow or pull incorrect vegetation. One innovative solution that has been implemented locally is to plant in simple patterns, such as creating groups of four plants in a square shape or planting species separately from each other in clusters or bands, so that weeds are easily recognized. Although the Design Manual recommends random and natural looking planting arrangements, in these examples, regular groupings have greatly improved maintenance accuracy without detracting from aesthetics or water quality benefits provided, and without being contrary to the overall intent of the Design Manual. Figure 11 provides examples of simple plant layouts.

Species were grouped into bands or strips. Photo credit: Javier Moreno, Montgomery County Department of Parks

Species were grouped into clumps. Photo credit: Cornelia Sarvey, Montgomery County Department of Parks

Figure 11. Examples of simple geometric layouts for plants to allow maintenance staff to easily distinguish weeds from desirable plants. Photos courtesy of Erin McArdle, Montgomery County Department of Parks.

To ensure it is clear who is assigned to perform maintenance, formal agreements must be in place that contain clear and specific language for replacement of dead vegetation and any assurance measures such as the withholding of bonds, deeds, or as-built drawings. For example, the administrator may require that the contractor ensure that 85% of all planted vegetation survives for the first year or else the maintenance contractor is responsible for the cost and labor of replacing it. A vegetation survival agreement may be established with the plant supplier and/or with the maintenance contractor. Maintenance responsibilities may be assigned to any entity, including a homeowner association, the nursery, a subcontractor, or the local administrator, as long as all responsibilities are clearly designated. Program administrators may also find it useful to require bonds for planting and maintenance, or withholding of use and occupancy certificates or deeds. If a homeowner's association is responsible for BMP maintenance, the association management documents and any associated fees should contain provisions to inspect and maintain the BMP as needed.

MDE further requires that administrators implement written standard operating procedures for inspection and enforcement of BMP vegetation guidelines. Procedures must be clearly communicated to all involved parties. Standardized, regular inspections reduce the likelihood that vegetation issues will become severe before they are observed. Clear enforcement procedures increase the efficiency with which issues are resolved. These measures can improve compliance rates when reviews of bioretention facilities are regular and consistent, and progressive enforcement measures exist for non-compliance.

In some instances, the species listed on the BMP planting plan do not survive because they are not suited to the local conditions or the specific site's conditions. If vegetation naturally establishes itself in the BMP, as long as it is not invasive, noxious, or a vine, that vegetation may be maintained. Although not the species originally called for in the design, it provides stable ground cover that prevents erosion of bare soil. However, the administrator must determine why the planned vegetation failed and examine whether those species should be excluded from future design approvals (see section titled "Species Selection"). MDE cautions that volunteer species may have aggressive rates of growth or reproduction and therefore may require more effort to restrict their growth to within the BMP and maintain the designed storage volume.

MDE discourages the use of pesticides (including insecticides and herbicides) in any capacity that is in a drainage path, including in stormwater BMPs and at outfalls. Introducing pesticides into the water flow to control weeds, insects, or other pests is counter to the premise that stormwater BMPs are treating runoff to remove pollutants. MDE has observed in various locations that bare soil was created from repeated chemical application, leading to erosion of pond slopes and sediment loading of the waterway. While it is more challenging to control weeds without chemical application, resources are available to determine alternative control options, including local horticultural companies, the Maryland Department of Natural Resources, or the University of Maryland Extension.

Similarly, fertilizers should not be applied to BMP vegetation during routine maintenance. Stormwater BMPs are designed to capture nutrients in runoff and therefore should not be a source of nitrogen or phosphorus. While a minimal amount of fertilizer may be necessary in some cases to initially establish vegetation, it should not be used during routine maintenance.

Working with homeowners, the public, and onsite staff

Public understanding and acceptance are important for BMPs that are visible to the public, such as on a homeowner's property or in commercial and retail spaces. Experiences throughout the State have shown that this can have a significant impact on BMP success. Local program administrators have described examples where residents have contacted them requesting to remove a BMP that was unattractive, or where a steep unfenced area of riprap was viewed as a safety hazard, or where a pond was regarded as mosquito habitat. In contrast, residents have contacted local government agencies requesting a rain garden after seeing a successful one in a neighbor's yard.

Safety should be a primary consideration in designing and maintaining BMPs that are accessible to the public. Avoid sudden drops and steep slopes next to houses and sidewalks. Consider installing a fence, rope, or hedges to discourage access to detention basins. Taking into consideration potential safety issues will make citizens more amenable to accepting BMPs near their homes.

Creating an attractive BMP usually includes selecting a higher number of species, including a collection of plants that are in bloom three to four seasons out of the year or otherwise have visually interesting traits, such as berries, fruits, bright stems, leaves, or bark. As the Design Manual currently states, aesthetics should be one of the primary considerations. When a BMP looks good and fits well within the property layout, it is more likely to be maintained and may even be seen as an amenity that increases property value.

MDE has observed that if homeowners do not understand the function of BMPs located on or near their property or believe they are only decorative, those installations may not receive the necessary upkeep to continue functioning properly. MDE has observed instances of BMPs on private residences that were modified by planting exotic plants and installing sprinkler systems, or converted to storage areas for household items and trash, or removed within a short time after installation. Actively educating the public, such as through one-on-one discussions, mailed pamphlets, and clear signage in public spaces, is essential to success. It is similarly important to educate onsite staff at private businesses and on government properties where BMPs are present. When the public and employees are knowledgeable about the functions of local BMPs, they can serve as a second set of eyes and hands for the administrator, ensuring those facilities are maintained in the long term in a more cost effective manner. MDE encourages administrators to consider the role that citizens and staff can play in enhancing local stormwater efforts.

Financial incentives may help BMP maintenance on private properties. Rain gardens and rain barrels can be installed as part of a cost-share program or stormwater fee rebate program. When homeowners contribute even a small amount of funding to a project, it is much more likely that they will accept and maintain the BMP.

Training

MDE has observed higher quality vegetation where local program administrators employ more extensively trained staff. Knowledge in landscaping or gardening improves one's ability to identify and correct issues with vegetation. MDE acknowledges that it is not always possible with limited resources to achieve this, and encourages innovative, cost-effective solutions wherever possible.

Local program administrators may determine that it is more efficient to subcontract any or all aspects of BMP vegetation, including design, installation, and maintenance. Alternatively, administrators may opt to require in-depth training for in-house staff and subcontractors. A third option is to create or acquire simple reference materials. This may be a checklist or timeline, and may summarize information such as watering and pruning instructions, or troubleshooting common issues. Administrators in the region have begun to develop these types of materials. High quality nurseries are staffed by knowledgeable professionals and often offer seminars, presentations, and informational materials such as quick reference plant identification pamphlets. Agriculture extension programs also offer vegetation guidance. MDE encourages seeking out training opportunities and sharing knowledge and materials among each other.

Scientific literature review

Extensive research has been conducted to determine the ability of vegetation to manage flood waters, remove pollutants, reduce soil erosion, and provide food and shelter for wildlife. Vegetation has been observed performing all these functions both in the natural environment and in areas constructed to manage stormwater and wastewater. However, the extent that vegetation performs these activities is dependent on many factors, including species, plant diversity, soil properties, retention time, and vegetation harvesting. Improved facilities can be created through better understanding of how these factors contribute to success of stormwater BMPs.

Key to stormwater management is vegetation's ability to slow the rate of water flow, which can increase water storage and pollutant retention (Davis et al., 2009), and lengthen the concentration time for stormwater runoff. All of these contribute to reduce flooding downstream (Davis, 2008). The volume of water captured by bioretention practices and the reduced rate of outflow measured during the 2008 study demonstrated that these practices "can be an effective technology for reducing hydrologic impacts of development on surrounding water resources." As Li et al. explained, improved water management reduces downstream channel erosion and promotes groundwater recharge (2009). Despite the "enormous repercussions on the hydrologic cycle and corresponding water quality" that increased impervious area can have, bioretention can reduce this impact by capturing and treating stormwater. However, Shuster et al. observed that a balance must be found in design of vegetated BMPs, specifically rain gardens, to create a soil that is permeable enough to allow adequate infiltration but not so much that it creates too short a retention time (2017).

Roots increase the porosity and permeability of soil in vegetated BMPs that in turn promote infiltration. Vegetation on the banks of streams and wetlands has been found to dissipate energy during flooding from storm events because the plants act as a physical buffer to slow water flow (Castelle et al., 1992; Lee and Scholz, 2007). As described by Castelle et al., plant matter obstructs and slows flow, allowing greater infiltration and reducing the erosion potential of stormwater runoff. Vegetated areas provide ground cover that can reduce erosion and facilitate sedimentation (Warford and Zedler, 2002). Plants also contribute to volume management through the ability to remove a significant amount of water via evapotranspiration (Li et al., 2009). However, maintenance is essential because accumulation of vegetation has been shown to reduce water storage capacity in constructed wetlands (Lee and Scholz, 2007). As plants lose their leaves seasonally, organic matter accumulates and reduces a stormwater BMP's storage volume.

Studies have shown that vegetation also increases the uptake of nutrients such as nitrogen and phosphorus (Zhang et al., 2011; Henderson et al., 2007; Lucas and Greenway, 2008). Zhang et al. found that nitrogen removal was greater in stormwater biofilters (treatment trains of vegetated filters) that included plants. Henderson et al. observed that the greatest nitrogen and phosphorus removal rates occurred where vegetation was present across soil compositions, and further found that nutrients did not leach from pots where vegetation was present despite being flushed with tap water. When "synthetic stormwater" containing nitrogen and phosphorus was applied in an experiment by Lucas and Greenway, retention of nitrogen and phosphorus was greater in pots with vegetation. Davis et al. (2006) measured high uptake of phosphorus and organic nitrogen by planted creeping juniper *(Juniperus horizontalis)* in bioretention facilities located in Maryland. Although the study resulted in variable nitrate uptake, possibly due to the nutrient's high mobility, overall nitrogen reduction was documented. The authors hypothesized that because vegetation incorporates nutrients and other materials relatively slowly, retention of water in a stormwater BMP is essential.

Lee et al. found that the success of a bioretention facility at performing nutrient uptake and transformation, particularly for nitrogen transformations, is partly determined by the amount of clay and organic matter in the soil (2009). Nutrient removal and transformation occur by vegetation and the microbial breakdown in the soil immediately adjacent to the plant roots. This root zone "facilitates various physical and biochemical processes caused by the relationship of plants, microbial communities, soil and contaminants." Shuster et al. found that rain gardens with a thick organic surface layer had greater resilience to sediment loading and greater hydrologic effectiveness (2017), and Davis et al. found that an organic mulch layer increased nutrient uptake (2006).

Uptake of the heavy metals copper, lead, and zinc, which are found in urban runoff, also increased in vegetated bioretention facilities during experiments performed by Davis et al. (2003), especially with increased soil depth. However, a study by Calijuri et al. (2010) found that accumulation of heavy metals in leaf and stem tissues was relatively low compared to in root tissues, necessitating full plant removal instead of mowing if managers wish to remove the accumulated metals from the bioretention areas. Ladislas et al. (2013) also observed that fully replacing plants is the most effective manner to harvest plant tissue in which pollutants have accumulated. The authors suggested that this is practical only with smaller plants because it can be expensive to frequently replace plants.

In addition to nutrient uptake, the partial settling of nutrients and metals within bioretention soil helps prevent their movement downstream where water quality can be negatively affected. Calijuri et al. (2010) found that increased water retention time improved a constructed wetland's ability to remove pollutants from the water via both plants and settling of suspended pollutants.

Liu and Davis (2013) studied whether soil amendments enhanced active wastewater treatment in wetland bioretention facilities. Phosphorus was bound to aluminum and iron ion soil additives, and phosphorus leaching was reduced even in media that was already high in initial phosphorus concentration. However, MDE notes that the soil composition must consider the BMP's purpose, including providing the specified infiltration rate, providing suitable growing conditions for the species selected, in addition to performing any pollutant mitigation.

Although there is evidence that vegetation contributes significantly to meeting stormwater management goals, the particular plant species present is one of the factors on which performance is dependent. For example, species should be chosen that have a greater ability to withstand the varying water levels found in stormwater facilities, described by Warford and Zedler (2002) as "flashier." Stormwater basins, in contrast to natural wetlands, have "different timing, frequency, and duration of high water," receiving greater volumes of runoff in shorter periods of time than similar natural systems. Therefore, the authors recommended planting species that are known to be tolerant to these hydrologic patterns. Castelle and Johnson (2000) noted that deep-rooted trees and shrubs on stream banks can better anchor themselves in high water velocity conditions, similar to those that can be experienced in bioretention during storm events. Several studies have measured differences in uptake of nutrients and metals across species. For example, Read et al. (2008) found variances as great as 18-50 times in nitrogen and phosphorus uptake among 20 species. Milandri et al. (2012) observed uptake differences among nine species in biofilters. The highest nitrate uptake was measured for species with higher growth rates; additionally, soil composition played a significant role in the removal of phosphate and ammonia, regardless of plant species.

Ladislas et al. (2013) found that greater pond sedge *(Carex riparia)* had a greater ability to uptake cadmium, nickel, and zinc compared to soft rush *(Juncus effusus),* although both species were able to absorb a significant amount of all three metals, which are common elements in urban stormwater runoff. The uptake rate for both plants increased as metal concentrations increased, and uptake was done in particular by the roots. These findings highlight the complexity of factors that influence vegetation performance.

MDE encourages the planting of species that are native to Maryland (MDE, 2009). Because native species have evolved to live in the region's climate, they have distinct genetic advantages that may result in greater survivorship and less replacement and maintenance. The Prince George's County Bioretention Manual (2007) points to natives' greater ability to tolerate local stresses. However, it is critical that natives be identified that can tolerate the stressful conditions of stormwater BMPs. In order to deter invasive species and weeds, Warford and Zedler (2002) planted a fast-growing species concurrently with a slower growing native that would grow to a larger size. This combination provided immediate cover and established larger plants in the long term. Quick establishment of ground cover is an especially important consideration for urban stormwater facilities because runoff that contains fertilizers can facilitate the establishment and growth of common invasive species such as common reed (*Phragmites australis*) (Rickey and Anderson, 2004).

Regardless of species choice, Wang et al. (2010) found that greater individual plant biomass correlated more strongly with higher nutrient removal rate than any other factor when measuring nitrogen and phosphorus accumulation in a mixture of introduced and naturally occurring species in a constructed wetland. Greenway and Woolley also observed that increased nutrient uptake occurred as plant biomass grew over consecutive years (2001). This can be attributed to the greater nitrogen and phosphorus required by larger plants to perform photosynthesis and grow. Although several studies have found species to be the determining factor in measuring water quality treatment, in many studies a large amount of vegetation was key.

Greenway and Woolley (2001) also found that the presence of many plant species increased nutrient uptake, despite lower total retention times. Nutrient removal was maximized by a high diversity of wetland species and types of plants (e.g., floating, submerged), and plants performed greater nutrient uptake even with higher nutrient loading rates.

As stated in the Design Manual, stormwater BMPs should have a high biodiversity that mimics natural hydrologic areas. A survey of literature published from 1960 through 2003 found that for the majority of studies reviewed, there was a positive correlation between species diversity of plants and the number of animal species that were supported (Tews et al., 2004). These findings support the hypothesis that more complex habitats, i.e., those with a greater number of vegetative species, increase the potential number of wildlife species that are supported by them (Macarthur and Wilson, 1967; Fisher et al., 2009). More complex plant communities create resources for a greater array of consumer species (Bazzaz, 1975). Therefore, high plant diversity creates improved water management but also creates areas that integrate well into the surrounding natural ecosystem.

Mulch is discussed in this MDE guidance document because of its common presence in stormwater BMPs. Research on alternatives to mulch supports the recommendations made previously in the MDE Design Manual. The primary goal of an investigation by Simcock and Dando (2013) was to identify mulches that did not float while still being appropriate for bioretention. The study demonstrated that shredded hardwood mulch had the least likelihood of floating compared to other mulches such as bark nuggets, and that triple shred hardwood mulch was least likely to float compared to single and double shred, presumably because of its more fibrous nature. The triple shred material bound together more tightly to resist displacement. The study identified three methods to suppress floating: adding 25% (by volume) compost or crushed shell, composting mulch to the point of increasing wet bulk density and speed of wetting, and shredding mulch into thinner, finer, stringy shapes. In addition to incorporating these methods and selecting non-floating mulches, three recommendations were identified to reduce floating: wetting organic mulches thoroughly at time of installation, designing to receive sheet flow or reinforcing with stone such as riprap any areas that have concentrated flow, and establishing a dense plant cover within the first two years to reduce the use of decorative mulch and the depth of mulch.

Current references in the Maryland Stormwater Design Manual

Appendix A of the Design Manual provides guidance for the establishment and maintenance of vegetation in stormwater BMPs. Advice was developed in the Design Manual for stormwater ponds and wetlands, infiltration and sand filter practices, bioretention, open channels, and filter strips and buffers. The following is a brief summary of key topics for which this memorandum provides clarification.

The Design Manual emphasizes the importance of plants in improving the function and appearance of stormwater BMPs. Plants provide food and habitat for wildlife and can provide aesthetic value. Vegetation can create safe and attractive barriers that restrict public access to hazardous areas. As the Design Manual states, “Aesthetics and visual characteristics should be a prime consideration.” Healthy vegetation can make facilities more attractive to the public and increase property values by screening unattractive views, providing it does not block pathways or prevent needed views, e.g., at road intersections.

While the Design Manual has basic requirements and provides guidance, it was created to serve as a starting point for local administrators. In a series of seminars conducted by MDE in October 2013, the Department explained that the “use of innovative solutions to unique problems is encouraged on a case-by-case basis.” This summarizes the philosophy of the document, which should be tailored to each administrator’s needs beyond the recommendations and requirements specifically listed.

Appendix A provides an alphabetic list of herbaceous and woody species that can be included in stormwater planting plans. For each species, the guidance lists common and scientific name, hydrologic zone, indicator status for suitability in wetlands, United States Department of Agriculture (USDA) hardiness zone, and whether each species tolerates salt or pollution. Since Appendix A was published, an updated 2012 Plant Hardiness Zone Map has been released to the public and is available on the USDA website, as well as included as an appendix to this document.

Specifically regarding trees, the Design Manual states that no woody vegetation is allowed on a dam embankment or within 15 feet of the toe of slope of the embankment and that vegetation on embankments must be a maximum of 10 inches in height. Trees and shrubs must be placed away from low flow orifices to prevent clogging. Additionally, they must located at least 25 feet away from perforated pipes and principal spillways to prevent roots or limbs from damaging structures. Vegetation in emergency spillways must have substantial roots that withstand strong flows, but that do not have a taproot. Trees or shrubs must never block maintenance access.

When selecting a number of species to plant, bioretention must have “diverse, dense plant cover” to better treat runoff and withstand urban stresses such as disease, pests, and drought. No minimum number of species is mandated. However, monoculture turf areas must be avoided because they typically require intensive chemical application, and because turf roots are shallow and do not promote infiltration as other species do. Dense, low maintenance ground cover must be planted instead to absorb runoff. Buffers must be planted with a combination of trees, shrubs, and grasses where possible to perform multiple functions from stabilizing banks to providing shade.

The Design Manual provides a limited amount of information on amount of vegetative cover and distribution. A “random and natural” layout must be planted to simulate an upland-species ecosystem. The layout must generally be partitioned into three hydric zones so that appropriate plants are planted in wet, fluctuating, and upland areas. In ponds and wetlands, dense tree cover can reduce maintenance and deter geese. When installing a stormwater BMP in poor soils that cannot be amended, vegetation must be chosen that establishes ground cover as quickly as possible.

With regard to planting seeds versus plugs, the Design Manual states that it may be more cost effective to source wetland seed mixtures from nursery suppliers if they are available. All purchased seed mixes must include plants that will tolerate wetland conditions, and mixes must list the proportion of each species included. A seed mix prepared by a nursery that includes wetland, upland, and riparian plants may be preferable in smaller stormwater facilities, e.g., pocket wetlands and open swales, or may be seeded along with woody plantings in larger bioretention areas.

The Design Manual recommended that any mulch included in the design must be comprised of a uniform layer of single or double shredded hardwood mulch or chips, at least three inches in depth. Mulch must be well aged, for a minimum of twelve months. Additionally, both Appendix B.3.B and Appendix B.4.C of the Design Manual indicate that 2" to 3" of shredded hardwood mulch must be spread over the surface of bioretention facilities. MDE provided updated recommendations in this stormwater vegetation technical memo to solve the issue of floating mulch.

Native plants are encouraged in stormwater facilities because of their "greater survivorship" and tendency to require "less replacement and maintenance." Existing natural vegetation must be preserved whenever possible.

Wetland plants should be planted generally between early April and mid-June so that plants have time to establish roots that will survive the winter. Plants should be ordered at least three months in advance to ensure availability.

The Design Manual strongly encourages planting of vegetation that has very low maintenance requirements, especially if BMPs are difficult to access. When choosing plants, designers must consider the "maintenance legacy" that is passed on to future owners and choose plants that are appropriate for the BMP conditions. Additionally, a maintenance agreement for future owners must be created that ensures vegetation is maintained in perpetuity.

Representative samples of soil must be analyzed to determine properties such as pH, nutrient content, and mineral content. Plants must be chosen that have a high chance of thriving in the particular site's soil conditions. Soil may be amended if needed to improve quality. The top 3-5 inches of soil must be loosened, and 4-8 inches of topsoil must be placed on top and lightly compacted.

Current references in guidance by local agencies in Maryland and other State agencies

Guidance documents have been created at the State and local levels throughout the region to provide information on establishing high quality stormwater BMPs. Many aspects of vegetation have been discussed in these documents, which MDE has considered in creating this memorandum. The following is a selection of stormwater vegetation requirements and recommendations from regional agencies.

The Maryland Nontidal Wetland Mitigation Guidance (MDE, January 2011) specifies that emergent wetlands must include three species by the end of the second growing season. The Prince George's County Bioretention Manual (2007) requires three species in submerged gravel wetlands, and in forested and forest fringe bioretention there must be three tree species and three shrub species. The Roadway Vegetated Stormwater Facility Landscape Guidelines prepared by the Montgomery County Department of Environmental Protection (January 2014) require two to six species in bioretention, and within this range there may be fewer species in smaller facilities. In rain gardens and bioretention, the Pennsylvania Stormwater Best Management Practices Manual of the Pennsylvania Department of Environmental Protection (PADEP) (December 2006) recommends three species of shrubs and three species of trees.

In Stormwater Design Specification No. 9 "Bioretention" Version 2.0, the Virginia Department of Conservation and Recreation (VADCR) (January 2013) requires a minimum 80% coverage within three years as well as diverse herbaceous cover. Eighty-five percent cover is required in constructed wetlands (and in sand filters when vegetation is included in the plan) by the New Jersey Department of Environmental Protection (NJDEP) Stormwater Best Management Practices Manual (November 2014) and the Citizen's Guide to Nontidal Wetland Mitigation Monitoring (MDE, February 2011). The Maryland Nontidal Wetland Mitigation Guidance (January 2011) requires 45% vegetative cover in constructed wetlands by the end of the second growing season, 70% by the end of the third season, and 85% by the end of the fifth season. Chapter 7 "Landscaping" of the NJDEP Stormwater Best Management Practices Manual (September 2009) requires a "diverse, dense plant cover" in stormwater BMPs, similar to Maryland's Design Manual. The Georgia Stormwater Management Manual requires "dense and vigorous" vegetative cover (2001). With respect to layout, VADCR recommends that plants preferring wetter conditions be planted nearer the center where water pools, and non-woody vegetation should be planted in clusters (January 2013).

Vegetation replacement is required by VADCR at 15% failure for herbaceous vegetation and for any failure for trees in bioretention (January 2013). VADCR further recommends that a qualified landscape architect be involved in design to ensure a high quality of planting plans with vegetation that is tailored to the site's specific conditions and selected based on the amount of resources available to maintain the BMP. The updated Chapter 9.2 Standard Constructed Wetlands of the NJDEP Stormwater Best Management Practices Manual (November 2014) states that vegetation must be replaced upon failure of 50% of constructed wetland vegetation. PADEP (December 2006) requires replacement after failure of 20% of bioretention plants and recommends an experienced landscape architect to design a layout of native plants in rain gardens and bioretention. It is further recommended that trees and shrubs be planted in rain gardens and bioretention generally only from mid-March through June or mid-September through mid-November to reduce risk of transplants not surviving. Montgomery County's Roadway Vegetated Stormwater Facility Landscape Guidelines (January 2014) advises designers to choose long-lived plants and use caution when selecting cultivars, which are often shorter lived.

The Prince George's County Bioretention Manual (2007) encourages planting native species, citing their improved ability to tolerate stress. NJDEP also encourages native plant use and native ornamentals in particular because of the distinct genetic advantages that native species have (September 2009). However, NJDEP acknowledges the water quality and limited wildlife benefits that common reed *(Phragmites australis)* and cattails *(Typha spp.)* provide, and does not recommend spending a large amount of effort or money on eradicating them.

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Richard Wilke, PLA (Maryland Dept. of Transportation State Highway Administration)

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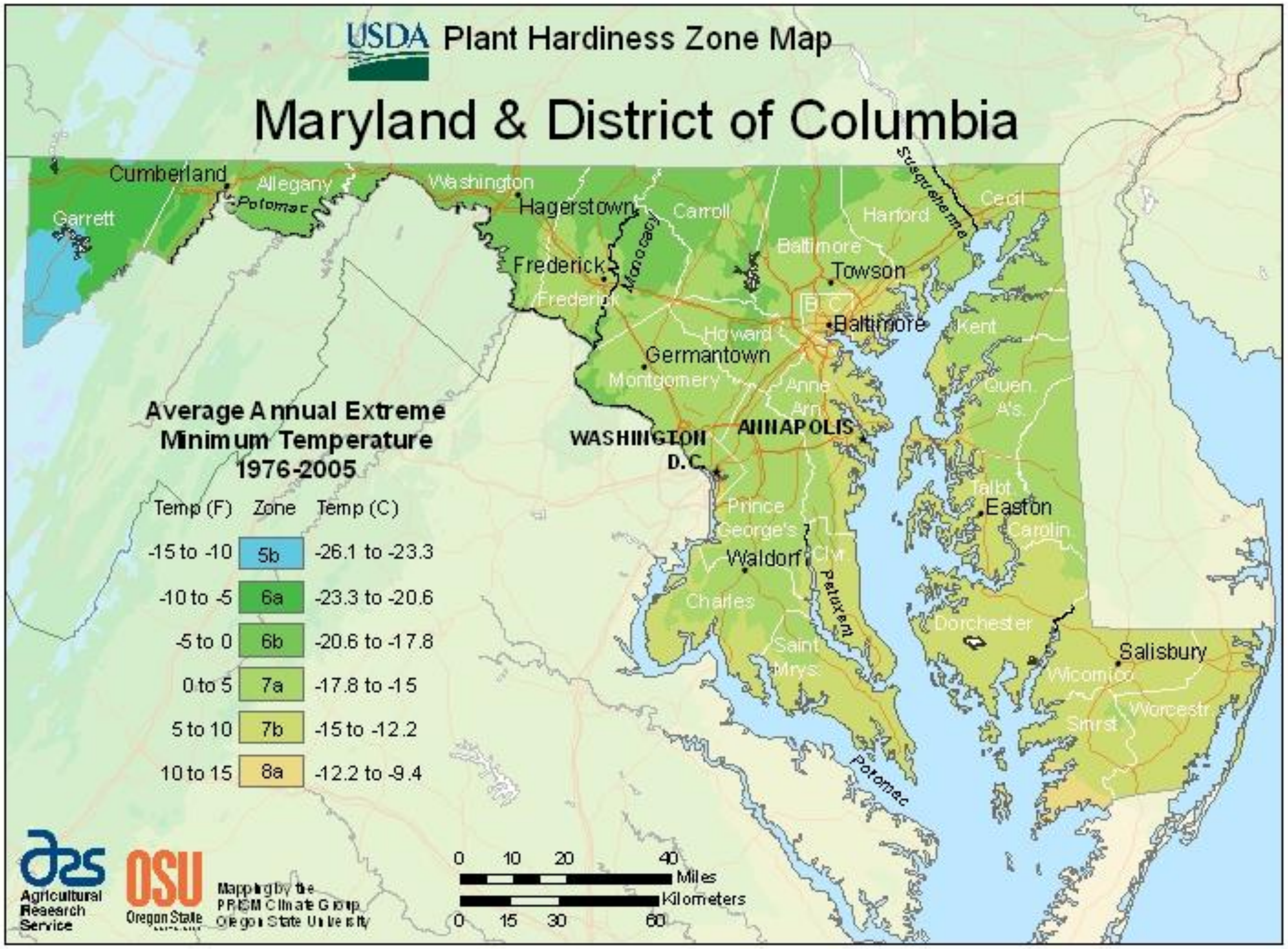
Appendix A. USDA Plant Hardiness Zone Map (2012)



Available at planthardiness.ars.usda.gov