APPENDIX G

Recommended Stormwater Best Management Practices

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RECOMMENDED STORMWATER BEST MANAGEMENT PRACTICES

Stormwater best management practices (BMPs) are defined as activities, facilities, measures, or procedures that are used to manage the volume, rate and water quality of stormwater runoff. The goal of stormwater management is to prevent or minimize stormwater problems through comprehensive planning and development techniques and also to mitigate potential problems through the use of nonstructural or structural BMPs.

Non-structural BMP's are land use planning and design approaches that use broad approaches (such as low impact design, better site design, principals and policy that prevent stormwater generation, allow infiltration for groundwater recharge and/or other BMPs for the protection of valuable water resources). Many non-structural BMPs are best suited for predevelopment conditions and require a sophisticated approach to total site design that will translate into reduced stormwater volume and rates thus not requiring mitigation. Areas that have previously been developed, non-structural BMPs can be incorporated into post construction stormwater management programs.

Structural BMP's are specific practices or structures that are designed and engineered to address stormwater impacts during construction and post construction that are due to increased impervious surfaces. Structural BMPs are typically grouped according to their primary, though not exclusive, stormwater function. Typical functions can include: volume/peak rate reduction by infiltration, volume/peak rate reduction, runoff quality/peak rate, restoration and other BMPs.

Best Management Practices have in this report have been adapted from the PA Stormwater BMP Manual. Additional information on each BMP that is included in this report can be found in the PA Stormwater BMP Manual (DEP BMP).

AG.1 Non-Structural BMPs

Several non-structural BMPs that have the proven ability to prevent stormwater generation are the protection of sensitive and high value water features, cluster and concentrate areas to be developed, minimize disturbance and maintenance, reduce impervious cover, disconnect/distribute/decentralize, and source control. Because so many of these practices are removed from the “traditional practices” of stormwater engineering, incorporating these BMPs is challenging.

AG.2 Protect Sensitive and Special Value Resources

AG.2.1 Protecting Sensitive Areas

The protection of sensitive or high quality areas to minimize stormwater impacts should include avoiding/ affecting areas that possess stormwater functional values such as floodplains, wetlands, riparian areas, drainage ways, and groundwater recharge areas.

AG.2.2 Protect, Conserve and Enhance Riparian Areas

Riparian areas provide a transition between aquatic and terrestrial environments that help maintain the hydrologic, hydraulic, and ecological integrity of the stream channel. Vegetated buffers are one of the most functionally beneficial and biologically diverse systems that provide services of great economic and social value. Benefits derived from vegetated riparian buffers, especially forested buffers, include water quality enhancement, stormwater and floodwater management, stream bank and shoreline stabilization, water temperature modification, wildlife habitat protection, and absorption of airborne pollutants. These benefits can translate into increased quality of life and real savings for the community.

Traditionally, buffers were viewed as a way to control the quantity and quality of stormwater runoff for erosion and sediment, but did not necessarily address issues related to the effects of infiltration and the quality of groundwater. A buffer’s value lies not only in the ability to moderate erosion and sedimentation, but also in the ability to improve water quality in groundwater and surface water runoff, increase the base flow of streams, provide a biologically diverse habitat and can become greenways and recreation areas for outdoor enthusiasts.

An important function of the riparian buffer is to slow the rate of runoff, increasing the potential for infiltration. The recharging of the groundwater is important for maintaining wells and supplying the baseflow waters that feed streams. Forested buffers, because of their absorptive capacity, moderate the effects of flooding as well as the consequences of drought (VA DCR).

AG.2.3 Protect and Utilize Natural Flow Pathways

Instead of replacing a sites natural drainage features with engineered systems that rapidly convey stormwater runoff downstream designers can utilize naturally occurring swales, depressions, watercourses, ephemeral streams and other naturally vegetated areas tend to slow runoff and allow some infiltration and evapotransporation to occur, and provide open space, habitat, improve site aesthetics and property values and reduce the amount of stormwater runoff. Some practices can include the construction of slight earthen berms around natural depressions to create additional storage, installing check dams with drainage pathways to slow runoff and planting additional native vegetation. Water quality can be improved through filtration, infiltration to groundwater, sedimentation, and thermal mitigation.

AG.3 Cluster and Concentrate

AG.3.1 Cluster Uses at Each Site and Build on the Smallest Area Possible

Through the practices of clustering (reducing lot sizes and/or building vertically) developers are able to accomplish their goals while minimizing environmental impacts and construction costs. Clustering reduces development costs through decreasing impacted and disturbed areas (site clearing and grading, road and sidewalk construction, curbing, less lighting, less sewer and water line connections, potentially reducing required mitigation etc.), maximizes undisturbed areas such as natural landscape and open space, allows for groundwater recharge through infiltration of the undisturbed areas,

AG.3.2 Concentrate Use Areas wide through Smart Growth Practices

Plan and zone for concentrated development patterns that can accommodate reasonable growth and development (clusters, hamlets, villages, towns and cities). Areas that are already developed can include appropriate in-fill developments and redevelopment at higher densities. Any development should include smart growth techniques such as: transfer of development rights, urban growth boundaries, purchase of development rights, donation of conservation easements, limited development and bargain sales by owners, and other private sector landowner options. These options can prevent and protect areas that are sensitive for groundwater recharge/infiltration and/or provide protection of a resource that is a “desirable sense of place” such as archaeological, scenic and aesthetic that can contribute to the improvement of the quality of life sensitivities and values.

AG.3.3 Minimize Disturbance and Soil Compaction

Minimize total disturbed area (grading), minimize soil compaction in disturbed areas ensuring topsoil quality for maximizing water-holding capacity for effective cycling nutrients, minimizing runoff and erosion and maximizing the sites ability for recharge.

AG.3.4 Re-Vegetate and Re-Forest Disturbed Areas Using Native Species

The reduction of landscape maintenance through planting native species and reducing landscaped mowed areas will reduce and/or eliminate chemical and fertilizer applications to the site. Native species are better adapted to weather conditions within their native range and provide the long-term effects of significant reductions in runoff volumes, increased infiltration, evapotranspiration, and recharge when contrasted with conventional lawn planting.

AG.4 Reduce Impervious Cover

Imperious cover can be accomplished through the relaxation of road requirements (reduce paved road width, turning radii, parking spaces) use paving blocks (pervious overload parking), porous pavement, reduced and/or shared parking spaces, smaller front yard setbacks etc. Functions of reduced impervious cover include infiltration, reduces stormwater runoff and pollutants.

AG.5 Rooftop Disconnection

Routing rooftop to naturally vegetated areas (on-lot swales bioretention areas etc.) will reduce runoff volume and peak discharges as well as improve water quality by slowing runoff, allowing for filtration and providing an opportunity for infiltration and evaoptranspiration to take place.

AG.6 Disconnection from Storm Sewers

Redirecting runoff from impervious streets and driveways to vegetated swales, infiltration trenches, bioretention areas or other vegetated systems designed to receive stormwater will minimize a large percentage of rapid-transport of post-development imperviousness runoff. Removal of curbs and elimination of gutters and other conventional collection and conventional from stormwater systems will allow for increased infiltration and evapotranspiration, increased infiltration that can provide on-site treatment and pollutant removal of stormwater mixing with atmospheric deposition, toxic chemicals, oil and metals. Thermal impacts can also be minimized through the redirection of stormwater from these areas and are a good treatment option within watersheds that drain into cold water streams because they do not pond water for a long period of time and will not typically be subjected to solar warming.

AG.7 Structural BMPs

Most structures are natural system based and include both soils and vegetation as mechanisms as part of their functioning and focus efforts on volume/peak rate reduction that can possess excellent water quality protection capabilities as well. It must be noted that site evaluation and soil infiltration testing should be conducted and infiltration systems and design and construction guidelines should be followed whenever infiltration-oriented BMPs are being developed. By following protocols failed infiltration BMPs will be minimized.

AG.8 Volume/Peak Rate Reduction by Infiltration BMPs

AG.8.1 Pervious Pavement

A permeable surface that is underlain with a uniformly-graded and clean-washed coarse aggregate provides temporary storage for peak rate control, promote infiltration and can help lower high water temperatures commonly associated with impervious surfaces. Stormwater pools on the surface of conventional pavement, where it is heated by the sun and the hot pavement surface. By rapidly infiltrating rainfall, porous pavement reduces stormwater's exposure to sun and heat. With pervious surfaces, stormwater drains through the surface, is temporarily held in the voids of the stone bed, and is allowed to drain into the underlying uncompacted soil. Pervious pavement works well in parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts and other similar areas. Properly installed and maintained has a significant life-span and existing systems that are more than 20 years in age continue to function and if designed properly can work well in cold-weather environments. Variations of pervious pavement can include pervious bituminous asphalt, pervious concrete, reinforces turf and gravel filled grids, pervious paver blocks,

AG.8.2 Infiltration Basin

Infiltration basins are shallow impoundments that hold and infiltrate stormwater. Basins should ideally be created in areas that are undisturbed with relatively permeable soils, and should have or be planted with native vegetation to reduce thermal impacts to coldwater streams. The quality of runoff will be improved by the natural cleansing process of the existing soil mantle and by the vegetation.

AG.8.3 Subsurface Infiltration Bed

Subsurface infiltration beds are similar to infiltration beds in that they hold and infiltrate stormwater runoff by placing various storage media beneath the surface grade. Vegetation also provides the benefits of reducing thermal impacts and improving the water quality of runoff. Subsurface infiltration beds can be connected with roof leaders, inlets, placed under recreational fields and open spaces areas. Additional applications may be determined by design professionals as appropriate.

AG.8.4 Infiltration Trench

Infiltration trench is a continuously perforated pipe set at a minimum slope in a stone filled, level-bottomed trench that is designed to have a positive overflow. Infiltration trenches may be used as part of a lager storm sewer system, or part of a stormwater system for a small area, such as a roof, or single catch basin that is intended to convey portions of runoff in many storm events. Generally, surfaces of the trenches are gravel or vegetated grass and can be located alongside or adjacent to roadways or other impervious areas. Connections to roof leaders, inlets and in combination with vegetative filters are other common ways to include infiltration trenches within a design.

AG.8.5 Rain Garden/ Bioretention Bed

Rain gardens and bioretention beds are vegetated surface depressions that are becoming more popular as developers become aware of their ability to provide infiltration of stormwater runoff for groundwater recharge, ability to provide runoff pollution reduction and also meet landscape requirements. Downspouts can be directly connected to bioretention areas instead of the stormdrain. Native vegetation that is tolerant of hydrologic variability should be planted to reduce stormwater thermal impacts, allow evapotransporation to occur, provide habitat, and improve site aesthetics and property values. Additionally, rain gardens can be incorporated into pre-development designs or be part of an area that is to be retrofitted. Some common areas where these BMPs are used are next to curbs or curb cuts, trench drains, residential on-lot, commercial/industrial/institutional areas, along roads and highways, in or adjacent to parking lots, within the center portion of cul-de-sacs etc.

AG.8.6 Dry Well/ Seepage Pit

A dry well or seepage pit is a subsurface facility that is used for the infiltration and temporary storage of rooftop runoff that provides adequate overflow for large storm events. By capturing runoff at the source, dry wells can reduce the increased volume of stormwater runoff, which are one of the most important sources of new or increased runoff volume from developed areas.

AG.8.7 Constructed Filter

A constructed filter is an area that has been excavated and filled with materials that are designed to filter stormwater and improve water quality. Filter areas may be designed for infiltration. There are a wide variety of filter applications, including surface and subsurface, contained, vegetated, perimeter, infiltration and others.

AG.8.8 Vegetated Swale

Vegetated swales are broad, shallow channels that are designed to slow run off and provide a wonderful alternative to conventional curb and gutter systems. Swales additionally can provide added benefits of pollutant removal, sedimentary filtering, and infiltration. Variations can include vegetated swale with infiltration trench, grass swale, wet swale, etc.

AG.8.9 Vegetated Filter Strip

A vegetated filter strip is defined by EPA as a "permanent, maintained strip of planted or indigenous vegetation that is located between nonpoint sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of nonpoint source pollutants such as nutrients, sediments, and suspended solids". Added benefits are also identified as volume reduction and groundwater recharge.

AG.9 Volume/Peak Rate Reduction Rate BMPs

Best management practices for peak rate reduction can include vegetated roof also known as a green roof and runoff capture and reuse techniques that are designed to capture precipitation and hold it for a period of time to be later reused. Common types of capture and reuse BMPs are cisterns, rain barrels, vertical storage, and storage beneath structures.

AG.10 Runoff Quality/Peak Rate BMPs

AG.10.1 Constructed Wetland

Constructed wetland or stormwater wetlands are shallow marsh systems planted with vegetation that is adapted to wet conditions and can treat stormwater runoff. The shallow water is easily warmed by the sun and air temperatures. The warmest water is located on the surface and when a storm event occurs, the warm runoff from parking areas or other impervious surfaces mixes with the already warm water, making the water level rise and flow into the outlet structure into nearby waterways, impacting cold water systems. Thermal impacts can be minimized by the incorporation of trees and broadleaf vegetation that can reducing direct heating by the sun, and also provide reduction of water temperatures through transpiration. Additionally, water can be drawn from the bottom of the wetland from the deepest portion of the pool at the wetland's outlet.

AG.10.2 Wet Pond/Retention Basin

Wet Ponds are stormwater basins that have a substantial permanent pool for water quality treatment and additional storage capacity for runoff. Wet ponds are typically not vegetated and are a very common stormwater management practice that is used in new construction and are similar to stormwater wetlands. Vegetate using the same principles above, and install a modified outlet structure at the bottom of the pond instead of at the top so that cooler water may drain into waterbodies. Additionally, aerate water with fountains or other devices before discharging to increase water oxygen levels. Fountains are also aesthetically pleasing.

AG.10.3 Dry Extended Detention Basin

Dry extended detention basins are surface stormwater control structures that provide temporary storage of runoff to prevent downstream flooding impacts. These basins are earthen structures that traditionally incorporate little to no infiltration, but can be retrofitted to incorporate for infiltration and planted with vegetation for added benefits.

AG.10.4 Restoration BMPs and Retrofitting

AG.10.4.1 Riparian Buffer Restoration

Buffers that are vegetated with trees and shrubs are one of the most functionally beneficial and biologically diverse systems. Benefits derived from riparian buffers, especially forested buffers, include water quality enhancement, stormwater and floodwater management, stream bank and shoreline stabilization, water temperature modification, wildlife habitat protection, and absorption of airborne pollutants.

Restoration of this habitat is a responsive action to past activities that may have eliminated any vegetation. Buffers can be planted using native trees and shrubs and are often times fenced off so that livestock can no longer impact the immediate riparian area. Tree shelters can be used, and select tree species that deer do not prefer if buffer is located in an area with heave deer populations. Minimum recommended buffer width is 35’ from top of each side of the stream bank, with 100’ on either side preferred.

AG.10.4.2 Landscape Restoration

Restoration efforts can include the restoration of forests and meadows using native plants, shrubs and trees that do not require significant chemical maintenance by fertilizers, herbicides and pesticides. Protection of and/or restoration of compacted or contaminated soils may also be a component of restoration goals. Areas should have minimal mowing (2 times per year) and minimize traditional turf lawn areas. Benefits include a greater water volume uptake, improved soil conditions, better infiltration and habitat.

AG.10.4.3 Soil Amendment and Restoration

Improving disturbed, contaminated, compacted and low organic content soils is important for reestablishing the soil's long-term capacity for infiltration and pollution control. Physically loosing of the soil, often called subsoiling, or tilling can help treat compaction. In addition, adding an amendment of organic matter to the soil, such as compost and then planting with a native, stabilizing ground cover (to prevent erosion) and planting with shrubs and trees is even more effective in efforts for restoring soils.

AG.10.4.4 Floodplain Restoration

Floodplain restoration is a natural, system-based BMP that uses native vegetation, soils, and other natural elements to mimic the predevelopment interaction of groundwater, stream base flow, and root systems (directly linked to base flow conditions). This practice can be easily integrated into initial site planning and can prevent riparian problems from getting worse or can fix problems that were caused from historical practices. Reconnecting the stream to the floodplain is an essential component of floodplain restoration and is often times associated with natural stream channel design (NSCD) techniques. NSCD techniques also include restoring the natural pattern of meanders that a stream would flow through (instead of a straightened channel) creating a more stable stream bed and bank.

AG.10.4.5 Retrofitting Existing Facilities

Retrofitting existing developed areas that did not take stormwater management practices into consideration or retrofitting existing stormwater facilities are different than designing new facilities. Often retrofits are located in highly constrained sites and need to be designed to maximize restoration objectives and not merely design toward a rule. Retrofits should add function to the watershed and will not impair existing wetlands, streams and forests. Retrofits are typically completed in watersheds where existing development is currently degrading stream quality. Designs should be completed to remedy problems such as chronic flooding problems, increase infiltration for groundwater recharge, trap trash and floatables, reduce runoff volumes to combined sewers, renovate stream corridors, reduce pollutants of concern, reduce channel erosion, create demonstration and education areas, support stream restoration and overall watershed restoration.

The six most common retrofits for stormwater storage in a subwatershed are completed through the addition of storage to existing ponds, creation of storage above readway culverts, constructing new storage below storage outfalls, creating storage in conveyance systems, road right-of-ways, and near parking lots.

The seven most common on-site retrofit locations in a subwatershed include hotspot operations, small parking lots, individual streets, individual rooftops, hardscapes, landscapes and underground.

Stormwater treatment options for retrofitting include extended detention, wet ponds, constructed wetlands, bioretention, filtering practices, infiltration practices, swales, and other retrofit treatments such as rain barrels, green roofs, cisterns, stormwater planters, dry wells and permeable pavers.

Common strategies to complete retrofit projects can include creating demonstration and educational retrofits, locating retrofits on public land, encouraging on-site retrofits in neighborhoods, bundle retrofit projects into municipal construction projects, require hotspot retrofits through permits and compliance, mitigation retrofits on public or private land, subsidize on-site retrofits on private land, trigger retrofits as part of public/private partnerships, and require stormwater treatment for redevelopment projects.

Impervious surface and soil compaction are the leading causes of decreased infiltration. Decreased infiltration can have hydrologic impacts on wetland systems, groundwater recharge and stream base flow. Proper planning for future development is essential to watershed health and sustainability for human use (adapted from the Urban Subwatershed Restoration Manual Series. *Urban Stormwater Retrofit Practices*, Version 1.0. August 2007. The Center for Watershed Protection. Manual 3).

Table AG.1: Ability to Meet Retrofit Objectives at Various Levels of Impervious Cover

Retrofit Objective	Subwatershed Impervious Cover			
	10 to 25%	**25 to 40%**	**41-60%**	**61-100%**
Correct Past Mistakes	**Achievable**	**Achievable**	**Feasible**	**Isolated**
Reduce Flood Damage	**Achievable**	**Achievable**	**Feasible**	**Isolated**
Education/Demonstration	**Achievable**	**Achievable**	**Achievable**	**Achievable**
Trap Trash and Floatables	**Achievable**	**Achievable**	**Feasible**	**Isolated**
Reduce Flows to CSOs	**Achievable**	**Achievable**	**Feasible**	**Feasible**
Renovate Stream Corridor	**Achievable**	**Achievable**	**Feasible**	**Isolated**
Reduce Pollutants of Concern	**Achievable**	**Achievable**	**Achievable**	**Feasible**
Reduce Bank Erosion	**Achievable**	**Feasible**	**Isolated**	**Not Achievable**
Support Stream Restoration	**Achievable**	**Feasible**	**Isolated**	**Not Achievable**
Full Watershed Restoration	**Achievable**	**Feasible**	**Isolated**	**Not Achievable**
KEY				
Achievable - Objective can normally be widely achieved across a subwatershed				
Feasible - Objective may be feasible, depending on individual reach characteristics				
Isolated - Objective can only be achieved in isolated reaches in the subwatershed				
Not Achievable - Objective is generally not achievable in the subwatershed				

Adapted from the Urban Stormwater Retrofit Practices Manual. Version 1.0. Manual 3. Center for Watershed Protection