4 Integrated Site Design

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4.0 Introduction

A recommended site design procedure for comprehensive stormwater management is set forth in this section. The site design procedure is based on the Pennsylvania Department of Environmental Protection (PADEP) recommendations, with minor modifications adapted to conditions in Philadelphia. This procedure includes nonstructural controls that reduce the quantity of stormwater to be managed and structural controls that meet the Water Quality, Channel Protection, and Flood Control requirements of the Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations). The integrated site design procedure can be summarized in three steps:

Nonstructural Project Design

1. Protect and Utilize Existing Site Features
2. Reduce Impervious Cover to be Managed

Structural Project Design

3. Manage Remaining Stormwater using a Systems Approach to Stormwater Management Practice (SMP) Design

These steps are implemented initially in sequence and then in an iterative approach leading to formulation of a comprehensive Post Construction Stormwater Management Plan (PCSMP). The intent of the planning process is to promote development of stormwater management solutions that protect receiving waters in a cost effective manner. By introducing stormwater management in the initial stages of site planning, it can be integrated effectively into the site design process.

4.1 Protect and Utilize Existing Site Features

4.1.1 Protect Sensitive/Special Value Features

In order to minimize stormwater impacts, land development should avoid encroachment on areas with important natural stormwater functional values (such as floodplains, wetlands, and riparian areas) and on areas that are especially sensitive to stormwater impacts (such as steep slopes). These features may not be widespread in the urban environment, but where they do exist they should be identified and steps should be taken to minimize impacts. On larger sites, existing drainage pathways should be identified and utilized whenever possible in the post-development condition.

The Existing Resources and Site Analysis (ERSA) worksheet guides the designer through this stage of the design process. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Best Management Practices (BMP) Manual (PA SBMPM):

- PA SBMPM BMP 5.4.1: Protect Sensitive and Special Value Features
- PA SBMPM BMP 5.4.2: Protect/Conserve/Enhance Riparian Areas
- PA SBMPM BMP 5.4.3: Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

4.1.2 Cluster and Concentrate

Clustering development in a smaller area can reduce disturbance, reduce maintenance, increase open space, and retain the urban character of the City. These principles apply on urban sites where large areas are being redeveloped. Detailed design guidance is available in the following section, taken directly from the PA SBMPM:

- PA SBMPM BMP 5.5.1: Cluster Uses at Each Site; Build on the Smallest Area Possible

4.1.3 Minimize Impacts of Disturbance

Site design can minimize re-grading, vegetation removal, and soil compaction. Areas left as open space following disturbance can be re-vegetated with native species where practical. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Management Manual:

- PA SBMPM BMP 5.6.1: Minimize Total Disturbed Area – Grading
- PA SBMPM BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas
- PA SBMPM BMP 5.6.3: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

4.2 Reduce Impervious Cover to be Managed

Reduction of impervious cover will reduce runoff from the site and will thereby reduce the structural stormwater management requirements for the development project. Impervious cover can be effectively removed by limiting the amount of actual impervious surfaces or by reducing the impervious area that is directly connected to the stormwater conveyance system. The directly connected impervious area (DCIA) Worksheet (Worksheet 2), guides the designer through this stage of the design process.

4.2.1 Green Project Review

PWD offers a Green Project Review for redevelopment projects that are able to disconnect 95% or more of the impervious area in the post construction condition. When performing a Green Project Review, PWD is committed to providing review of the stormwater management component within 5 business days of receipt of a complete project submittal. A Green Project Review may not necessarily include review of additional elements outside stormwater management such as Private Cost or Act 537 review. To be eligible for a Green Project Review a project must meet the following criteria**:**

- Project is redevelopment;
- 95% or more of the post construction impervious area is disconnected;
- Project may not adversely impact or further exacerbate rates and quality of runoff contributing to public infrastructure; and
- Public Health and Safety issues may preclude a project from a Green Project Review.

The submittee **MUST** identify their project as eligible for a Green Project Review in the letter of transmittal sent with the technical submittal. PWD may not be able to provide review comments within 5 business days without this notification. For more information or to determine if a project is eligible for a Green Project Review please contact PWD**.**

4.2.2 Minimize Area of Impervious Cover

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced impervious area. Minimizing the area of pavement and rooftops will reduce the size and cost of SMPs that must be constructed. Detailed guidelines, examples, and additional references are discussed in **Section 6**: Integrated Site Design.

- **Section 6.1**: Street Design
- **Section 6.2**: Parking Lot Design

4.2.3 Disconnect Impervious Cover

Impervious area is considered either connected or disconnected depending on where stormwater runoff is discharged. When stormwater runoff from an impervious area flows directly to a stormwater management facility it is considered DCIA. However, some impervious cover can be disconnected by directing the flow over a pervious area which allows for infiltration, filtration, and increased time of concentration. When this is done correctly, the area may be considered Disconnected Impervious Cover (DIC). Depending on the configuration, all or a portion of the DIC may be deducted from total impervious cover. Minimizing DCIA will reduce the size and cost of SMPs that must be constructed. When performing calculations for applicability and runoff estimation, DIC should be considered as follows:

- DIC may be treated as pervious when determining stormwater control requirements and whether a redevelopment site has met the 20% reduction in impervious surface.
- DIC need not be managed for Water Quality or Channel Protection.
- If the site is required to provide flood control appropriate Curve Number (CN) values must be utilized.

The following sections describe situations in which impervious area can be considered partially or fully disconnected.

Rooftop Disconnection

An adjustment to DCIA is permitted when the downspout is disconnected and then directed to a pervious area which allows for infiltration, filtration, and increased time of concentration. PWD will support the applicant in their request to obtain relevant necessary plumbing Code variances for approved rooftop disconnections DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

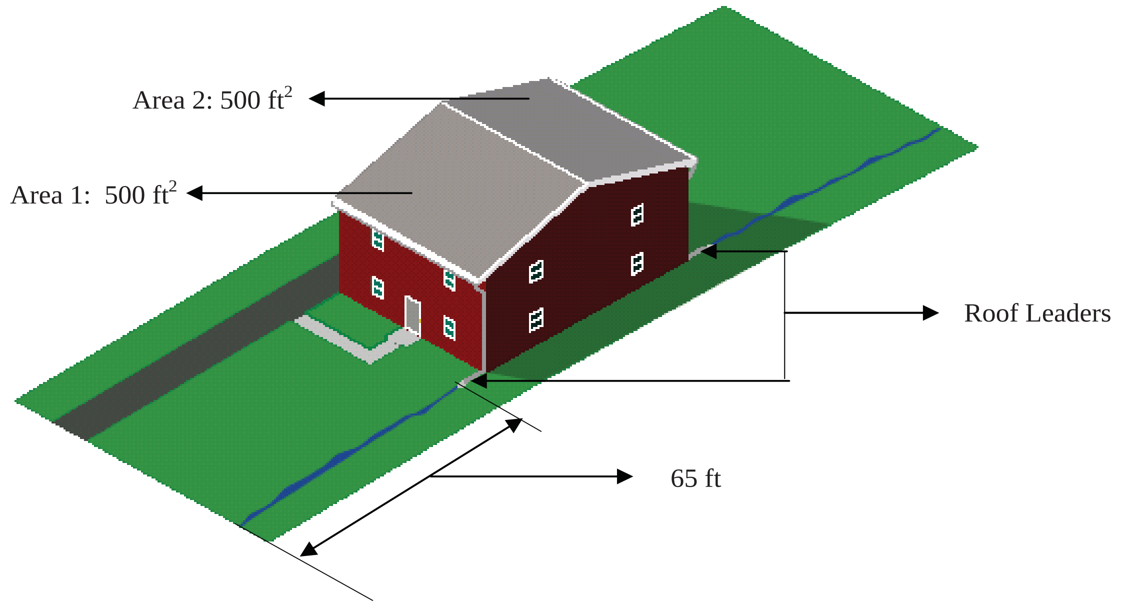
■ A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 square feet or less, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.

For designs that meet these requirements, the portion of the roof that may be considered disconnected depends on the length of the overland path as designated in Table 4.1.

Table 4.1: Partial Rooftop Disconnection	
Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0 - 14	0
15 - 29	20
30 - 44	40
45 - 59	60
60 - 74	80
75 or more	100
* Flow path cannot include impervious surfaces and must be at least 15 feet from any ground level impervious surfaces.	

For example, consider a 1,000 square foot roof with two roof leaders each draining an area of 500 square feet. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from the downspout discharge point to the street is 65 feet. Therefore, based on Table 4.1, 80% of the roof area may be considered disconnected and treated as pervious cover when calculating stormwater management requirements. Disconnecting the roof leaders will significantly reduce the size and cost of stormwater management facilities at this site.



Total Roof Area: (Area 1 + Area 2): 1000 ft^2
Disconnected Roof Area: (0.8) x (Total Roof Area): 800 ft^2
Remaining DCIA: (Total Roof Area - Disconnected Roof Area): 200 ft^2

Figure 4.1: Rooftop disconnection

Pavement Disconnection

An adjustment to DCIA is permitted when pavement runoff is directed to a pervious area which allows for infiltration, filtration, and increases the time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the DIC may be deducted from the total impervious cover. DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations. The following sections describe situations in which impervious area can be considered partially or fully disconnected.

■ Pavement is disconnected if it meets the requirements below:

- The contributing flow path over impervious cover is no more than 75 feet, and
- The length of overland flow over pervious areas is greater than or equal to the contributing length, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.
- If discharge is concentrated at one or more discrete points, no more than 1,000 square feet may discharge to any one point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

4.2.4 Maximize Tree Canopy over Impervious Cover

A reduction in DCIA is permitted when new or existing tree canopy from approved species list extends over or is in close proximity to the impervious cover. Under these circumstances, a portion of impervious cover may be treated as disconnected. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

■ The DCIA reduction is calculated for **new trees** as follows:

- The tree species must be chosen from the approved list (see **Section 8**: Landscape Guidance).
- New trees planted must be planted within 10 feet of ground level DCIA within the limits of earth disturbance.
- New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.

- A 100 square foot DCIA reduction is permitted for each new tree. This credit may only be applied to the impervious area adjacent to the tree.

- The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

■ The DCIA reduction is calculated for **existing trees** as follows:

- The tree species must be on the approved list (see **Section 8**: Landscape Guidance).

- Existing trees whose canopies are within 20 feet of ground level DCIA within the limits of earth disturbance.

- Existing trees must be at least 4-inch caliper to be eligible for the reduction.

- A DCIA reduction equal to one-half the canopy area is permitted. This credit may only be applied to the DCIA adjacent to the tree.

- The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets, specifically Worksheet 2: Directly Connected Impervious Area for guidance on using the tree adjustment calculations.

4.2.5 Install Green Roofs to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a green roof is installed on a proposed building. The design, construction, and maintenance Plan must meet the minimum requirements specified in **Section 7**: SMP Design Guidelines. To encourage this emerging technology, the entire area of the green roof area may be considered DIC. However, since a green roof is not a zero discharge system, the remaining site design must safely convey roof runoff to the approved point of discharge. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

4.2.6 Install Porous Pavement to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a porous pavement system is installed on the site such that it does not create any areas of concentrated infiltration. Porous pavement systems, including porous asphalt; porous concrete; porous/permeable pavers; and other PWD-approved porous structural surfaces can be considered to be DIC if they receive direct rainfall only and are underlain by a crushed stone infiltration bed that is at least 8 inches deep. Porous/permeable pavers must also meet minimum standards for flow-through rate or void percentage. If an underdrain is proposed, the porous pavement will only be considered DIC if the first inch of runoff can be stored below the lowest overflow from the underdrain system. Porous asphalt systems must meet the minimum requirements detailed in **Section 7.13**: Porous Pavement. Infiltration testing is not required for disconnected porous pavement areas; however, it is recommended to ensure timely drainage of the stone base. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

In most cases, if the porous surface receives runoff (overland or piped directly into the subsurface storage bed) from adjacent conventional pavement surfaces, roof, or other impervious surfaces, the porous pavement/infiltration bed system will be considered a structural SMP and the porous surface will be considered DCIA. Those areas considered structural SMPs will require infiltration testing. In some cases, where a small amount of run-on cannot be avoided, it may still be possible to consider the porous pavement disconnected. Such allowances will be considered on a case-by-case basis by PWD.

4.3 Manage Remaining Stormwater

Worksheets 3A and 3B: Stormwater Control Sizing guide the designer through the stage of the design process that manages remaining stormwater after utilizing existing site features and reducing impervious cover. Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets.

4.3.1 Estimate Level of Control Needed

After determining which stormwater management requirements are applicable to the site, the Design Professional then determines the magnitude of those requirements. All requirements must be met concurrently. The Design Professional may choose to meet multiple requirements using a single facility or multiple facilities.

Water Quality Requirement

The required water quality volume is calculated from the following formula:

$$WQ_v = \left(\frac{P}{12}\right) * \left(I\right) \qquad \text{Eqn: 405.1}$$

Where:
WQ_v = Water Quality Volume (cubic feet)
P = 1.0 inch
I = DCIA within the limits of earth disturbance (square feet)

To meet the Water Quality requirement, SMPs must be designed to collect and treat the first inch of runoff from all DCIA. It is not acceptable to treat an equivalent volume collected from only a portion of the DCIA.

The water quality volume must be infiltrated except in cases where the Design Professional determines that infiltration is infeasible on the site. Infiltration systems must provide adequate static storage for the entire water quality volume; see design guidelines in **Section 7:** SMP Design Guidelines for information on calculation of static storage. Please note, all infiltration practices must be located a minimum of 10 feet from all building foundations. Infiltration systems must also be a minimum of 10 feet from property lines not adjacent to open public streets unless a deed restriction is put in place extending at least 10 feet from the perimeter of the infiltrating system.

To determine whether or not infiltration is feasible, the Design Professional must perform the following three procedures:

Appendix A: Hotspot Investigation Procedure

Appendix B: Soil Infiltration Testing Procedure

Appendix C: Geotechnical Investigation (Subsurface Stability) Procedure

The intent of the Water Quality requirement is to protect Philadelphia's rivers and streams from polluted runoff associated with rain events. Runoff from the first inch of rainfall accounts for the majority of the annual rainfall volume, and typically carries the majority of the pollutants. Runoff from impervious surfaces is generally more polluted than runoff from pervious surfaces because of the associated uses. Because the Water Quality requirement is designed to make sure that this first inch of water is infiltrated or treated before it leaves the site, the water quality volume must be collected as the first inch of runoff from all DCIA.

Infiltration provides groundwater recharge needed to restore more natural (historical) dry weather flows in creeks while reducing high stream flows and velocities during small storms. However, some sites may not be able to infiltrate all of the water quality volume safely and may request a waiver from infiltration. Waivers are available in **Appendix F.4**: Special Circumstances and Waiver Requests and online at www.PhillyRiverInfo.org/PWDDevelopmentReview. In cases where a waiver is requested for all or a portion of the infiltration component of the Water Quality requirement, the Design Professional is required to supply the following documentation:

- summary of testing as outlined in **Appendices A**, **B**, and **C,**
- a complete infiltration waiver request cover letter and worksheet detailing the reasons that infiltration is not feasible, and
- supporting evidence why a site should be released from the infiltration requirement.

If it is determined that infiltration of all or part of the water quality volume is not feasible, remaining water quality volume must be treated and released. Treatment and release requirements differ for separate and combined sewer areas, but all areas must route a minimum of 20% of the water quality volume through a PWD-approved SMP that provides volume reduction (See Table 4.3)

Separate Sewer Areas: The water quality volume must be routed through a SMP that provides volume reduction, flow attenuation, and water quality treatment. PWD-approved practices include: underdrained filters, underdrained bioretention, swales with check dams, ponds and wet basins, and constructed wetlands (see Table 4.3 for a complete list).

Combined Sewer Areas: Runoff from a minimum of 20% of the DCIA must be routed through a PWD-approved volume reducing SMP (see Table 4.3 for a complete list). The release rate for the water quality volume must not exceed 0.24 cfs per acre DCIA*, and the volume must be detained in the SMP for no less than 24 hours and no more than 72 hours.

*If a SMP will be emptied by a pumping system the average rate must not exceed 0.12 cfs per acre DCIA.

Channel Protection Requirement

SMPs must be designed to detain the runoff from all DCIA within the limits of earth disturbance from a one-year, 24-hour NRCS (Natural Resources Conservation Service) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility. Discharge of water may begin at the beginning of the storm.

Channel Protection requirement: Detain and release runoff from DCIA at a maximum rate of 0.24 cfs per acre of DCIA in no less than 24 hours and no more than 72 hours.

However, the Channel Protection requirement does not apply to redevelopment which is under one acre or discharging to the Delaware River and the Schuylkill River main channels.

■ *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Channel Protection requirement.*

The effects of infiltration may be accounted for when performing Channel Protection calculations. Infiltrating more than the water quality volume is allowed; the Design Professional must determine the best management option based on site-specific conditions.

Flood Control Requirement and Management Districts

Table 4.2 lists the required level of flood control based on location (Management District) within the City. Refer to **Appendix D.2**: Management Districts to determine which Management District requirements apply to a given site. Peak runoff in the proposed condition (left column) must be no greater than peak runoff in the pre-development condition (right column) using the stated design storms. For a given district, the five criteria must be met concurrently. Peak rate reduction provided by facilities that meet the Water Quality and Channel Protection requirements may be considered in sizing calculations for peak rate controls.

If a project is located near or across a Management District border it is strongly recommended that the Developer contact PWD to confirm the Management District requirements that apply to the project. In most cases, a project that is located in multiple management districts will be required to meet the requirements of the management district that covers the majority of the disturbed area.

In Flood Management District C, development sites which can discharge directly to the Delaware River main channel or Schuylkill River major tributary without the use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the pre-development conditions peak rate as required in District A provisions for the specified design storm. Refer to **Appendix F.5**: PWD Review Policies.

■ *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Flood Control requirement.*

Table 4.2: Peak Runoff Rates for Management Districts		
District	**NRCS Type II 24-hour Design Storm applied to Proposed Condition**	**NRCS Type II 24 –hour Design Storm applied to Pre-Development Condition**
A	2 - year	1 - year
A	5 - year	5 - year
A	10 - year	10 - year
A	25 - year	25 - year
A	100 - year	100 - year
B-1	2 - year	1 - year
B-1	10 - year	5 - year
B-1	25 - year	10 - year
B-1	50 - year	25 - year
B-1	100 - year	100 - year
B-2	2 - year	1 - year
B-2	5 - year	2 - year
B-2	25 - year	5 - year
B-2	50 - year	10 - year
B-2	100 - year	100 - year
C*	Conditional Direct Discharge District	

4.3.2 Design Stormwater Management Practices Using a Systems Approach

The intent of this section is to propose a systems approach as an organizing principle in SMP design. The designer first defines the level of control needed and then designs a system to provide that level of control.

SMP Selection and Design Process

The following is a general procedure for choosing and designing SMPs on a site.

- Determine whether infiltration is feasible according to **Appendix B:** Soil Infiltration Testing Procedures.
- Identify space constraints, and adjust site design as much as possible to provide open space for stormwater management.
- Where infiltration is feasible, vegetated techniques are preferred. When infiltration is not feasible other volume reducing techniques should be used (see Table 4.3).
- Determine pretreatment requirements for the selected SMP.
- Determine release rate requirements. Design of orifices and underdrains to meet the release rate requirements for small structures on small sites will be the most challenging.

On sites where infiltration is not feasible some or all (20% in combined sewer areas, 100% in separate sewer areas) of the DCIA must be routed to an approved volume reducing stormwater management practice. Table 4.3 below presents the SMPs that PWD currently accepts as reducing stormwater volume. Each SMP has design guidelines detailed in **Section 7**. Alternate volume reducing practices may be proposed and will be reviewed on a case-by-case basis. A waiver from the accepted volume reducing practices must be submitted and approved. See **Section F.4**: Special Circumstances and Waiver Requests or www.PhillyRiverInfo.org/PWDDevelopmentReview for the required forms.

Table 4.3: Acceptable Volume Reducing Stormwater Management Practices

		Infiltration and Groundwater Recharge	Volume Reduction without Infiltration
Landscaped-Intermittently Wet			
Section 6.3	Planter Boxes	Yes	Yes
Section 7.4	Filters	Yes	No
Section 7.5	Bioinfiltration/Bioretention	Yes	Yes (U)
Section 7.7	Berms and Retentive Grading	Yes	No
Section 7.8	Swales	Yes	Yes (U)
Landscaped-Usually Wet			
Section 7.9	Constructed Wetlands	No	Yes
Section 7.10	Ponds & Wet Basins	No	Yes
Subsurface			
Section 7.12	Subsurface Infiltration	Yes	No
Section 7.13	Porous Pavement	Yes	No
Rooftops			
Section 7.1	Green Roofs	No	Yes
Capture & Reuse			
Section 7.2	Rain Barrels and Cisterns	No	Yes
U =	Underdrained Systems		

SMP Functions and Configurations

SMPs are systems that use physical, chemical, and biological processes to provide the level of stormwater control required. This level of control typically includes a required storage volume, a volume to be infiltrated, and an acceptable release rate. These requirements are met through the five principle hydraulic functions of SMPs: storage, infiltration, evapotranspiration, controlled release, and overflow or bypass flow. Figure 4.2 illustrates a variety of design elements available to provide these functions. Depending on the configuration, physical, chemical, and biological processes lead to removal of pollutants during these processes.

By combining design components in a variety of ways, the designer can identify alternative systems that achieve a given function. Figure 4.3 illustrates several different designs that are capable of meeting the Water Quality and Channel Protection requirements.

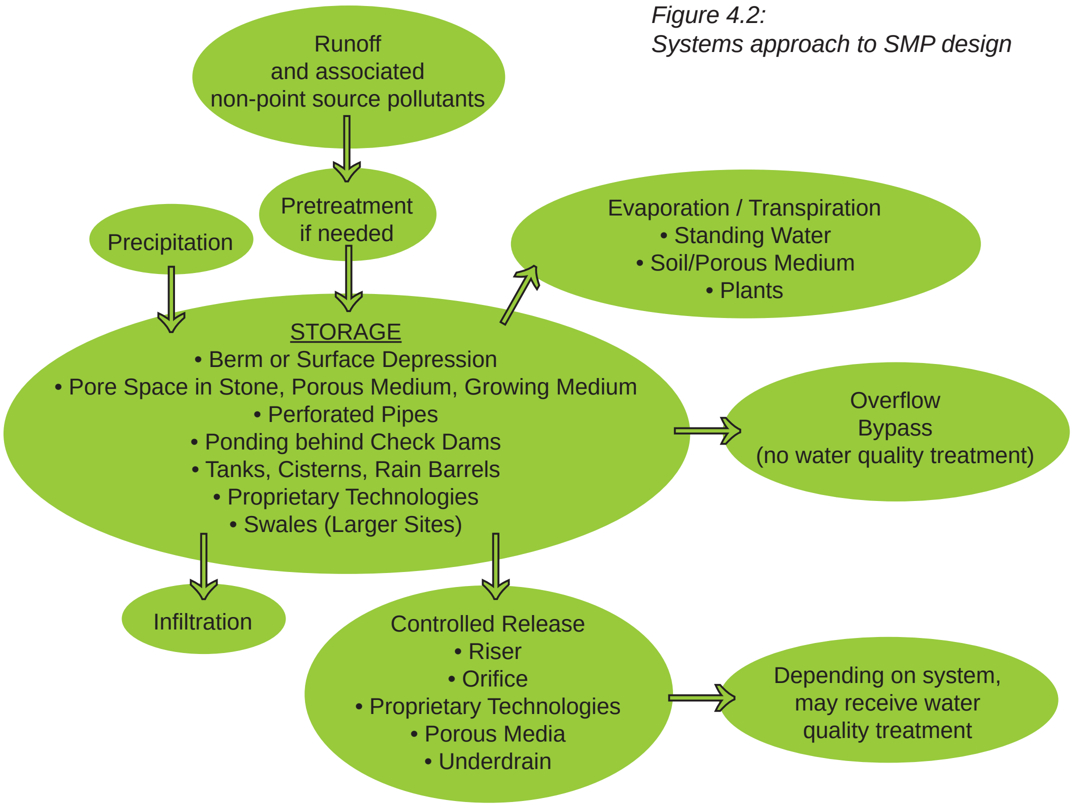
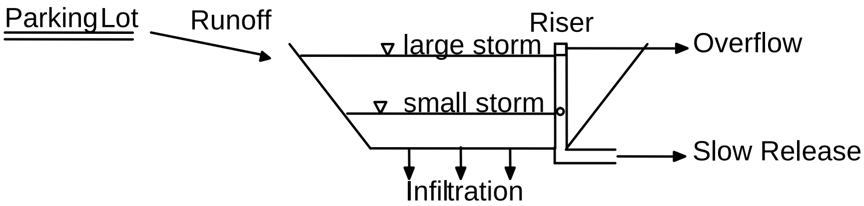


Figure 4.2:
Systems approach to SMP design

Figure 4.3: Alternative designs for storing runoff

Site: 1 acre parking lot
Objective: Meet Water Quality and Channel Protection requirements
Note: These diagrams are intended to depict general design concepts. Please refer to **Section 7** for detailed design requirements.

Alternative 1: Traditional detention / infiltration basin



Alternative 2: Porous pavement with deep sub-base

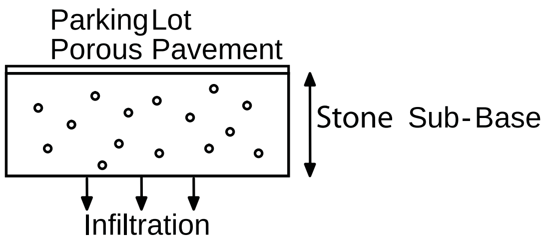
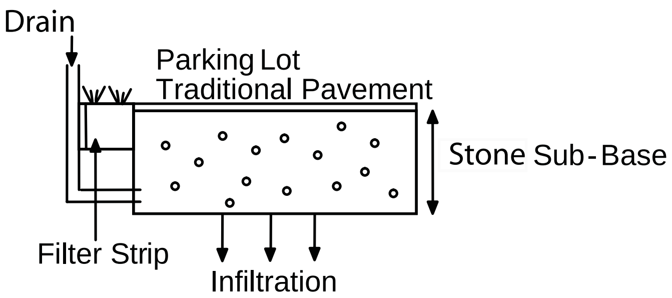
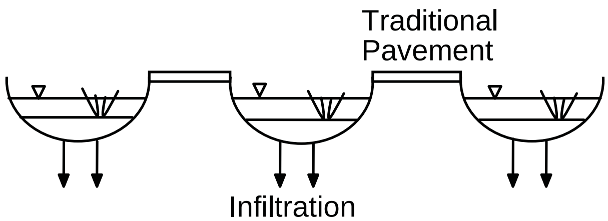


Figure 4.3: Alternative designs for storing runoff (continued)

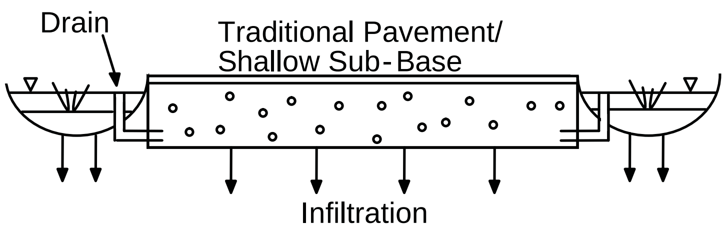
Alternative 3: Traditional pavement with perimeter drains and subsurface infiltration



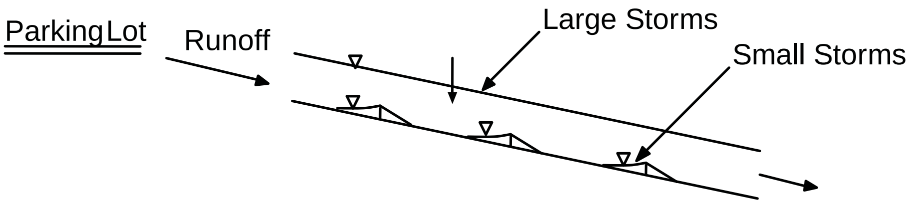
Alternative 4: Bioretention only



Alternative 5: Bioretention and subsurface storage



Alternative 6: Swale (large site option)



Storage A traditional detention/infiltration basin (alternative 1, Figure 4.3) provides storage entirely through surface ponding. Subsurface stone storage beds (alternatives 2 and 3) provide storage in stone pore spaces. A bioretention system (alternative 4) provides a combination of surface ponding and storage in soil pores. Bioretention combined with a subsurface stone bed (alternative 5) provides storage in a combination of surface ponding, storage in soil pores, and storage in stone pores. A swale (alternative 6) can provide storage through surface ponding behind check dams, while also functioning as a conveyance system during larger events.

Infiltration All six alternatives allow stored water to infiltrate into the underlying soil. Surface vegetation (alternatives 1, 4, 5, and 6) helps prolong design life because growth of plant roots helps to keep the soil pore structure open over time. This effect is greatest with vegetation that has a deeper root structure (e.g., trees, shrubs, and native herbaceous species rather than turf grass). Traditional structures such as detention basins and swales can be designed with either type of vegetation. Using such attractive landscaping practices improves quality of life in the urban landscape.

Slow Release Stored water is either infiltrated or released at a slow rate to a sewer or receiving stream. The subsurface storage and bioretention designs (alternatives 2-5) are designed to infiltrate the entire design storm. These designs have a relatively large ratio of infiltration area to drainage area; they provide diffuse infiltration and do not require design or maintenance of a slow release structure. The traditional infiltration basin (alternative 1) provides more concentrated infiltration; depending on site conditions, the designer may choose to infiltrate a portion of runoff and release the remainder slowly through a riser structure. This structure may require design and maintenance measures to avoid clogging. Finally, the swale (alternative 6) infiltrates the portion of runoff that pools behind check dams. The designer in this case ensures that detention behind check dams and peak attenuation in the flowing swale combine to meet any release rate requirement by the time flow reaches the end of the swale. The swale does not store the entire design storm through ponding at any one time, but it is functionally equivalent to the other designs when resulting flows leave the property.

Evaporation and Transpiration Evaporation and transpiration are minor SMP functions when measured over the course of one storm, but they are significant when measured over time. Surface systems will provide the greatest evaporation and transpiration benefit, particularly if they are vegetated. Some water that infiltrates the surface will evaporate. For this reason, vegetated systems provide both water quality and volume reduction.

Controlled Overflow or Bypass Flow Although not shown for all the examples, all designs must have a mechanism for water to overflow or bypass the system unimpeded during events larger than the design event. For alternatives 1 through 5, a riser or other overflow structure can be incorporated in the design. For alternative 6, the flow capacity of the swale itself acts as a bypass mechanism.

Water Quality Treatment All six design alternatives provide some water quality benefit by slowing water down and allowing settling of suspended solids. A portion of pollutants in stormwater (e.g., nutrients, metals, and/or organics) is associated with this solid fraction. Systems combining soil, water, and plants (alternatives 4 and 5) provide the most treatment. The level of treatment provided by the traditional detention basin (alternative 1) and swale (alternative 6) depends on configuration and vegetation type.

Infiltration reduces the pollutant load reaching surface water and should not endanger groundwater if the soil layer is sufficiently thick. Vegetated filter strips in alternative 3 remove solids through settling and filtration. In alternative 5, a small bioretention basin provides pretreatment for a subsurface stone system. Both pretreatment methods will prolong the life of the subsurface stone bed. The choice between alternatives 3 and 5 is one of designer preference and cost, not one of function.

In areas with combined sewers, two factors contribute to receiving water quality. First, any water that is infiltrated does not reach a combined sewer, does not contribute to combined sewer overflows (CSO), and will not contribute to receiving water pollution. Second, detention and slow release reduces peak flow in the combined sewer during wet weather events, reducing the frequency and magnitude of overflows. Water quality improvement in combined sewered areas is more a matter of managing the quantity and timing of runoff, rather than reducing pollutant concentrations in that runoff.

Space Constraints Traditional basins (alternative 1) and swales (alternative 6) can be implemented on larger sites. On smaller sites, bioretention is an attractive solution due to the benefits of vegetation, including appearance, design life, and water quality. However, surface vegetation does require space to install. A designer might choose to combine bioretention with a subsurface stone bed (alternative 5) to save space, or to use a subsurface stone bed (alternative 2 or 3) alone if all available space is needed for parking.

4.4 Consider Operations and Maintenance in Design

An Operations and Maintenance (O & M) Plan is required to be submitted with the PCSMP. Decisions made in the design phase can affect operations and maintenance and can extend the design life of stormwater facilities. Key factors to consider are ownership, access, maintenance tasks and frequency. The Operations and Maintenance Plan worksheet found at www.PhillyRiverInfo.org/PWDDevelopmentReview provides a simple format.

4.4.1 Designing to Minimize Maintenance

Consider the following design features to minimize maintenance and maximize design life:

- Maximize use of pretreatment systems, particularly for infiltration systems. Reducing velocities and pollutant loads entering SMPs will extend their design lives. (See **Section 7** for appropriate pretreatment design.)

- For infiltration, choose surface vegetated SMPs with deeper-rooted vegetation (trees, shrubs, and native herbaceous species) whenever possible. Root growth helps to keep the soil's pore structure open and maximizes the life of infiltration SMPs. Routine landscaping tasks are the primary maintenance required.

- On smaller sites, choose SMPs that do not require slow-release control structures. These structures can clog and require periodic inspection and maintenance.

4.4.2 Provide Access

Vehicle access from a public right-of-way can help to minimize the difficulty of maintenance. A 15-foot wide vehicle access path leading from a public right-of-way to all stormwater controls is strongly recommended.

4.4.3 Post-Construction Ownership

The owner of the land where the SMP is located is responsible for performing long term maintenance. In the case of a single property owner, that owner is responsible for maintenance. In cases of common ownership, a homeowners' or condominium association may assume responsibility for maintenance. Considering the type of ownership and owner preference can help the designer choose between smaller, distributed SMPs and a single centralized SMP.

4.4.4 Maintenance Tasks and Schedule

Maintenance tasks and frequencies are specific to each type of SMP. Maintenance guidance is provided in **Section 7**: SMP Design Guidelines for each SMP. A Maintenance Plan must be completed, signed and filed with the Recorder of Deeds to comply with the requirements of the Stormwater Regulations.