5 Post Construction Stormwater Management Plans

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5.0 Introduction

This section is provided to guide developers through the necessary submittals required for stormwater management in Philadelphia. **Section 5.1** describes requirements for the Erosion and Sediment Pollution Control (E & S) Plan. **Section 5.2** describes the required components of the Post Construction Stormwater Management Plan (PCSMP). Acceptable calculation methods for determining sizing and appropriate stormwater management practices (SMPs) are contained in **Section 5.3**. **Section 5.4** describes the PCSMP submittal process.

5.1 Erosion and Sediment Pollution Control Plan

The Owner is responsible for ensuring that their active construction site is not creating violations of 25 Pa. Code Chapters 92 and/or 102 and the Clean Streams Law, the act of June 22, 1937, P.L. 1987, 35 P.S. §691.1 et seq. Depending on the limit of earth disturbance associated with a project there are specific preparation, review, and approval requirements. All E & S Plans must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines as laid out in the following Manual:

> PADEP, Bureau of Watershed Management, April 15 2000. *Erosion and Sediment Pollutant Control Program Manual*. Document 363-2134-008.

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine the level of review and approval required. Submittal requirements for E & S Plans are located in **Section 2.2**: Determining Applicability. Once the limits of earth disturbance have been accurately determined the applicant will follow one of the four E & S review paths listed below:

Earth Disturbance Categories:

A. Less than 5,000 square feet (not located in the Wissahickon Watershed*)
- E & S Plan is not mandatory.
- Owner must implement E & S best management practices (BMPs) in accordance with the most recent version of PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000).

B. More than 5,000 square feet, less than 15,000 square feet**
- E & S Plan must be prepared, implemented, and kept on site available for inspection at all times.
- The E & S Plan which complies with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000) must be maintained on submitted to the Philadelphia Water Department (PWD), but does not need to be approved.
- If the site is not subject to the PWD Stormwater Management Regulations (Stormwater Regulations), then submit E & S Plans as an attachment to the Existing Resources and Site Analysis (ERSA) online application at www.PhillyRiverInfo.org/PWDDevelopmentReview.

C. More than 15,000 square feet, less than 1 acre (43,560 square feet)**
- E & S Plan must be prepared, approved, implemented and kept on site available for inspection at all times.
- The E & S Plan must be reviewed and approved by PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to the Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

  Projects Control
  Philadelphia Water Department
  1101 Market St, 2nd Floor
  Philadelphia, PA 19107

The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

- A copy of the approved plans must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of earth disturbance.

D. More than 1 acre (43,560 square feet)

- E & S Plan must be prepared, approved, implemented and kept on site at all times.
- A NPDES Permit application must be submitted to PADEP. Proof of issuance of the NPDES Permit must be provided to PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

  Projects Control
  Philadelphia Water Department
  1101 Market St, 2nd Floor
  Philadelphia, PA 19107

The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

- A copy of the approved E & S Plan must be forwarded to the PWD E & S Unit.
- Notify the PWD E & S Unit of any pre-construction meetings, and notify the PWD E & S Unit three days prior to commencement of earth disturbance.

*Projects located in the Wissahickon Watershed may be subject to additional requirements which will be assessed as part of the project review performed by Philadelphia City Planning staff.

**If during the course of construction additional area is disturbed which changes the applicable requirements, construction will have to cease until new plans are prepared and approved by all relevant regulatory agencies.

Inspections

E & S inspections occur on both a scheduled and complaint driven basis. The E & S inspectors expect that the E & S controls contained within the prepared or approved E & S Plan (depending on the limits of disturbance) are implemented and maintained on site at all times. The E & S Inspectors are authorized to access a site and inspect the effectiveness of E & S BMPs. E & S Inspectors will advise the Owner or responsible party(s) of E & S control problems found during the inspection and what must be done to correct the violations. This may include implementing additional E & S BMPs not shown on the approved plans. Should a project site be disturbing earth without the appropriate approvals or ineffective E & S control BMPs,a Stop Work Order will be issued.

For a more detailed discussion of E & S issues please refer to Fact Sheet #7: Understanding Erosion and Sedimentation Control requirements in Philadelphia located on www.PhillyRiverInfo.org/PWDDevelopmentReview

5.2 Components of the Post Construction Stormwater Management Plan

The PCSMP must contain the elements found in the Checklist B: The Standard Submittal Format. If any of these are missing from a submitted plans, the plan will be returned to the developer for completion prior to review. All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

5.2.1 The Standard Submittal Format

Checklist B: The Standard Submittal Format contains an easy to use checklist to determine completion of the PCSMP. It is provided to assist the developer in ensuring that all necessary elements of the PCSMP are complete. Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets. This process has been designed to make submittal of the PCSMP easier for both developers and reviewers.

5.2.2 Proof of Application for Applicable Permits

Other state and federal permits may be required for development on a given site. PWD approval of a PCSMP is contingent upon approval by other regulatory agencies. Other permits that may be required include but are not limited to:

- NPDES (National Pollutant Discharge Elimination System) Phase II Permit for Construction Activities
- Pennsylvania Code and Charter Chapter 105: Water Obstruction and Encroachment General and Joint Permits

This list is not exhaustive nor does it imply that all of these permits are required. It is the **responsibility of the developer** to determine which permits are required by other regulatory agencies. **Appendix F.3**: Local Permitting requirements and **Appendix F.4**: Federal and State Permitting requirements provide resources to assist in determining which permits may apply.

Proof of the issuance of all applicable permits **MUST** be provided to obtain PWD sign off on any Building Permit. However, at the time of submittal of a PCSMP, the applicant must demonstrate that they have applied for all relevant permits. A photocopy of permit applications will serve as proof of application. If for some reason approval is denied or revoked by another regulatory agency, it is the developer's responsibility to notify PWD and other City agencies and rectify the situation before the project can proceed any further.

5.2.3 Documentation of Special Circumstances

The City recognizes that on-site stormwater management may not be feasible in part or in full for some development projects. Under these circumstances PWD requires that technical documentation demonstrating the site constraints be submitted to and reviewed by PWD. Alternatives to on-site stormwater management are accepted at the sole discretion of PWD. Complete details of documentation, stormwater management alternatives and contact information are provided in **Appendix F.4**: Special Circumstances and Waiver Requests.

5.3 Acceptable Methods for Calculations

The worksheets are intended to standardize and summarize the results of design calculations. The designer must also attach relevant data, field testing results, assumptions, hand calculations, and computer program results. This section summarizes calculation methods that are considered acceptable by PWD. Other methods will be considered on a case-by-case basis.

5.3.1 Design Storms

Sizing requirements for the Stormwater Regulations have been developed using long-term computer simulations. These requirements have been translated to single event design conditions that yield roughly equivalent results.

Design Rainfall Totals

The rainfall depths of design storms shown in Table 5.1 are taken from the Pennsylvania Department of Transportation Field Manual (1986). These totals indicate the largest depth one can expect over the specified interval in the specified return period. These design precipitation depths are similar to those found in other standard references such as National Oceanic and Atmospheric Administration (NOAA) Technical Publication 40 or the NOAA Atlas 14; however, Design Professionals must use the values provided in Table 5.1 for their design calculations.

Table 5.1: Design Precipitation Depths (in)

	Return Period						
Duration	1 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	0.33	0.38	0.45	0.50	0.56	0.63	0.68
15 min	0.64	0.75	0.90	1.00	1.15	1.35	1.50
1 hr	1.10	1.35	1.61	1.85	2.15	2.60	2.98
2 hrs	1.34	1.66	2.00	2.34	2.70	3.26	3.76
3 hrs	1.50	1.86	2.28	2.67	3.09	3.69	4.29
6 hrs	1.86	2.28	2.82	3.36	3.90	4.62	5.40
12 hrs	2.28	2.76	3.48	4.20	4.92	5.76	6.72
24 hrs	2.64	3.36	4.32	5.28	6.24	7.20	8.40

Design Rainfall Distribution

For the Channel Protection and Flood Control calculations, the design rainfall depth must be distributed in a NRCS (National Resources Conservation Service) Type II dimensionless rainfall distribution. The Type II distribution was selected not because it represents a typical event but because it includes periods of low-intensity and high-intensity rainfall; design using this distribution results in a facility that can manage a variety of event types, particularly high intensity storms.

Table 5.2: Tabulated NRCS 24-Hour Type II Distribution		
Time	Dimensionless Rainfall	
(hr)	Cumulative	Incremental
0.00	0.000	0.000
2.00	0.022	0.022
4.00	0.048	0.026
6.00	0.080	0.032
7.00	0.098	0.018
8.00	0.120	0.022
8.50	0.133	0.013
9.00	0.147	0.014
9.50	0.163	0.016
9.75	0.172	0.009
10.00	0.181	0.009
10.50	0.204	0.023
11.00	0.235	0.031
11.50	0.283	0.048
11.75	0.357	0.074
12.00	0.663	0.306
12.50	0.735	0.072
13.00	0.772	0.037
13.50	0.799	0.027
14.00	0.820	0.021
16.00	0.880	0.060
20.00	0.952	0.072
24.00	1.000	0.048

Storm Return Periods for Large Events and Flow Bypass

At a minimum, safe conveyance of the 10-year, 24-hour design storm must be provided to and from SMPs to comply with the requirements of §14.1603.1.6.C.4. Additionally, the flow that is leaving the system must meet the requirements of the Stormwater Regulations. Many SMPs will be designed to manage smaller storms. A designer might choose to allow runoff from larger storms to bypass or quickly pass through a storage element.

5.3.2 Runoff Estimation

A number of mathematical models are available to estimate stormwater runoff from a given storm. For sites that are dominated by impervious cover, most methods will yield similar results. For sites with significant pervious cover contributing flows to SMPs, infiltration loss models provide more realistic results than the empirical, statistically based methods. However, a thorough understanding of soil behavior is necessary to generate realistic runoff estimates.

The empirical methods can be implemented by computer programs. Examples of computer programs available in the public domain are listed in Table 5.3. In addition, a wide range of proprietary programs are available. Designers are strongly urged to consider the assumptions and mathematical models underlying these programs when choosing an appropriate tool to aid in design.

Table 5.3: Acceptable Calculation Methods for Runoff Estimation					
Type	Mathematical Model	Impervious Cover	Experience Modeling Soil Properties	Hand/Spreadsheet Calculations	Example Computer Programs
Empirical Methods	NRCS Curve Number method	Any	Moderate-High	Yes (smaller sites)	NRCS, TR-55, TR-20, HEC-HMS
Infiltration Loss Models	Constant Loss	Any	Moderate-High	Yes (smaller sites)	HEC-HMS
	Green-Ampt	Any	High	No	EPA SWMM, HEC-HMS
	Horton	Any	High	No	EPA SWMM

Rational Method

The rational method may **not** be used for SMP design, outlet control design, or detention routing. It may be used for storm sewer capacity design as described in **Section 5.3.5**: Storm Sewer Design.

NRCS Curve Number (Soil Complex) Method

The NRCS Curve Number Method is widely used to produce estimates of runoff for both pervious and impervious cover. It empirically accounts for the fact that soils become saturated and gradually yield more runoff during the course of a storm. For a detailed description of the Curve Number Method, see Urban Hydrology for Small Watersheds (NRCS Technical Release 55).

Care should be taken to select appropriate curve number (CN) values since this calculation method is very sensitive to changes in these values. In order to obtain conservative results, use separate calculations for pervious and impervious area. The resulting flows can be routed if necessary and then added. See Table 5.4 for PWD approved CN values for each Hydrologic Soil Group.

Infiltration Loss Models

Infiltration loss models estimate runoff quantity by subtracting depression storage and infiltration losses from rainfall. These models are based on the physics of soil behavior and provide more precise results than empirical models. Used by an experienced modeler with ample soil data, these models produce more realistic estimates than empirical models on sites where a significant portion of runoff is generated by pervious cover. Results depend most strongly on soil properties.

Table 5.4: PWD Accepted Curve Number Values

Cover Description		Curve Number for Hydrologic Soil Group				
Cover Type	Hydrologic Condition	A	B	C	D	Ub
Lawns, parks, golf courses, etc...						
	Poor (grass cover < 50%)	68	79	86	89	79
	Fair (grass cover 50% to 75%)	49	69	79	84	69
	Good (grass cover > 75%)	39	61	74	80	61
Meadow		30	58	71	78	58
Athletic Fields		68	79	86	89	79
Porous Turf		70	70	79	84	69
Brush (brush-weed-grass mixture with brush the major element)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods-grass combination (orchard or tree farm)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods						
	Poor	45	66	77	83	66
	Fair	36	60	73	79	60
	Good	30	55	70	77	55
Paved parking lots, roofs, driveways. streets, etc.		98	98	98	98	98
Gravel		76	85	89	91	89
Dirt		72	82	87	89	87
Porous Pavement		70	70	74	80	70
Permeable Pavers		70	70	79	84	70
Pour-in-Place Rubber		70	70	74	80	70
Green Roof*		86	86	86	86	86

* Existing rainfall runoff models are limited in their ability to predict runoff from green roofs since this process is dominated by percolations through a thin veneer of soil and is not surface runoff. Green roof research studies have back-calculated a range of CN values for various storms and roof media types/ thicknesses. CN values different from that listed in the table may be permitted if appropriate citations are provided with the stormwater report.

Determining the Predevelopment Conditions for Runoff Calculations

The predevelopment condition for any project is determined by the dominant land use for the previous ten (10) years preceding the planned project. If a redevelopment project is able to reduce the DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development conditions, is it exempt from the Channel Protection and Flood Control requirements.

When performing Flood Control calculations, PWD requires the following land use designations for all development and redevelopment in City of Philadelphia:

1) Redevelopment sites in the predevelopment condition:

- All nonforested, pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations.
- In addition to any other pervious area, twenty percent (20%) of the existing impervious cover on site, when present, **must** be considered meadow (good condition) for the predevelopment runoff calculations.

2) New Development sites in the predevelopment condition:

- All nonforested, pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations.

5.3.3 Storage Volume Estimation

Surface storage: A rough estimate of surface storage can be obtained by averaging the surface area and bottom area of a basin and multiplying by the average depth. For irregular shapes, volume can be estimated by finding the area inside each contour, multiplying each area by the contour interval, and adding the results.

Stone Storage: Storage in stone pores is equal to the volume of the crushed stone bed times the porosity. A design porosity of 40% can be assumed for the stone if specifications for the crushed stone meet those provided in **Section 7**: SMP Design Guidelines.

Porous Media Storage: Storage available in porous media is equal to the initial moisture deficit, the portion of total porosity that is not already occupied by moisture. This portion varies at the beginning of every storm; acceptable design values are 30% for sand and 20% for growing soil.

Active Storage: Not all physical space in a given SMP is active. The maximum elevation that should be considered as active storage is the overflow elevation. In tanks draining by gravity whose bottoms do not infiltrate, any volume below the invert of the orifice or control structure is not considered active storage.

5.3.4 Flow Routing

Sheet Flow and Shallow Concentrated Flow

Sheet flow consists of shallow flow spread out over a plane. Eventually, this flow will generally concentrate into a deeper, narrower stream. There is debate over how prevalent sheet flow is in the natural environment. However, it provides a reasonable mathematical basis for predicting travel time and infiltration losses over short distances. *Urban Hydrology for Small Watersheds* (TR-55) provides a sheet flow equation based on Manning's kinematic solution. Tables of roughness values for sheet flow are available in *Urban Hydrology for Small Watersheds* and in Table 5.5 shown below. There is debate over the appropriate length of sheet flow; however, PWD will only accept sheet flow for the first 150 feet. After sheet flow,

overland flow is considered shallow concentrated flow. Shallow concentrated flow will be considered as flowing over paved or unpaved surface for the purpose of estimating velocity. Another method for routing overland flow is the kinematic wave solution, obtained by coupling the momentum and continuity equations with simplifying assumptions, may be solved in a computer program using numerical methods. A computer program also allows practical calculations at a much smaller time step than hand or spreadsheet calculations.

Channel Flow

Channel flow equations may be used to estimate flows in free-flowing gutters and swales. Manning's equation is sufficient for these estimates on many sites. Tables of roughness values are available in *Civil Engineering Reference Manual* (CERM*)* Appendix 19.A. For channels with significant backwater, culverts which may flow under pressure, or other complex features, the St. Venant equations may be needed. These equations represent the complete solution of the momentum and continuity equations in one dimension. They require a computer program to solve.

For reference, the post development time of concentration will be less than or equal to the predevelopment time of concentration values unless the site is specifically altered to increase this path.

Table 5.5: Roughness Coefficients (Manning's n) for sheet flow

Surface Description	n [1]
Roof tops	0.011
Concrete	0.013
Asphalt	0.015
Bare Soil	0.018
Sparse Vegetation [2]	0.1
Grass:	
Short grass prairie	0.15
Dense grasses [3]	0.24
Range (natural)	0.13
Woods: [4]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986) and Akan (1985).

[2] Areas where vegetation is spotty and consists of less than 50% vegetative cover.

[3] Species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[4] Consider cover to a height of 0.1 ft. This is the part of the plant cover that will obstruct sheet flow.

Storage Routing

For small storage elements where travel time within the element is insignificant, simple mass balance routing may be performed in a spreadsheet. At each time step, the change in storage volume is the difference between inflows and outflows. Inflows and outflows are a function of design and soil properties.

For larger or more complex structures, where the shape and size of the element have a significant effect on outflows, the Modified Puls (also called storage-indication) method provides more accurate routing.

Table 5.6: Summary of Recommended Methods for Flow Routing				
Type	Mathematical Model	Appropriate For…	Hand/ Spreadsheet Calculations	Example Computer Programs
Overland Flow	simplified Manning kinematic solution	sheet flow path up to 150 feet	Yes	TR-55, TR-20
	shallow concentrated / NRCS empirical curve	overland flow longer than 150 feet	Yes	TR-55, TR-20
	kinematic wave	larger or more complex sites	No	EPA SWMM, HEC-HMS
Channel Flow	Manning equation	uniform flow without backwater	Yes	TR-55, TR-20, EPA SWMM, HEC-HMS
	St. Venant equations	channels with storage, backwater	No	EPA SWMM, HEC-RAS
Storage Routing	simple mass balance	small storage elements	Yes	USACE STORM
	Modified Puls / storage-indication	large or irregularly-shaped elements	Yes	TR-55, TR-20, HEC-HMS

5.3.5 Storm Sewer Design

The storm sewer must be designed to safely convey the 10-year storm without surcharging inlets. If Flood Control is required, runoff from larger storms must be safely conveyed off the site, either through overland flow or a storm sewer. Please note, runoff may not be conveyed to a neighboring property.

Rational method may be utilized when designing storm sewers. Recommended assumptions to obtain conservative results using the rational method include:

- Choose appropriate runoff coefficients based on the Engineer's best judgment of land use type (e.g., see CERM Appendix 20.A).

- For pervious areas with rational coefficients less than 0.2, use a coefficient of 0.2.

For a table of rational method coefficients, see CERM Appendix 20.A.

5.4 Post Construction Stormwater Management Plan Submittal Process

Because the **PWD Approval Signature and Stamp on Building Permits will only be issued upon approval of Water, Sewer and Stormwater, it is strongly recommended that developers submit Water, Sewer and PCSMP materials at the same time.** All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

The PCSMP submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

5.4.1 Project Screening

Only a complete PCSMP will be accepted for review. When a new project is received it undergoes a screening process to make sure it includes all the components necessary to complete a review. If any portion is found to be missing or incomplete the developer will be notified by email. Any additional information that is required should be mailed to PWD Projects Control. If necessary, incomplete PCSMP submittals will be returned to the developer for completion. When a project is screened incomplete no additional review of the project will be done until the required materials have been received. Once a project submittal is found to be complete the developer will be notified and the project will be moved into technical review.

Refer to www.PhillyRiverInfo.org/PWDDevelopmentReview for the most recent checklists and worksheets. Checklist B: The Standard Submittal Format is provided to guide the developer and help them ensure that their application is complete prior to submittal.

5.4.2 Technical Review Process

Once a project submittal has been screened and determined to be complete, it will be put in line for technical review. Projects are generally reviewed in the order in which they were received. Because of this, review times depend heavily on the number of projects under review at the time of the submittal.

During the technical review, PWD will examine the submittal to determine if all applicable requirements are being met. Should any deficiencies be identified, PWD will email a letter of review comments to the developer. Additional information or revised materials required based on the comments should be submitted to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

Technical review of the submittal will not continue until a new submittal addressing the comments is received. This submittal should include all required revisions and new material as well as an explanation of how each review comment was addressed. PWD will review the comment responses and new and revised material for compliance with all applicable requirements. Should any deficiencies are identified PWD will update the review letter and email the developer. Please note that additional comments may be added to the review comments based on changes to the plans and calculations. This process continues until all review comments are addressed.

The developer can influence the amount of time their review will take in several ways. If the developer chooses to use development practices that allow disconnection of 95% or more of the post construction directly connected impervious area (DCIA) most projects will be eligible for a Green Project Review. PWD is committed to performing Green Project Reviews within 5 business days. For more information see **Section 4.2**: Reduce Impervious Cover to be Managed. The developer may also influence the length of the review time by being responsive when review comments are issued. Reviews often take less time when a project is resubmitted in a short amount of time because reviewer is less likely to be involved in other projects and will be more familiar with the original comments.

Once all of the review comments have been addressed PWD will email the developer an approval letter. The developer **must** bring this approval letter and proof of issuance of any additional required permits to PWD when acquiring signature on Building Permit applications.

5.4.3 Inspections

During any stage of work, if the City or its designee determines that the permanent SMPs and/or stormwater management facilities are not being installed in accordance with the permitted PCSMP, the City shall revoke any existing permits or other approvals and issue a “Stop Work Order.” Work will be suspended until the installation is corrected according to the original PCSMP or a revised PCSMP is submitted, a permit granted, and the deficiencies are corrected.

Prior to the final inspection, all SMPs and/or stormwater management facilities as-built drawings must be submitted to PWD. The final inspection shall be conducted by the City or its designee to confirm compliance with the permitted PCSMP prior to the issuance of any Certificate of Occupancy. The City or its designee may inspect any phase of the installation of the permanent SMPs and/or stormwater management facilities as deemed appropriate by PWD.