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:


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 and 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 http://www.pwdplanreview.org/.

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.

- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

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.

- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

*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, the site will be subject to the enforcement actions outlined in the Stormwater Regulations.
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 the Technical Library under the Stormwater Management tab at http://www.pwdplanreview.org/ 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>
<thead>
<tr>
<th>Table 5.1: Design Precipitation Depths (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Period</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Duration</td>
</tr>
<tr>
<td>5 min</td>
</tr>
<tr>
<td>15 min</td>
</tr>
<tr>
<td>1 hr</td>
</tr>
<tr>
<td>2 hrs</td>
</tr>
<tr>
<td>3 hrs</td>
</tr>
<tr>
<td>6 hrs</td>
</tr>
<tr>
<td>12 hrs</td>
</tr>
<tr>
<td>24 hrs</td>
</tr>
</tbody>
</table>

**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
Table 5.2: Tabulated NRCS 24-Hour Type II Distribution

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Cumulative Dimensionless Rainfall</th>
<th>Incremental Dimensionless Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>2.00</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td>4.00</td>
<td>0.048</td>
<td>0.026</td>
</tr>
<tr>
<td>6.00</td>
<td>0.080</td>
<td>0.032</td>
</tr>
<tr>
<td>7.00</td>
<td>0.098</td>
<td>0.018</td>
</tr>
<tr>
<td>8.00</td>
<td>0.120</td>
<td>0.022</td>
</tr>
<tr>
<td>8.50</td>
<td>0.133</td>
<td>0.013</td>
</tr>
<tr>
<td>9.00</td>
<td>0.147</td>
<td>0.014</td>
</tr>
<tr>
<td>9.50</td>
<td>0.163</td>
<td>0.016</td>
</tr>
<tr>
<td>9.75</td>
<td>0.172</td>
<td>0.009</td>
</tr>
<tr>
<td>10.00</td>
<td>0.181</td>
<td>0.009</td>
</tr>
<tr>
<td>10.50</td>
<td>0.204</td>
<td>0.023</td>
</tr>
<tr>
<td>11.00</td>
<td>0.235</td>
<td>0.031</td>
</tr>
<tr>
<td>11.50</td>
<td>0.283</td>
<td>0.048</td>
</tr>
<tr>
<td>11.75</td>
<td>0.357</td>
<td>0.074</td>
</tr>
<tr>
<td>12.00</td>
<td>0.663</td>
<td>0.306</td>
</tr>
<tr>
<td>12.50</td>
<td>0.735</td>
<td>0.072</td>
</tr>
<tr>
<td>13.00</td>
<td>0.772</td>
<td>0.037</td>
</tr>
<tr>
<td>13.50</td>
<td>0.799</td>
<td>0.027</td>
</tr>
<tr>
<td>14.00</td>
<td>0.820</td>
<td>0.021</td>
</tr>
<tr>
<td>16.00</td>
<td>0.880</td>
<td>0.060</td>
</tr>
<tr>
<td>20.00</td>
<td>0.952</td>
<td>0.072</td>
</tr>
<tr>
<td>24.00</td>
<td>1.000</td>
<td>0.048</td>
</tr>
</tbody>
</table>

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. The stormwater model must use the minimum time step allowable by the hydrologic...
software. Also, a curve number of 98 must be used with a precipitation depth of 1.2 inches when performing water quality calculations for combined sewer areas where infiltration is not feasible, and a curve number of 100 must be used for the area below the water surface elevation in an above-ground wet pond (retention basin).

<table>
<thead>
<tr>
<th>Table 5.3: Acceptable Calculation Methods for Runoff Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Empirical Methods</td>
</tr>
<tr>
<td>Infiltration Loss Models</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

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, separate calculations for pervious and impervious area runoff must be used (weighted curve numbers between pervious and impervious areas are not acceptable). 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: PWDAccepted Curve Number Values

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

* Ub refers to “Urban Land” and generally conforms to a hydrologic soil group classification of B. A Ub CN should be used on redevelopment projects unless the engineer provides soil mapping indicative of another, more appropriate, soil classification.

**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, it is 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 non-forested pervious areas must be considered meadow (good condition) for the predevelopment runoff calculations. Pervious area is considered to be area covered by a pervious surface that allows water to drain through it rather than running off of the site. Non-forested pervious area includes the following cover types: meadow, grass/lawn, brush, gravel, dirt, pervious pavements, and any combination of these cover types. Compacted dirt or gravel is generally considered to be pervious cover.
   - 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. Only areas covered by an impervious surface or structure should be considered impervious cover in the predevelopment condition.

2) New Development sites in the predevelopment condition:
   - All non-forested, 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 100 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, which can be obtained by coupling the momentum and continuity equations with simplifying assumptions, and it 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

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>n (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof tops</td>
<td>0.011</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.013</td>
</tr>
<tr>
<td>Asphalt</td>
<td>0.015</td>
</tr>
<tr>
<td>Bare soil</td>
<td>0.018</td>
</tr>
<tr>
<td>Sparse vegetation (^2)</td>
<td>0.1</td>
</tr>
<tr>
<td>Grass:</td>
<td></td>
</tr>
<tr>
<td>Short grass prairie, Lawn</td>
<td>0.15</td>
</tr>
<tr>
<td>Dense grasses (^3), Meadow (good condition)</td>
<td>0.24</td>
</tr>
<tr>
<td>Range (natural)</td>
<td>0.13</td>
</tr>
<tr>
<td>Woods: (^4)</td>
<td></td>
</tr>
<tr>
<td>Light underbrush</td>
<td>0.40</td>
</tr>
<tr>
<td>Dense underbrush</td>
<td>0.80</td>
</tr>
</tbody>
</table>

\(^1\) 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.
5. Post Construction Stormwater Management Plans

### Table 5.6: Summary of Recommended Methods for Flow Routing

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

5.3.5 Storm Sewer Design

All storm sewer pipes must be designed to have adequate capacity to safely convey the 10-year storm without surcharging the crown of the pipe. Pipe capacity calculations are required for all stormwater conveyance that is not connected to the roof drainage system. Refer to the Philadelphia Plumbing Code for guidance on sizing roof drainage systems.

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.
- Use a runoff coefficient value of 0.35 for pervious areas and a value of 0.95 for impervious areas.
- Use the precipitation intensity for a 5-minute inlet concentration time in the 10-year storm event, which is 6.95 inches per hour. Refer to the 2010 Edition of the “Field Manual for Pennsylvania Design Rainfall Intensity Charts” PADOT Storm-Intensity-Duration-Frequency Charts (PDT-IDF) for Region 5 for more information.

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

For use with Manning’s Equation for calculating full channel flow, a Manning’s n value of 0.013 should be used for RCP, VCP, and CIP, and a value of 0.011 should be used for PVC and HDPE.
When designing a site’s storm sewer system, be mindful of the following requirements:

- Inlets may not be connected in series. Similarly, roof drainage systems may not tie directly into an inlet. Wye connections, or similar, may be used to ensure that inlets are offline.

- A minimum of 12 inches of vertical clearance is required when a sanitary sewer line crosses above a storm sewer line. The sanitary sewer must be encased in concrete if the clearance is less than 12 inches.

- Any manholes between outlet structures and sewer connections in combined sewer areas must have sanitary (non-vented) covers.

- A cleanout must be provided for all 90-degree bends.

- If curb cuts or non-standard inlets are used to capture runoff, especially from driveways or roadways where the inlets are not in a sump condition, verification that the 1-year storm will be captured by the inlet must be provided.

- All proposed connections to the City sewer must be reviewed and approved by the PWD Water Transport Records Unit. Instructions for obtaining a sewer connection permit can be found in the Technical Library under the Construction Information tab at http://www.pwdplanreview.org/.

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 the Technical Library at http://www.pwdplanreview.org/ 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. Post Construction Stormwater Management Plans

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

PWD or its designee shall inspect the project site during the construction phase. A pre-construction meeting must be held prior to the start of construction activity. Additionally, PWD’s Inspections Staff must be contacted to schedule an inspection prior to installation of any SMP. PWD or its designee may inspect any phase of the installation of the permanent SMPs as deemed appropriate by PWD. During any stage of work, if PWD or its designee determines that the permanent SMPs are not being installed in accordance with the PCSMP most recently approved by PWD (Approved PCSMP), or that adequate erosion and sedimentation pollution control practices are not being implemented on-site, the site will be subject to the enforcement actions outlined in the PWD Stormwater Regulations.

A final inspection shall be conducted by PWD or its designee to confirm the constructed conditions of the site and its general accordance with the Approved PCSMP prior to the issuance of the Certificate of Occupancy or other equivalent issuance. Prior to the final inspection, the project’s Record Drawing Submission, which documents the as-built conditions of all SMPs, must be submitted to PWD for review.
5.4.4 Operations and Maintenance Agreement

Regular inspections and maintenance, or the lack thereof, can result in significant changes to the performance of a SMP. Routine maintenance is important to ensure the functionality and aesthetic qualities of a SMP, and can also reduce the need for larger, more expensive repairs.

An Operations and Maintenance (O&M) Agreement is a required component of the PWD Stormwater Management Regulations. The owner of any land upon which SMPs will be placed, constructed, or implemented shall have an O&M Agreement. The O&M Agreement is a legally binding agreement between the property owner and the City that must be executed and filed with the Department of Records. This agreement requires the property owner to construct the on-site SMPs in strict accordance with the Approved PCSMP and to maintain these SMPs such that they will adequately perform their design functions.

The maintenance guidelines included in Sections 7.1 through 7.15 represent typical basic maintenance tasks and frequencies for the SMPs in each of these sections; however, the process of choosing appropriate maintenance tasks and frequencies is both SMP-specific and site-specific. A SMP-specific and site-specific O&M Schedule is required to be prepared by the design engineer and submitted to PWD as part of the PCSMP submittal. The O&M Schedule should be provided to and implemented by the property owner as a guide for long-term operations and maintenance of the SMPs on-site.

The standard O&M Agreement consists of the terms of the agreement followed by a signatory section, signatory acknowledgement sections, an Exhibit A, and an Exhibit B. Should amendments to the O&M Agreement become necessary, the amendments shall be sequentially numbered, and the Exhibits for these amendments shall continue alphabetically. Within the signatory section, each signatory will execute the agreement, including a representative of PWD as well as for the property. The signatories for the property must be authorized to bind the property owner(s) and the property lessee(s), if applicable, in legal agreements with PWD. The signatory acknowledgement sections must be notarized and serve to verify the identities of all parties executing the signatory section of the agreement. Exhibit A contains a legal property description for each parcel on which SMPs are to be constructed.

PWD compiles the signatory section, the signatory acknowledgement sections, and Exhibit A based on the information provided by the applicant within Worksheet 4. Worksheet 4 can be found in the Stormwater Management section of the Technical Library on http://www.pwdplanreview.org/ and must be completed and submitted as part of the initial PCSMP technical submittal. The submitted Worksheet 4 will be reviewed as part of the PCSMP screening process. Incomplete and/or incorrect information within Worksheet 4 will prevent the PCSMP review from proceeding until all omissions and/or discrepancies are addressed.

The O&M Agreement is prepared by PWD as part of the PCSMP technical review process, including the completion of an Exhibit B which lists all SMPs to be constructed on-site. Prior to PCSMP Approval, PWD will issue an electronic copy of the O&M Agreement to the applicant to be signed and notarized by the signatories for the property as specified in the signatory section of Worksheet 4. The applicant must return two (2) executed copies of the O&M Agreement along with the recording fee payment to PWD before a PCSMP Approval will be issued for the project. Upon PWD’s receipt of the signed agreement and the recording fee payment, a representative of PWD will sign the agreement, and PWD will then record the agreement with the Department of Records on behalf of the property owner. A copy of the signed, fully-executed agreement will be mailed to the signatory at the conclusion of the recording process.
5.4.5 Record Drawings

It is important, both for the property owner and for PWD, to ensure that all SMPs are constructed in strict accordance with the Approved PCSMP. Even small variations in the characteristics of an SMP (i.e. footprint area, elevations, layer thicknesses, pipe sizing, etc.) can have large effects on the SMP's ability to perform its designed stormwater function. With this in mind, the PWD Stormwater Regulations stipulate that Record Drawings for all PCSMP components must be submitted to the Department.

Record Drawing Overview

- Record Drawing plans are construction drawings revised to represent the as-built conditions, including, at a minimum, all locations, dimensions, elevations, and materials as constructed and installed. PWD uses the project’s Record Drawing(s) to verify compliance with the PWD Stormwater Regulations and to document and verify the quantity of stormwater managed on a site. It is critical that the Record Drawing(s) reflect any changes from the approved design that may affect the performance of the SMP(s).

- It is important that the Owner/Developer be aware of the Record Drawing requirements within this Manual and within the PWD Stormwater Regulations, budget accordingly, and consider these requirements when issuing the project for construction bid.

- The design engineer must customize an SMP Construction Certification Form for each SMP proposed on-site. These forms, which are described in further detail in the Record Drawing Submission and Review Process section below, must be provided to PWD for review as part of the PCSMP technical review process. It is recommended that the SMP Construction Certification Form(s) be included in the construction bid documents for the project to ensure that the selected contractor is aware of the requirement to complete the forms during construction. The project’s sequence of construction must identify all stages of SMP construction for which the contractor must document the specific elevations and measurements found on the SMP Construction Certification Form(s).

- The contractor must install all on-site SMPs, conveyance piping, structures, and any other features associated with the stormwater management design in strict accordance with the Approved PCSMP. In order to help demonstrate that all SMPs are properly installed during construction, the contractor must complete all SMP Construction Certification Forms, which are described in further detail in the Record Drawing Submission and Review Process section below. All elevations identified on the forms must be documented as they are measured. These forms must be on-site and available for PWD inspection at all times. Upon completion of the construction, all SMP Construction Certification Forms must be submitted to PWD as part of the Construction Certification Package, described below, and the measurements documented on these forms must be reflected on the Record Drawing(s).

PWD Record Drawing Requirements

- The contractor must keep the Approved PCSMP on-site at all times throughout the construction process and document all changes from the Approved PSCMP as they occur. PWD recommends marking up and tracking changes on an actual copy of the Approved PCSMP to simplify preparation of the Record Drawing(s). Using the Approved PCSMP as a base, the Record Drawing(s) should highlight information confirmed to be in accordance with the Approved PCSMP in yellow and identify any deviations in red ink. The Record Drawing(s) must be clear and legible.

- The Record Drawing(s) should include, at a minimum, the following information:
  - Horizontal variations greater than 1.0 foot should be shown dimensionally or
through stations.

- Vertical elevation variations greater than 0.1 feet should be provided for all shown design elevations.
- Measurable plan scale (not to exceed 1” = 50’)
- North arrow
- Locations of all proposed stormwater management facilities in plan view
- Distance from lot lines to the constructed SMPs
- Benchmark elevation, description, and location on each plan sheet
- Locations of all utilities
- Spot grades and grade lines
- Stormwater flow direction arrows
- Elevations at the following locations (minimum): across dam embankment, top of riser, at the invert and rim of all orifice openings in the riser, across the emergency spillway, across the bottom of the pond (dry ponds only), at the outlet of the structure, and the outlet of the pipe
- Measurements for all openings, weirs, or other flow control devices
- Pipe and culvert information (material, length, size, slope, inlet and outlet locations, and rim and invert elevations) and information for any energy dissipation measures
- Drainage areas for each stormwater management facility if they differ from the Approved PCSMP
- Detail or cross-section of each stormwater management practice

- Record Drawings may be prepared by Professional Engineers, Registered Architects, Landscape Architects, Professional Land Surveyors, Professional Geologists, and Licensed Contractors. The preparer of the plan must prominently display their signature and professional seal, or, in the case of Licensed Contractors, their signature and City of Philadelphia Department of Licenses and Inspections Contractor License Number, on each Record Drawing plan sheet.

Record Drawing Submission and Review Process

**Record Drawing Submission**

The Record Drawing Submission must consist of the following items, which must be submitted to PWD for review after construction has been completed but prior to the post-construction inspection:

- One (1) hard copy and one (1) electronic copy of the Record Drawing(s)
- One (1) electronic copy of the Construction Certification Package
- All materials must be submitted to:
  
  PWD Projects Control  
  1101 Market Street, 2nd Floor  
  Philadelphia, PA 19107

The Construction Certification Package must consist of the following items:

- An SMP Construction Certification Form must be prepared by the design engineer for each SMP on-site and provided to PWD for review as part of the PCSMP technical review process. Each form must indicate the measurements which are most critical to the listed SMP’s ability to perform its design function (i.e. elevations, surface areas, layer depths, etc.). All SMP Construction Certification Forms, as prepared by the engineer and found acceptable by PWD during the PCSMP technical review process, must be completed by the contractor during construction. Each measurement documented on the forms must include a measurement date and be initialed by the contractor, or the contractor’s designee, who took, or
witnessed the taking of, the measurement. Once all of the required measurements have been appropriately documented, the contractor must execute and date the form.

- Receipts for materials which pertain to the stormwater management system must be provided to PWD. The material receipts must clearly specify the types, qualities, and quantities of the materials purchased. The materials for which receipts are required may include, but are not limited to, stone, geotextile fabric, perforated pipes, subsurface storage units, soil, porous pavement or pavers, impermeable liner, concrete structures, hoods or traps, and vegetation or plantings.

- Photographs documenting all SMP installations must be provided. The photographs should clearly depict the installation of all components of the SMP. These photographs may include, but are not limited to, photographs of the basin excavation, fabric or liner placement, stone placement, pipe placement, and weir installation.

For more information, please refer to the Construction Certification Package document, which can be found in the Technical Library at [http://www.pwdplanreview.org/](http://www.pwdplanreview.org/).

**Record Drawing Review Process**

PWD will review the submitted Record Drawing(s) and Construction Certification Package to determine if the project has been constructed in strict accordance with the Approved PCSMP. When constructed conditions differ from the Approved PCSMP, calculations performed by a qualified design professional must be provided to demonstrate compliance with PWD’s Stormwater Regulations. Specifically, PWD may review and analyze the SMP storage volume, release rate, drainage areas, and any other items that affect the Development Site’s compliance with the PWD Stormwater Regulations and other requirements.

**Response from PWD**

- PWD will issue a letter either confirming the acceptance of the Record Drawing(s) or detailing the deficiencies with the constructed SMPs or submitted materials. Based on PWD’s evaluation of these deficiencies, revised plans, details, and/or other documentation, as needed, may be required to demonstrate that the project complies with PWD’s Stormwater Regulations. If compliance with PWD’s Stormwater Regulations cannot be demonstrated, corrective actions to bring the project into compliance must be proposed by the property owner.

- Projects confirmed to be in compliance with PWD’s Stormwater Regulations through a Record Drawing review and post construction inspection may be eligible for Stormwater Billing credits. A Stormwater Credits Application (Form B) may be submitted to PWD for review once the aforementioned steps are completed. This form, and more information on PWD’s Stormwater Billing program, can be found at [http://www.phila.gov/water/stormwater_billing.html](http://www.phila.gov/water/stormwater_billing.html).