CHAPTER 5: STORMWATER MANAGEMENT AND CONVEYANCE FACILITIES

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Illustration 5-a. Swale with Check Dam

In Pennsylvania, local governments have the authority to establish standards for the design and construction of stormwater management facilities. In addition, Pennsylvania's Stormwater Management Act of 1978 (Act 167) requires that counties prepare stromwater management plans for designated watersheds. These plans include stormwater ordinances that must be adopted by the municipalities comprising each specific watershed. Stormwater ordinances based on watershed Act 167 Plans approved by the Department of Environmental Protection subsequent to July 2001 include provisions that address peak rate, volume, and water quality. The standards in these ordinances are based on specific watershed characteristics and, as such, supersede the more general requirements contained in section 5.3 of this document.

Recommended Standards

5.0 OVERVIEW

Stormwater facilities collect, convey, and manage surface runoff from a developed site. Collection and conveyance facilities include general site grading, inlets, pipes, and swales or channels that are designed to move water to stormwater management facilities or to discharge points at the property boundary. Stormwater management facilities include structural and non-structural practices intended to manage the volume, rate, and quality of stormwater runoff.

All land disturbance activities impact the magnitude and characteristics of stormwater discharged from a site. These changes can be positive or negative. Activities that reduce impervious area and the overall intensity of development can have a positive impact on the environment by reducing the volume and peak-rate of runoff, and improving the quality of runoff leaving the site. However, activities that increase impervious area and/ or compact pervious areas increase the volume and peak-rate off, and reduce the overall quality of water leaving the site; these changes often result in flooding, surface erosion, streambank erosion, and environmental degradation of habitat within receiving waters. The goal of stormwater facilities, is to manage the quantity and quality of post development surface runoff, and to provide for the safe conveyance of surface flows to downstream receiving waters.

The recommended standards contained in this chapter comply with the Comprehensive Stormwater Management Policy issued by the Pennsylvania Department of Environmental Protection on September 28, 2002. The recommended standards are designed to be generally applicable on a Statewide basis. Stormwater ordinances based on unique watershed characteristics as defined by a stormwater management plan developed under Pennsylvania Act 167 and approved by the Department of Environmental Protection subsequent to July 2001 shall supersede the standards contained herein.

Recommended Standards

5.1 GENERAL PROVISIONS

5.1.1 Purpose

The purpose of these standards is to minimize stormwater impacts from development activities, and to promote the health, safety and welfare within the municipality through provisions designed to:

a. Meet water quality requirements under State law, including regulations at Title 25, Chapter 93 of the Pennsylvania Code;
b. To the extent possible, preserve natural drainage systems;
c. Protect the quality and quantity of water resources within individual watersheds;
d. Prevent erosion of stream banks and beds;
e. Provide for proper operation and maintenance of stormwater facilities; and
f. Provide standards to meet National Pollutant Discharge Elimination System (NPDES) permit requirements.

5.1.2 Authority

The municipality is empowered to regulate these activities by the authority of the following Acts:

a. Act of July 31, 1968, P.L. 805, No. 247, "The Pennsylvania Municipalities Planning Code", as amended.
b. Act of October 4, 1978, P.L. 864 (Act 167), 32 P.S. Section 680.1, et seq., as amended, the "Stormwater Management Act."

5.1.3 Applicability

All regulated activities and all activities that may affect stormwater runoff, including land de-

Commentary

The design of stormwater facilities and best management practices requires a high level of competence and scientific understanding in hydrology, hydraulics, soils, geology, and hydropedology. Owing to the complexity of site level stormwater facility design, and the potential for significant down-gradient impacts if appropriate design practices are not employed, all elements of the proposed stormwater management plan must be certified to and sealed by an appropriately licensed design professional. This may require certifications by more than one professional to cover all aspects of the design (for example, a soil scientist and a professional engineer).

In accordance with state law, it is illegal for any licensed professional to certify or seal a design or analysis that is not within the professional's area of competent practice or experience. Appropriately licensed Civil Engineers have historically certified stormwater management plans owing to their expertise in surface water hydrology and hydraulics. However, these same design professionals may require additional education in soils, soil physics, and hydropedology prior to being qualified to certify and seal stormwater management plans that include engineered infiltration practices.

In addition, since design liability lies with the certifying design professional(s) and not regulatory staff, regulatory reviews shall be limited to administrative and compliance issues. However, if operation and maintenance of stormwater facilities is to be the municipality's responsibility, regulatory staff may direct the design professional to evaluate alternate designs and comment on the appropriateness of said designs.

Municipal stormwater ordinances enacted under the provisions of PL 864 (Act 167) subsequent to July 2001, include provisions for stormwater peak,

Commentary

volume, and water quality control as required under Federal NPDES regulations. In addition, it is the intent of the Act 167 program that these ordinances be based on watershed-specific characteristics, data analysis, and knowledge of local flood conditions. Since the standards contained here are intended to provide sufficient flexibility to be applicable state-wide, the more watershed specific standards resulting from Act 167 planning activities supersede the stormwater management standards recommended here. Creative solutions for the mitigation of stormwater impacts are encouraged. The U.S. Environmental Protection Agency web site (Ref. 21) maintains a list of up-to-date publications and resources describing stormwater impact mitigation techniques.

The one acre of disturbed area trigger for post construction stormwater management plans is based on State NPDES Permit Requirements. Ordinances based on Act 167 Plans or Permit requirements for Municipal separate storm sewer systems may dictate a lower threshold.

Recommended Standards

velopment or earth disturbance, are subject to these regulations. Where this chapter does not include provisions for a particular technique or method, the design and construction shall be in accordance with (in order of preference) the Pennsylvania Stormwater Management Manual (Ref. 1), Urban Drainage Design (Ref. 2), or other manual of practice for stormwater conveyance and management.

5.2 REQUIREMENTS

All regulated land development and earth disturbance activities within the municipality shall manage and control surface runoff in accordance with the standards set forth herein.

A Post-Construction Stormwater Management Plan (PCSMP), prepared in accordance with the standards in this chapter, shall be submitted to the municipal authority for all land development projects disturbing more than 1 acre.

For land development projects disturbing less than 1 acre, a formal Post-Construction Stormwater Management Plan is not required. However, best management practices shall be used to mitigate potential stormwater impacts to downgradient properties, structures, and/or waterways.

The project PCSMP shall be signed and sealed by an appropriately licensed design professional (a design professional licensed by the State of Pennsylvania to practice engineering, geology, or other profession within the limitations defined in Title 49 of the Pennsylvania State Code).

The representative of the municipal approving body as well as all other State and local regulatory staff shall limit their review of a submitted stormwater plan to administrative compliance issues.

Recommended Standards

5.2.1 Post-Construction Stormwater Management Plan

Post-Construction Stormwater Management Plans shall include the following information to demonstrate compliance with the requirements of this chapter:

a. Narrative and graphics as necessary to outline the overall stormwater management concept for the project including identification and location of all proposed stormwater best management practices;

b. Evaluation and documentation of existing site conditions as they relate to the management of storm runoff. The following minimum information shall be included.

- Mapping and narrative description of site topography, surface cover, existing structures and structure remnants, soils, geology and all significant environmental features, including steep slope areas, significant vegetation, wetlands, seeps, springs, etc.

- An interpretive narrative describing existing site soils and their structure as these relate to hydropedologic processes occurring on the site. In addition to providing soil and soil profile descriptions, this narrative shall identify depth to seasonal high water tables and depth to bedrock, and provide a description of all subsurface elements (fragipans and other restrictive layers, geology, etc.) that influence the direction and rate of subsurface water movement. A qualitative assessment of the site's contribution to annual aquifer recharge shall be made, along with identification of any restrictions or limitations associated with the use of engineered infiltration facilities .

- A narrative description of the site soils investigation and justification for the level of detail included.

- Description of and justification for field infiltration/permeability testing with respect to the type of test and test locations).

- Justification for design infiltration/permeability rates used in the analysis of individual BMPs.

Commentary

Establishing an appropriate level of detail for soil mapping and assessment is the responsibility of the design professional based on his judgment and specific project characteristics (including development density, risk of hazards, etc.).

Hydropedologic processes control how water moves through the soil. Understanding the hydropedologic processes controlling subsurface water movement at a site is critical to the successful selection and placement of appropriate engineered infiltration facilities. It also helps to define when and where engineered infiltration facilities are not appropriate.

The level of detail associated with a site soils investigation will depend on project goals, site characteristics, as well as economic considerations. It is critical that the project soil scientist be involved in developing an appropriate soils investigation plan.

Appropriate evaluation should test the hydrologic characteristics of the most restrictive layer. The infiltration/permeability testing method used should provide a reasonable estimate of this value. Percolation tests ("perc test"), conducted in accordance with procedures outline in title 25, section 73.15 of the Pennsylvania code, were designed for the design of on-lot wastewater facilities and are gener-

Commentary

ally not appropriate for the design of engineered infiltration systems.

Appropriate separation distances between natural and/or engineered infiltration practices and other critical features are a function of a variety of site and critical feature characteristics, including:

- Soil type, structure, and profile;
- Potential for restrictive layers in soil;
- Topography;
- Geology/depth to bedrock;
- Volume of surface water directed to the management facility;
- Surface water contamination risk;
- Type of "other feature"';
- Location of "other feature" (up or down gradient);
- Etc.

Due to the extreme variability in surface and subsurface conditions across the state and from site to site, it is impossible to establish uniform separation distances that would apply in all cases. Establishing appropriate separation distances is the responsibility of the design professional and should be based on the above factors. (See also commentary associated with "Special Management Areas", section 5.4.5.)

Being overly conservative in setting separation distances will result in a need for more land area to serve the same development function and number of units. This impact is contrary to the goal of minimizing the area of disturbance and associated environmental impacts resulting from land development.

Since design liability lies with the certifying design professional(s) and not with municipal regulatory staff, regulatory comments shall be limited to administrative compliance issues, and the adequacy

Recommended Standards

c. Documentation illustrating and justifying separation distances between natural or engineered infiltration practices and other critical features is needed. An appropriate separation distance should be used between engineered infiltration facilities and the following critical features:

    - Water supply wells (individual or community);
    - On-lot septic systems;
    - Building foundations; and
    - Underground utility lines and trenches;
    - Sinkholes (unless an appropriate reverse filter is specified for the sinkhole).

d. Hydrologic analysis and computations documenting compliance with the standards in section 5.4, including a description of the modeling approach, rainfall–runoff model used, assumptions and limitations of the model as applied, and all analysis results.

e. Stormwater Best Management Practice design documentation shall include all assumptions, computations, and details for each practice used. A reference for the design guidance used, shall also be provided.

f. Analysis and computations for the sizing and design of all conveyance and hydraulic control structures to demonstrate compliance with section 5.5. Details shall be provided for all stormwater control structures.

g. An operations and maintenance narrative for all elements of the stormwater management system.

5.2.2 Plan Review

The stormwater management plan shall be reviewed by a Qualified Municipal Representative. Plan review shall focus primarily on administrative compliance issues, and the adequacy of engineering support documentation. Recommendations for design changes can be suggested by the municipal representative. If a change suggested by the municipal repre-

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sentative is deemed inappropriate by the licensed stormwater professional, documentation shall be provided demonstrating the scientific basis for the suggested change. However, the final determination of appropriateness for any suggested changes shall be the responsibility of the licensed stormwater professional.

After review, the Qualified Municipal Representative shall provide a written recommendation for the municipality to approve or disapprove the Post-Construction Stormwater Management Plan. If the plan is not recommended for approval, the Qualified Municipal Representative shall state the reasons for disapproval in writing. The Qualified Municipal Representative may also recommend approval of the Post Construction Stormwater Management Plan with conditions, and if so, shall provide the conditions for approval in writing.

The Post-Construction Stormwater Management Plan (see also section 5.2.1) plan review and recommendations shall be completed within the time allowed by the Municipalities Planning Code for reviewing land development plans.

5.2.3 Field Modifications

During construction, if it is found that soils and other field conditions are not as assumed in the approved stormwater management plan, and these changed conditions would result in a malfunction or failure of the approved stormwater management facilities, construction of said stormwater facilities shall be halted, and appropriate revisions shall be made to the stormwater management plans. These field changes shall be designed by the developers' Stormwater Design Professional, and reviewed and approved by the Qualified Municipal Representative prior to proceeding with construction of said stormwater facilities. These modifications will then be reflected in the As-Built Survey (see section 5.2.4).

Commentary

of the engineering support documentation provided.

If the Qualified Municipal Representative disagrees with respect to the appropriateness of a proposed stormwater management practice, the following options exist for resolution and approval:

a. An alternate approach or management practice acceptable to the Qualified Municipal Representative and the Licensed Stormwater Professional can be used.

b. An appropriately licensed municipal representative can design the suggested plan change and prepare any necessary stormwater analysis and/or engineering support documentation, and construction details for the change. This information shall be provided to the applicant's design engineer for inclusion in the permit documents and construction plans. In addition, a statement shall be placed on the permit documents and construction plans waiving the licensed professional's liability for that aspect of the design and making the licensed municipal representative liable for any future damage and repairs resulting from that aspect of the stormwater management plan. This statement shall be signed by the applicant's licensed stormwater professional and an appropriate agent of the municipality.

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Illustration 5-b. Natural Drainage Area

Natural drainage area is preserved and used as a focal amenity. The houses face this natural open space.

Land development activities impact the peak discharge rate, volume, and quality of surface produced by a land area. Mitigating these impacts requires design flexibility, and the use of both natural and constructed facilities.

Guidance for the integration of site design with stormwater controls through the use of non-structural BMPs is provided in chapters 4 and 5 of Reference 1. These approaches will often require creativity and flexibility in zoning and other municipal standards. For example, protecting sensitive and special value areas, minimizing disturbed areas, and allowing room for decentralization of stormwater functions may require lot sizes and configurations not permitted in conventional zoning districts. For a given site yield (number of lots or homes), the use of smaller lots will permit a developer to protect and conserve sensitive or special value resources and open space. This approach also has cost benefits for the municipality: the use of smaller lots will minimize street and utility length, reducing opera-

Recommended Standards

5.2.4 As-Built Surveys, Completion Certificate, and Final Inspection

The developer shall be responsible for completing an “as-built survey” of all stormwater BMP’s and other facilities included in the approved Post-Construction Stormwater Management Plan. The as-built survey and an explanation of any discrepancies with the design plans shall be submitted to the municipality.

The submission shall include a certification of completion from the site engineer verifying that all permanent stormwater BMPs have been constructed according to the plans and specifications and approved revisions thereto.

After receipt of the completion certification by the municipality, the municipality may conduct a final inspection.

5.3 APPROACH

Stormwater management planning shall strive first to minimize stormwater impacts through an integration and retention of natural site characteristics, and site layout and design. This can be accomplished through the use of non-structural stormwater best management practices as identified in Reference 1, including:

1. Protection of sensitive and special value resources critical to site stormwater management;
2. Use of cluster development techniques;
3. Minimizing disturbed area;
4. Minimizing impervious areas;
5. Re-vegetation and reforestation of disturbed areas;
6. Decentralization of stormwater functions; and
7. Source control of pollutants.

After maximizing the use of non-structural practices, structural or built management practices shall be integrated into the design to further mitigate anticiptated impacts. Structural practices include, but are not limited to, the following as described in Reference 1:

1. Infiltration beds, basins, and trenches;
2. Raingardens and bioretention areas;
3. Dry wells and seepage pits;

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4. Vegetated swales and filter strips;
5. Infiltration berms and retentive grading;
6. Vegetated roofs;
7. Rainwater capture and re-use systems;
8. Constructed wetlands;
9. Retention / detention basins;
10. Water quality filters and hydrodynamic structures; and
11. Restoration BMP's, such as riparian buffer restoration, landscape restoration, soils amendment and restoration, and floodplain restoration.

Responsible stormwater management design demands that stormwater issues and options be considered early in the design process. Evaluation of existing site soils, topography, and other natural features must be completed as part of the preliminary design process to maximize opportunities for stormwater mitigation.

5.4 SITE IMPACT MITIGATION STANDARDS

The hydrologic standards for stormwater management design and analysis presented here meet State water quality standards as specified in Title 25, Chapter 93 of the Pennsylvania Code. The design of specific stormwater best management practices shall be in accordance with guidance provided in the *Pennsylvania Stormwater Best Management Practices Manual* (Ref. 1) or other appropriate design guidance (see Ref. 21, for example).

5.4.1 General

All stormwater management designs shall respect natural drainage divides and the character of discharges to adjacent properties. Any change in these drainage characteristics shall require prior authorization by the Qualified Municipal Representative.

Commentary

tion and maintenance costs for the municipality and municipal authorities.

Maximizing the use of non-structural controls will typically reduce, but not eliminate, the need for structural controls. Design standards for structural controls are contained in chapter 6 of Reference 1.

Illustration 5-c. Vegetated Swale

State water quality requirements for post-construction stormwater runoff can be met through the use of stormwater best management practices (BMPs), including site design, which mitigate the negative impacts of development on runoff peak, volume, and quality.

The standards contained in this section are intended as minimum standards generally applicable throughout Pennsylvania. These standards are recommended for application in all municipalities or locations where stormwater standards have not been developed using watershed-specific data in accordance with the Pennsylvania Stormwater Management Act of 1978 (Act 167) as interpreted

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subsequent to July 2001.

In addition, it is recognized that the design of stormwater Best Management Practices (BMP) is an evolving science. The Pennsylvania Stormwater BMP Manual (Ref. 1) is only one source of information. New and innovative approaches for the design of stormwater BMP's are encouraged. The EPA Low Impact Development web site (Ref. 21) is continually updated to reflect new approaches and design procedures for stormwater impact mitigation.

The intent of this regulation is to maintain, to the extent practical, the pre-development direction and character of discharges from a site. Minor changes in drainage divides may be acceptable as long as they don't result in significant off-site impacts. In addition, flow concentration at the development site boundary may be acceptable if there will be little or no impact to adjacent properties.

The purpose for controlling the peak rate of runoff is to protect downstream property and infrastructure from damage and inconvenience caused by nuisance and severe flooding. These impacts are a natural consequence of land development practices (see Ref. 1, chapter 2).

The compliance criteria are based on the following:

a. The 24-hour rainfall events are used because a 24-hour storm produces a design storm of sufficient duration to generate peak runoff rates for moderate to large watersheds, and at the same time, contain high-intensity, short-duration peak rainfall amounts that result in peak floods for small drainage areas.

b. The discrete storm events (1-yr., 2-yr., 10-yr., and 100-yr.) were selected to cover the range of events typically analyzed in engineering hydrologic analysis (up to the 100-yr. event),

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5.4.2 Peak Runoff Rate Control

The peak surface runoff rates discharged from a site subsequent to development shall not exceed pre-development peak discharge rates.

Compliance with this standard shall be documented through analysis of runoff resulting from the one (1)-, two (2)-, ten (10)-, and one hundred (100)-year return period twenty-four (24)-hour rainfall events.

In addition, the following conditions shall be used for analysis:

1. Design storm precipitation values shall be based on partial duration series statistics.

2. Existing non-forest areas shall be considered meadow or its equivalent in good hydrologic condition.

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5.4.2.1 Peak Rate Control Exemptions

A. Any site at which the increase in post-development peak runoff rates is determined to be negligible by the Qualified Municipal Representative is exempt from the requirement to provide peak rate control. In support of this exemption, it must be shown that the downstream conveyance systems have adequate capacity to convey the additional discharge without flooding or otherwise adversely affecting downstream properties. This exemption does not waive the requirement for implementation of designs for volume control, water quality control, or stormwater conveyance.

   Written documentation and computations supporting a request for this waiver must be submitted to the Qualified Municipal Representative for review and consideration. This exemption can only be used if authorized by the Qualified Municipal Representative.

B. Peak rate controls may be waived in special cases when it can be demonstrated that the rapid release of stormwater from a site will reduce peak flood levels in tributary streams and waterways. Any such request for a waiver of peak rate control must be supported by adequate documentation and engineering analysis. This documentation must demonstrate a flood peak reduction in the receiving waterway for all flood events as demonstrated through analysis of the 2-year, 10-year, and 100-year design 24-hour storm events. The final determination on the waiver request shall be made by the Qualified Municipal Official.

5.4.3 Volume Control

Stormwater management facilities shall be designed to capture and manage the net increase in surface runoff volume resulting from proposed site development activities for runoff events having return periods equal to or less than two years. This increase in volume is referred to as the design capture volume.

Compliance with this standard shall be documented through analysis of runoff resulting from the 2-year, 24-hour rainfall event. This event shall be referred to as the volume control

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maintain focus on control of more frequent extreme events (see Ref. 7), and maintain reasonableness in the number of events that must be included in the stormwater analysis. Practice has also demonstrated that the 25-yr. and 50-yr. events are adequately managed by the outlet control for the 10-year event and don't need to be analyzed separately.

The intent of this exemption is to eliminate the need for multiple or "piggyback" detention facilities as a result of minor changes in imperviousness or land use upstream of existing stormwater control facilities. A 5% increase in peak runoff rate is suggested as the benchmark for defining "negligible".

The intent of this exemption is to permit the advance release of discharges from sites located in lower portions of a watershed ahead of flows from areas further upstream in the watershed. The goal of these early releases is to reduce downstream peak flood levels.

The purpose of volume control is to mitigate the impacts resulting from the increase in surface runoff volume characteristic of land development activities. Rain falling on a parcel of ground either infiltrates, is intercepted by surface depressions and vegetation and evaporates, or runs off the surface. Volume increases result from surface compaction, removal of vegetation and topsoil, and the cre-

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ation of impervious surfaces. The impacts include changes in *stream morphology* (exhibited through channel erosion), a *reduction in groundwater recharge*, and a potential increase in downstream *flooding*.

The volume control standard presented is based on the following justification:

a. *Channel Stability (morphology)*: Henderson (Ref. 15) summarizes research by Nixon, and Wolman and Leopold, indicating that bank-full steam flow (considered to be the dominant channel forming discharge) occurs with a frequency of approximately 6 to 9 months based on a count of all storms. A count of all storms is a frequency measure similar to return periods based on partial duration series statistics. Therefore, a 1-year 24-hour design storm based on partial duration series precipitation statistics is appropriate and conservative from a channel stability / degradation perspective.

b. *Groundwater Recharge*: Groundwater recharge occurs variably across a watershed. In general it can be stated that a significant percentage of the total recharge occurring within a watershed will occur in discrete locations, and not uniformly across the watershed. From watershed to watershed, the percentage of annual precipitation that becomes recharge can vary significantly. The most efficient way to maintain recharge within a watershed is to identify the critical recharge areas and protect them.

   In lieu of a study to identify recharge specific characteristics within individual watersheds and on land development sites, all that can be done is make an educated generalization of the recharge impact that should be mitigated. The recharge potential and resulting deficit recommend in these standards are based on the potential maximum (soil) retention, S, defined

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design storm. In addition, the following criteria shall apply:

a. Design storm precipitation values shall be based on partial duration series statistics.

b. Existing non-forest areas shall be considered meadow or its equivalent in good hydrologic condition.

c. Non-structural stormwater best management practices (as specified in Chapter 5 of the Pennsylvania Stormwater Best Management Practices Manual [Ref. 1]) shall be used to the maximum extent practical to minimize the design capture volume resulting from the proposed development activities. Volume credits for the use of non-structural stormwater best management practices shall be computed as specified in Chapter 8 of the Pennsylvania Stormwater Best Management Practices Manual (Ref. 1).

d. After maximizing the use of non-structural stormwater best management practices, the remaining design capture volume shall be eliminated from the surface discharge stream through the use of a non-discharge alternative such as natural or engineered infiltration, evapotranspiration, consumptive re-use, or a combination of these practices.

e. When it is demonstrated that no environmentally sound or cost effective non-discharge alternative exists on a site to completely remove the design capture volume from the surface discharge stream, extended detention practices may be used to manage the release of the increased site discharge. When extended detention releases are used to manage any portion of the design capture volume, it shall be demonstrated that the resulting release rates will maintain and protect the quality of receiving surface waters. This requirement will be considered met when the extended detention release rate standards specified in paragraph g of this section are met.

f. Minimum Recharge Volume: A portion of the design capture volume represents lost recharge potential. The recharge deficit created by land development activities shall be restored using natural or engineered infiltration practices. The recharge deficit is established as the minimum recharge volume. An estimate of the recharge deficit shall be made using the following relationship:

$$\mathbf{RD = A_d\,(Spre - Spost) / 12}$$

Where:
RD = Recharge deficit to be mitigated (ac-ft)

Recommended Standards

A_d = Site disturbed or impacted area (including undisturbed areas compacted by construction equipment) (acres)
S pre = $(s_1a_1 + s_2a_2 + \ldots s_ia_i)$ pre / $(a_1 + a_2 + \ldots + a_i)$ pre
S post = $(s_1a_1 + s_2a_2 + \ldots s_ia_i)$ post / $(a_1 + a_2 + \ldots + a_i)$ post
$s_1, s_2 \ldots s_i$ = potential maximum retention for each cover complex combination (inches).
$a_1, a_2 \ldots a_i$ = area for each cover complex (acres)
Spre = Pre-development potential maximum retention (inches)
Spost = Post-development potential maximum retention (inches)

The potential maximum retention identified above is as defined in Ref. 27 and is given by the following equation:

$$S = (1000 / CN) - 10$$

Where:

CN = NRCS Runoff Curve Number

The recharge deficit (RD) is best mitigated through the use engineered infiltration facilities which introduce this volume into the subsoil. However, surface infiltration techniques may be used to mitigate this volume. Volume credits identified under item c above may be applied to the recharge deficit.

A waver of the minimum recharge volume shall be granted when it is demonstrated that infiltration of this volume will pose an unacceptable risk of economic loss down-gradient of the engineered infiltration facility.

g. When extended detention practices are used to mitigate all or a portion of the design capture volume, the single or cumulative maximum flow rate resulting from extended detention releases shall not exceed 25% of the receiving channel's estimated dominant discharge (DD25). Compliance with this standard shall be assumed when the following conditions are met:

- Limit extended detention release rates from individual sites to their proportionate share of the DD25 value in all tributary streams to a limiting point-of-interest having a drainage area at least 20 times the project site area tributary to that point. The maximum extended detention release rate shall be evaluated at the site discharge point, at the limiting point-of-interest, and at all steam junctions between these two points. The maximum extended detention release rate shall be computed as follows:

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in the *Natural Resource Conservation Services National Engineering Handbook*, Part 630, Hydrology (Ref. 27). The method presented allows the user to relate recharge deficit to pre- and post-development cover-complex curve numbers, a familiar parameter to most design professionals involved in stormwater management analysis.

However, it must be emphasized that the recharge requirement established here is only an approximation intended to be used as a design tool in the absence of a more rigorous analysis of recharge within a specific watershed.

c. *Prevent Downstream Flooding*: In addition to peak rate, the increase in post-development runoff volume can contribute to an increase in flooding. The additional volume control provided by mitigating the increased runoff from the 2-year event, beyond that necessary for channel stability and groundwater recharge, provides an additional level of protection against flood impacts.

Site design shall always attempt to maximize the use of natural or structural volume removal practices. However, it is recognized that the complexity of site soils and geologic conditions, coupled with the potential risk of down gradient impacts (water in basements, saturated slope failures, potential for sinkhole formation, saturation of down-gradient on and off-site land areas, etc.) will not always permit complete mitigation of the increased volume of runoff resulting from the volume control design storm. For this reason, extended detention is included as a volume control option.

The implementation of the Commonwealth's antidegradation requirements codified in Title 25, Chapter 93.4c of the Pennsylvania State Code, require that persons proposing a new, additional or increased discharge in high quality or exceptional value waters demonstrate that

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- no environmentally sound and cost effective non-discharge alternative exists, and
- that the discharge will maintain and protect the existing quality of receiving surface waters.

The intent of the extended detention release rate standards in paragraph g of this section is to ensure that individual and potential cumulative extended detention release rates from developing sites within a watershed do not pose a threat to downstream channel stability or degradation. Mitigating the threat of channel instability eliminates the degradation risk associated with an increase in surface runoff volume. However, the use of extended detention release rates as a runoff volume management tool should only be used when it can be demonstrated that there is no environmentally sound or cost effective volume removal alternative available.

When the design capture volume can not be completely mitigated using volume removal practices, and downstream flooding is a concern, consideration should be given to requiring that post development peak runoff rates be controlled to magnitudes less than pre-development values. Reduced peak release rates should be established based on consideration of environmental impact and flood damage risk.

Recommended Standards

MEDR = [SA / WA] X DD25

Where:

MEDR = the maximum extended detention release rate (cfs);
SA = Site area tributary to the analysis point-of-interest (acres);
WA = Watershed area tributary to the analysis point-of-interest (acres); and
DD25 = Twenty-five percent of the estimated watershed dominant discharge at the point-of-interest.

The dominant discharge is defined as the surface runoff resulting from the 1-year, 24-hour rain event using partial duration series precipitation statistics.

- Extended detention release rates shall be set so that the time to discharge the extended detention volume is greater than 24 hours and less than 72 hours. In both cases, basin release times shall be measured to when 80 percent of the extended detention volume has been released. If the maximum extended detention release rate identified in b and c above does not permit the release of at least 80% of the extended detention volume in less than 72 hours, consideration should be given to permitting a larger extended detention release rate.

Engineered infiltration practices designed to mitigate all or a portion of the design capture volume, introduce more water into sub-soils than occurred naturally. Therefore, an understanding of local soil characteristics and structure, engineering properties of soils, and soil-water physics as it relates to the movement of water through soils is critical to the responsible design of infiltration facilities. Every effort shall be made to safely remove as much of the design capture volume as possible from the site surface discharge stream. However, subsurface conditions (soils and geology) may restrict the volume that can be safely removed through natural or engineered infiltration practices. The final design infiltration volume and rate shall be established by a licensed design professional qualified to perform said services. Documentation substantiating said volumes and rates shall be submitted as part of the Post Construction Stormwater Management Plan.

Adequate pre-treatment of stormwater shall be provided prior to infiltration of stormwater originating from the following areas to minimize health and safety risks:

a. Stormwater from areas of high – pollutant loading. High-pollutant loading areas are areas in industrial and commercial developments where solvents and/or petroleum products are loaded/unloaded, stored, or applies; areas where pesticides

Recommended Standards

are loaded/unloaded or stored; areas where hazardous materials are expected to be present in greater than "reportable quantities" as defined by the United States Environmental Protection Agency (EPA at 40 CFR 302.4; and areas with high risk for spills of toxic materials, such as gas stations and vehicle maintenance facilities.

b. Industrial stormwater exposed to "source material." "Source Material" means any material(s) or machinery located at an industrial facility that is directly or indirectly related to process manufacturing, or other industrial activities, which could be a source of pollutants in any industrial stormwater discharge to ground water. Source materials include, but are not limited to, raw materials; intermediate products; final products; waste materials; by-products; industrial machinery and fuels; and lubricants, solvents, and detergents that are related to process, manufacturing, or other industrial activities that are exposed to stormwater. Coal mine reclamation areas may be included in this category when infiltrated water would aggravate or create acid mine drainage to tributary streams.

c. Coal Mine Reclamation Areas - A partial or complete waver of the volume control standards shall be considered if adequate pre-treatment can not be provided and a health and safety risk would result if infiltration practices were used.

5.4.4 Water Quality Control

Water quality control shall be implemented using the following treatment standards and practices.

5.4.4.1 Treatment Practices

Particulate associated pollutants are best treated by stormwater management practices that filter or permit the settlement of suspended solids. Filtering practices include:

- Street sweeping (removes large particulate matter from paved surfaces);
- Runoff filtering through vegetative areas (vegetated filter stripes, grassed swales, etc.); and
- Manufactured inlet filters.

Settling practices include:

Commentary

Nonpoint source pollution occurs when rainfall, snowmelt, or irrigation runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, and coastal waters, or introduces them into the groundwater. According to EPA (Ref. 23), agricultural practices are the leading source of water quality impairment to our rivers, lakes and estuaries.

Runoff from land development activities is also identified as an important source of nonpoint pollution (Ref. 23). The most significant water quality impact from developing land areas is the increase in runoff volume and peak-rate generated from

Commentary

the built impervious area. These increased runoff volumes and rates can result in significant instability and erosion in receiving channels, which can contribute to habitat degradation.

Developed land areas have also been observed to produce other pollutant loads associated primarily with transportation sources and turf and garden management. These include oil, grease, and toxic metals from motorized vehicles; nutrients and pesticides from turf management and gardening; viruses and bacteria from failing septic systems; and road salts. Sediments and solids constitute the largest volume of pollutant loads to receiving waters in urban areas (typically reported as Total Suspended Solids [TSS]). In addition, dissolved pollutants (reported as nitrates and nitrites) from some heavily fertilized lawns and planting areas have also been identified as a nonpoint source pollutant in urban runoff.

Although it is important to minimize overall pollutant loading to receiving waters, it is also important to recognize that residential development may reduce nonpoint pollutant loadings when compared with some pre-development land uses. For example, farmland and pasture have been observed to produce higher concentrations of Total Suspended Solids and Total Phosphorus, and nitrite and nitrates than many residential developments (Ref. 24 and 25 provide examples).

Suspended pollutants are typically scoured from the land surface near the beginning of storm events (referred to as the “first flush”). This results in a spike in pollutant levels in receiving waters in advance of the runoff peak, followed by a significant drop in concentration levels. In contrast, the concentration of dissolved pollutants has been observed to remain fairly constant during storm events, with some dilution evident during the peak runoff period (Ref. 1).

Recommended Standards

- Wet ponds;
- Dry ponds with forebay settling areas;
- Dry extended detention ponds;
- Constructed wetlands; and
- Manufactured hydrodynamic/vortex structures.

Figure 5.1. Constructed Wetland

In addition, all natural and engineered infiltration practices will also filter particulate matter. Where heavy sediment loads of silt and sand size particles are anticipated, the runoff stream should be appropriately filtered before it reaches any infiltration practices.

Dissolved pollutants are best treated by practices that include vegetative uptake functions. These practices include:

- Bio-retention areas/rain-gardens;
- Vegetated swales;
- Vegetated areas behind berms and other retentive grading areas;
- Constructed wetlands;
- Wet ponds; and
- The dispersed discharge of surface waters to natural undisturbed areas.

Any practice that infiltrates surface runoff into natural vegetated topsoils (A horizon soils) or a designed planting bed containing 20-30% organic material can be used to treat dissolved pollutants. Planting beds should be designed in accordance with standards for same in Reference 1.

Application and design guidance for individual water quality practices is provided in the *Pennsylvania Stormwater Best Management Practices* Manual (Ref. 1).

Recommended Standards

5.4.4.2 Water Quality Standards

The following water quality standard shall be met:

Achieve an 85% reduction in post-development particulate associated pollutant load (as represented by Total Suspended Solids), an 85% reduction in post-development total phosphorus loads, and a 50% reduction in post-development solutes (as represented by NO3-N), all based on post-development land use.

This standard is intended as a performance-based goal. It does not represent specific effluent limitations but a composite efficiency expectation for use in selecting appropriate management practices.

This standard shall be considered met when one of the following criteria are satisfied:

1. The Design Capture Volume is completely removed from the surface discharge stream, and 90% of site disturbed area is controlled by a water quality BMP. In addition, complete Worksheet 10 from the Pennsylvania Stormwater BMP Manual (Ref. 1) for nitrate compliance; or

2. Computationally demonstrate compliance with water quality standard by estimating pollutant loadings for the proposed development and pollutant load reductions resulting from specific site BMP's as outlined in Tables 5.1 and 5.2 below. In addition, complete Worksheet 11 from the Pennslvania Stormwater BMP Manual (Ref. 1) for nitrate compliance.

Post-development pollutant loadings shall be computed for the land cover classifications and loading rates indicated in Table 5.1. The pollutant load for each component to be treated shall be computed using the following equation:

Pollutant Load = [EMC, mg/l] X [Treated WQV, ac ft] X [2.7, unit conversion]

Where:
EMC = the event mean concentration of the pollutant (mg/l)
WQV = 0.5 X QIMPV + 0.25 X QPERV)/12
QPERV = Qualifying pervious area (acres) *
QIMPV = Qualifying impervious area (acres) *

* Qualifying pervious and impervious areas are identified by the described land cover classifications in the Table 5.1.

Commentary

The suggested water quality standards are intended to capture and collect the "first flush" runoff from medium- to high-volume streets and parking areas, and the initial surface runoff from moderately to heavily maintained lawn and planting areas. Golf courses and professionally maintained athletic fields would be examples of heavily maintained areas; moderately maintained lawn areas would typically be expected in subdivision of 30 lots of larger having one-quarter acre or smaller lot sizes, where the cost of houses is at or above the median housing price for the region.

The data reported in Reference 1 indicate that rooftops, low-volume (traffic) streets and parking lots, residential driveways, playcourts, etc., do not produce significant concentrations of suspended or dissolved pollutants. Therefore, these impervious areas are excluded from the water-quality volume calculation.

In addition, research has established that a significant majority of water-quality impacts from paved land areas are associated with the "first flush" described above. This first flush has typically been defined as the first 0.5 inches of runoff from impervious land areas.

Capturing the initial 0.5 inches of surface runoff from impervious areas (CN = 98) results in capture and treatment of the runoff resulting from over 60% of the rainfall falling annually on these surfaces. Similarly, capturing the initial 0.25 inches of runoff from maintained landscapes (average CN = 77) results in capture and treatment of the runoff resulting from about 92% of the annual rainfall falling on these surfaces. The rainfall percentages reported here are based on data presented in Appendix F of Reference 16.

Commentary

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Table 5.1. Typical Pollutant Loadings by Land Cover Classification.
(Modified from Ref. 1 to reflect land cover definitions characteristic of this manual)

Land Cover Classification	TSS (EMC in mg/l)	Total Phosphorus (EMC in mg/l)	Nitrate-Nitrite (EMC, mg/l as N)
Residential Lawns (avg lot size < ¼ ac)	180	0.4	0.44
Commercial Lawn Area	180	2.22	1.46
Commercial Planting Beds	55	1.34	0.73
Golf Course Greens and Fairways	305	1.07	1.84
Grassed Athletic Fields	200	1.07	1.01
Athletic Courts	60	0.46	0.47
Residential Driveways	60	0.46	0.47
Low Volume Streets	86	0.36	0.47
Medium Volume Streets	113	0.33	0.58
High Volume Streets	261	0.40	0.83
Low Volume Parking Lots	58	0.15	0.39
High Volume Parking Lots	120	0.39	0.6

Table 5.2. Summary of Pollutant Removal Percent Efficiencies of Stormwater BMP
Source: Ref. 1

Comprehensive BMP List		Pollutant Removal		
		TSS	TP	NO3
Non-Structural BMP's				
5.4.1	Protect Sensitive / Special Value Features	SC	SC	SC
5.4.2	Protect / Conserve / Enhance Riparian Areas	SC	SC	SC
5.4.3	Protect / Utilize Natural Flow Pathways in Overall Stormwater Plan Design	30	20	0
5.5.1	Cluster uses at Each Site: Build on the Smallest Area Possible	SC	SC	SC
5.5.2	Concentrate uses Area-wide through Smart Growth Practices	SC	SC	SC
5.6.1	Minimize Total Disturbed Area – Grading	40	0	0

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5.6.2	Minimize Soil Compaction in Disturbed Areas	30	0	0
5.6.3	Re-vegetate and re-forest Disturbed Areas using Native Species	85	85	50
5.7.1	Reduce Street imperviousness	SC	SC	SC
5.7.2	Reduce Parking Imperviousness	SC	SC	SC
5.8.1	Rooftop Disconnection	30	0	0
5.8.2	Disconnection from Storm Sewers	30	0	0
5.9.1	Street Sweeping	85	85	50
Structural BMP's				
6.4.1	Porous Pavement with Infiltration Bed	85	85	30
6.4.2	Infiltration Basin	85	85	30
6.4.3	Subsurface infiltration Bed	85	85	30
6.4.4	Infiltration Trench	85	85	30
6.4.5	Rain Garden / Bioretention	85	85	30
6.4.6	Dry Well / Seepage Pit	85	85	30
6.4.7	Constructed Filter	85	85	30
6.4.8	Vegetated Swale	50	50	20
6.4.9	Vegetated Filter Strip	30	20	10
6.4.10	Infiltration Berm and Retentive Grading	60	50	40
6.5.1	Vegetated Roof	85	85	30
6.5.2	Rooftop Runoff – Capture and Reuse	100	100	100
6.6.1	Constructed Wetland	85	85	30
6.6.2	Wet pond / Retention Basin	70	60	30
6.6.3	Dry Extended Detention Basin	60	40	20
6.6.4	Water Quality Filter	60	50	20
6.7.1	Riparian Buffer Restoration	65	50	50
6.7.2	Landscape Restoration	85	85	50
6.7.3	Soil Amendment and Restoration	85	85	50
6.8.1	Level Spreader	20	10	5
6.8.2	Special Detention Areas – Parking Lot, Rooftop	0	0	0

Consideration shall also be given to potential thermal impacts to receiving waters from

Commentary

Commentary

Special management areas pose unique restrictions and challenges for implementation of infiltration and other stormwater best practices. The most significant of these limiting characteristics are outlined below. Guidance is provided in Reference 1 for the application of specific BMP's within these environments.

Brownfields: Contaminated soils on brownfields sites can limit the use of infiltration practices. Contaminated soils can be completely removed from the site, isolated and capped, or blended with clean soil to meet state public health and safety requirement as a part of an overall stormwater management plan.

Karst Areas: The complexities of karst systems demand more rigorous scrutiny of geologic setting than other areas. In these areas, natural infiltration occurs across wide areas of the landscape through conducive natural soil structure, closed depressions, and sinkholes. Development activities significantly alter these natural characteristics and concentrate infiltration functions. With appropriate care, the standards proposed here can be implemented successfully on many sites in karst regions.

Mined Lands: Disturbed lands that have been surface mined or deep mined pose a significant threat to water quality. Rainfall that percolates through residual mine wastes on the land surface or into and through deep mines becomes extremely acidic prior to emerging as stream base-flow or through hillslope springs and seeps. Infiltration practices implemented on these sites will have the same result.

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stormwater discharges. Anticipated thermal impacts shall be mitigated to the maximum extent possible. Cooling can be achieved through the use of below ground storage or vegetative shading as examples.

5.4.5 Special Management Areas

Unique areas and development activities warrant special consideration from a stormwater management perspective. These areas include:

- Brownfields
- Karst areas (areas underlain by limestone and dolomite formations)
- Mined lands
- Areas close to water supply wells
- Areas close to surface water supplies, and special protection waters
- Urban land areas
- The development of highways and roadways

Due to the unique risk of pollution or undesirable downstream impacts that might result from the use of engineered infiltration and other stormwater control practices in these areas, it may be necessary to waive strict compliance with the design standards of section 5.4.3. In addition, the development of highways and roadways pose their own unique design challenges that may necessitate variance in the application of stormwater controls.

The design of stormwater management facilities in special management areas must consider the unique nature of these areas while attempting to minimize off-site impacts from stormwater runoff. Stormwater management planning in these areas should be coordinated with the Qualified Municipal Representative as well as appropriate agency personel early in the design process to identify appropriate standards to be applied on a project by project basis. Chapter 7 of Reference 1 shall provide general guidance about the design of stormwater management facilities in Special Management Areas.

Recommended Standards

Figure 5.2. Bioswale in Parking Lot

Commentary

Areas Close to Water Supply Wells: Care must be exercised to ensure that infiltration practices don't pose a risk of groundwater pollution near water supply wells.

Areas Near Surface Water Supplies and Special Protection Waters: Again, care must be exercised to ensure that stormwater practices don't pose any significant risk of pollution to these areas.

Urban Land Areas: The intensity of land development in most urban centers not only creates dense development of impervious surfaces on the surface, but also results in complex web of underground utilities (water, wastewater, stormwater, gas, electric, communications infrastructure, etc.). This results in limited area for the construction of stormwater best practices. In addition, the design of stormwater infiltration facilities must consider potential risks to downgradient foundations, and utilities.

Highways and Roadways: Highways and roads face the following specific challenges in managing stormwater:

- The need to manage stormwater while maintaining safe road conditions;
- Limited ROW space (especially on betterment projects);
- As linear systems, roads cross many local watershed divides;
- High percentage of imperviousness;
- Extent of land disturbance and compaction necessary within ROW;
- Potential for hazardous material spills;
- Use of deicing chemicals, salts, and anti-skid;
- High concentration of pollutants per acre; and
- Potential for significant thermal impacts.

The above items individually and in combination pose significant challenges for highway projects.

Commentary

The most common hydrologic analysis methodology used in Pennsylvania for stormwater management design is the NRCS curve number method (TR-55 tabular hydrograph method [Ref. 3] or the TR-20 unit hydrograph model [Ref. 4]). This methodology is recommended because it has a sound scientific basis and was originally developed as a rainfall to runoff volume transformation tool. References 3, 5, 6, 7, 8, 9, and 11 provide additional information on the curve number methods, including discussions of appropriate application and limitations. Many of the limitations identified for the curve number methods also apply to other available hydrologic analysis tools.

The rational method was originally developed as a rainfall intensity to peak runoff rate transformation tool for developed urban areas. Its application for runoff volume computations, particularly under undeveloped conditions, is questionable.

The NRCS models and methods recommended are based on data collected from actual watersheds. In contrast to this, stormwater management analysis for land development activities is often conducted using property lines to define drainage boundaries. Drainage areas based on property boundaries are not true watersheds and are referred to here as “hypothetical” drainage areas. It is known that these hypothetical drainage areas do not respond like natural watersheds. Peak runoff rates from hypothetical drainage areas are often much smaller than comparable runoff rates from natural watersheds of the same size. This often results in post-development nuisance flooding since the models over-estimate the pre-development runoff magnitude.

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5.4.6 Calculation Methods

The following calculation methods shall be used for all stormwater management analyses unless otherwise authorized by the Qualified Municipal Representative.

The conversion of a design rainfall event to a runoff event shall be performed using one of the following methodologies. The size criteria are based on drainage area size, including site area and all off-site areas draining across the development.

Up to one-hundred (100) acres: NRCS’s Cover Complex Method (TR-55 or TR-20)

Over one-hundred (100) acres: NRCS’s Cover Complex Method as implemented in TR-20 or one of the hydrologic methods implemented in HEC-HMS or HEC-1.

A rational hydrograph method (Modified Rational, or Universal Rational) may be used for any site less than or equal to two (2) acres in size without prior authorization from the Qualified Municipal Representative. These methods may also be used for sites between two (2) and twenty (20) acres in size where the Qualified Municipal Representative has approved the methods use. In this case the licensed design professional must make a written request to the Qualified Municipal Representative explaining why the use of the Rational Method is more appropriate than the NRCS’s methods for the site in question.

If other methods are proposed, a detailed discussion of the hydrologic method used, its applicability to specific site conditions, and a discussion of method assumptions and limitations shall be included in the stormwater management plan narrative.

Commercial software packages that use the basic computational methods of TR-55 or TR-20 are permitted.

In addition, the following standards are established for specific elements of the computational analysis methods:

a. Design runoff hydrographs shall be developed based on the most current PennDOT regional twenty-four (24)-hour rainfall depths (Ref. 17), or NOAA Atlas 14 data (Ref. 18).

b. The NRCS Type II precipitation distribution shall be used to establish the rainfall distribution for stormwater management hydrologic analysis.

c. The NRCS’s dimensionless unit hydrograph “k” factor of 484 shall be used for both

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pre- and post-development stormwater analyses unless a different value is found to be appropriate based on watershed-specific data analysis.

d. NRCS published curve numbers shall be used as the rainfall-to-runoff transformation parameter. However, when supported by sound scientific reasoning and data, and approved by the qualified municipal representative, published curve numbers may be modified to more appropriately reflect actual surface runoff response.

e. NRCS curve numbers (CN) shall be rounded to the nearest whole number for use in pre-packaged hydrologic models.

f. Area weighting of curve numbers may only be done for land areas having curve numbers that vary by a magnitude of 5 or less.

g. The NRCS's method of determining unconnected impervious area adjustments for CN can be used for distinctly defined impervious land areas that flow onto pervious areas in a dispersed manner. The method may only be used to calculate runoff from site impervious areas that actually flow across pervious areas. The method cannot be applied to the entire site using average weighted CN values.

h. Areas draining to closed depressions must be modeled by removing the volume from the pre-development condition. However, the designer may assume that infiltration in the closed depression does not occur during a design runoff event. Areas draining to closed depressions may also be used to adjust peak runoff rates for the post-development analysis. This allowance has been developed to entice designers to intentionally design or leave in place small closed depressions that can serve as infiltration areas during rain events. The site designer is responsible to document downstream impacts if the closed depression were removed.

i. The following Time of Concentration (Tc) computational methodologies shall be used unless another method is pre-approved by the Qualified Municipal Representative:

- Pre-development -- NRCS's Lag Equation.
- Post-development; commercial, industrial, or other areas with large impervious areas (greater than 20% impervious area) -- NRCS's Segmental Method.
- Post-development; residential, cluster, or other low impact designs less

Commentary

Adjustments in curve numbers on some sites may be appropriate. However, any variation from published curve numbers and conventional engineering practice must be supported by observed runoff conditions and data, and/or a clear description of how curve number may change as a result of landscape position in a local portion of a watershed as documented in Reference 26.

It should be recognized that the CN is only a design tool with a large degree of statistical variability. Use of other than whole number increments in CN is not justified.

When curve number weighting is used for land areas represented by curve numbers that vary by a magnitude greater than 5, the watershed runoff will be significantly reduced. This is especially problematic with pervious/impervious combinations: "combination of impervious areas with pervious areas can imply a significant initial loss that may not take place" (Ref. 3).

The time of concentration (Tc) represents the average condition that best reflects the hydrologic response of the area. For example, large impervious areas bordered by small pervious areas may not consider the effect of the pervious areas in the Tc computation. If the designer wants to consider the affect of the pervious area, runoff from the pervious and impervious areas must be computed separately with the hydrographs being combined to determine the total runoff from the area.

Under no circumstance will the post-development

Commentary

Tc be greater than the pre-development Tc for any watershed or sub-watershed analysis. This includes when the designer has specifically used swales to reduce flow velocities. In the event that the designer believes that the post-development Tc is greater, it shall still be set equal to the pre-development Tc for post-development analysis.

The purpose of limiting peak flow reporting to tenths of a cfs is to recognize the accuracy and precision limitations of hydrologic modeling procedures. Small differences, generally those less than 10% between pre- and post-development discharge rates, should be permitted when no negative downstream impacts will result.

This check is used to determine if flooding may occur due to poor modeling choices specifically related to the time of concentration. The check will frequently yield higher values if a watershed's impervious area is located primarily near the watershed outlet or point of interest.

It is the responsibility of the licensed design profession to determine the standard of practice appropriate for individual stormwater management practices. However, it is the licensed design professional's responsibility to ensure that all design assumptions and computations are clearly documented.

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than or equal to 20% impervious area -- NCRS's Lag Equation.

j. All lined stormwater management ponds in carbonate and non-carbonate areas must be considered impervious and may not be used as pervious areas for stormwater management computations. "Lined" here means lined with synthetic liners or Bentonite. All other compacted soil liners will be considered to be HSG D for hydrologic computations.

k. All pre- and post-development comparisons of peak flows shall be rounded to tenths of a cubic feet per second.

l. An Impervious Area Flash (IAF) analysis shall be conducted for all sites. The analysis requires that the watershed impervious area be modeled without the pervious areas. The time of concentration should also be determined from the impervious areas only. If the IAF analysis results in a higher post-development peak runoff rate, this higher value must be reported for the final design/comparison.

m. Stormwater management ponds must provide safe passage of the one-hundred (100)-year return period peak runoff rate assuming that all of the principal spillway orifices are fully clogged, and the principal spillway overflow is 50% clogged. A six (6)-inch minimum freeboard must also be maintained above the resulting "maximum" water surface elevations (W.S.E.). Embankment emergency spillways can be assumed to be unclogged. Stormwater management ponds with embankments completely made up of natural undisturbed soils (fully in "cut") or where roadways act as the emergency spillway, are permitted. However, the Design Engineer must verify downstream stability and control.

n. The hydrologic and hydraulic design of all structural stormwater best management practices shall be designed in accordance with the standards contained in the *Pennsylvania Stormwater Best Management Practices* Manual (Ref. 1) or other manual of design practice as deemed appropriate by the licensed design professional. All design shall follow current standards of engineering practice, including clear documentation of all assumptions and computations.

Recommended Standards

5.5 CONVEYANCE SYSTEM STANDARDS

Storm drainage conveyance systems consist of storm sewer pipes, swales, and open channels. Computational methods for design of conveyance systems shall be based on the following standards.

5.5.1 General

1. Stormwater conveyance systems shall be designed based on a ten (10)-year design storm and a one-hundred (100)-year check storm. All stormwater pipe systems shall be sized to convey the ten (10)-year design event without causing a pressure flow condition in any segment of the conveyance system.

2. Piped stormwater conveyance and collection systems shall have a minimum diameter of fifteen (15) inches. A waiver of this requirement will be considered for pipes discharging from stormwater detention or infiltration facilities where flow must first pass through a restriction less than fifteen (15) inches in diameter. In addition, Twelve (12)-inch culverts may be used at driveway crossings if they can adequately pass the design flows. In no case shall a stormwater conveyance pipe be less than six (6) inches in diameter.

3. It shall be demonstrated that adequate and safe conveyance exists for the one-hundred (100)-year check storm.

4. Culverts crossing under roadways shall be designed on the basis of a twenty-five (25) year rainfall event at a design headwater depth of two (2) feet above the crown of pipe. In addition, two (2) feet of freeboard must be maintained between the roadway centerline elevation and the design water level on the upstream side of the crossing.

5. Any storm drain within State or Federal rights-of-ways or that falls under the design criteria of any higher authority must meet the requirements of that agency in addition to the minimum requirements of this ordinance.

6. Stormwater conveyance system stability (swales, open channels, and pipe discharge aprons) shall be computed using a ten (10)-year return period peak runoff rate and/or as required by PA DEP Chapter 102, whichever is greater.

7. When located in undedicated land, stormwater conveyance systems shall be placed within a drainage easement not less than ten (10) feet wide as approved by the

Commentary

Pressure flow in stormwater pipe systems occurs when the combination of flow magnitude and energy losses in pipes and conveyance structures results in water backing-up in manholes to a depth greater than the pipe diameter. This condition is often referred to as “surcharging.”

Minimum pipe sizes are typically established to minimize the risk of clogging. The intent of the waiver here is to allow for smaller pipe in the specific case outlined where clogging would typically not be expected.

Easement widths for stormwater conveyance systems should be set to permit access to the pipe

Commentary

or swale for maintenance purposes. The easement should encompass the entire width of swales or other surface drainage-ways. Adequate width should be included in easements for pipe systems to permit safe excavation of the pipe for maintenance purposes.

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Qualified Municipal Representative. Easement width shall be established to provide adequate access to the conveyance system for maintenance purposes. If drainage easements are adjacent to a municipal right-of-way, the Municipal Representative may approve a narrower easement.

8. The use of properly designed, graded and turfed drainage swales is encouraged in lieu of structural storm sewers. In addition to carrying the required discharge without excessive erosion, consideration should always be given to designing grass-lined swales to provide increased surface contact time and enhanced infiltration characteristics.

9. Inlet types and inlet assemblies shall conform to the Pennsylvania Department of Transportation Standards for Roadway Construction as approved by the Municipality.

   a) Inlets shall, at a minimum, be located at the lowest point of street intersections to intercept the stormwater before it reaches pedestrian crossing, or at sag points of vertical curves in the street alignment that provide a natural point of ponding of surface stormwater.

   b) Where the municipality deems it necessary due to special land requirements, special inlets may be approved.

      1. The interval between inlets collecting stormwater runoff shall be determined in accordance with DM-2, chapter 10, section 5, “Capacity of Waterway Areas” (Ref. 17).

      2. In curbed roadway sections, the maximum encroachment of water on the roadway pavement shall not exceed half of a through traffic lane or one (1) inch less than the depth of curb during the ten (10)-year design storm of five (5)-minute duration. Inlets shall be provided to control the encroachment of water on the pavement. When inlets are used in a storm system within the right-of-way limits of a street in lieu of manholes, the spacing of such inlets shall not exceed the maximum distance of four hundred fifty (450) feet.

10. Accessible drainage structures shall be located on a continuous storm sewer system at all vertical dislocations, at all locations where a transition in storm sewer pipe sizing is required, at all vertical and horizontal angle points exceeding five (5) degrees, and at all points of convergence of two (2) or more influent storm sewer mains. The construction locations of accessible drainage structures shall be as indicated on the land development drainage plan or area drainage plan approved by the municipality.

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11. When evidence available to the municipality indicates that existing storm sewers have sufficient capacity as determined by hydrograph summation and are accessible, the subdivider may connect their stormwater facilities to the existing storm sewers so long as the peak rate of discharge does not exceed the amount permitted by this ordinance.

5.5.2 Hydrologic Design Standards

1. Recommended computational methods (models) for the design of stormwater conveyance systems, based on site or watershed drainage area, are as follows.

Table 5.3 Recommended Computational Methods

Up to two-hundred (200) acres in size	Rational Method
Between two-hundred (200) acres and one-and-one-half (1.5) square miles in size	HEC-1 PSRM TR-20
Over one-and-one-half (1.5) square miles in size	PSU-IV with the carbonate adjustment factor at the discretion of the Qualified Municipal Representative

Other methods may be used as approved by the Qualified Municipal Representative.

2. Rainfall intensities as reported in the most current edition of Reference 17 shall be used to establish peak flow rates for design.

3. Rational Coefficients used are to be from Rawls et al. (Ref. 19), *PA DOT Design Manual* 2-10 (Ref. 17) or other acceptable source. The Design Engineer may choose to use the following Rational C coefficients to conservatively estimate pipe or channel flows. However, it is recommended that they be used only for storm drains up to twenty-four (24) inches in diameter.

   All impervious areas: C = 0.95
   All pervious areas: C = 0.30

4. For stormwater conveyance system design, the time of concentration (Tc) can be computed by any method that best represents surface conditions tributary to each inlet. For any drainage area smaller than five (5) acres in size, a Tc of five (5) minutes may

Commentary

Adequate and safe conveyance may include surcharging of inlets and surface discharges. However, it implies that there will be a safe route for all flows without causing flooding or structural damage to buildings and other infrastructure facilities.

For pipe sizes exceeding 24 inches, more accurate selection or Rational C values may be appropriate to avoid excess costs associated with pipe sizes that are overly conservative.

Commentary

The licensed design professional maintains liability for the design of all civil infrastructure. Therefore, the specific design tools and methods used for conveyance system design are the responsibility of the licensed professional.

Vegetated channels provide additional opportunity for stormwater impact mitigation. The vegetation acts as a filter to enhance deposition of suspended solids, providing a water quality benefit. In addition, infiltration can occur across the wetted channel surface.

Grassed swales are commonly used instead of curb and gutter drainage systems in low- to moderate density (16 to 21% impervious) single-family residential developments. Since grassed swales do not function well with high volumes or velocities of stormwater, they have limited application in highly urbanized or other highly impervious areas. However, swales may be appropriate for use in these areas if they are constructed in series or as pretreatment facilities for other BMPs. Grassed swales are usually located within the right-of-way when used to receive runoff from subdivision or rural roadways. They may also be installed within drainage easements along the side or rear of residential lots. Grassed swales can be strategically located within the landscape to intercept runoff from small impervious surfaces (small parking lots, rooftops, etc.) as a component of a subdivision-wide or development-wide BMP strategy. Water quality swales are appropriate for the same development conditions as those listed for grassed swales with

Recommended Standards

always be assumed at the discretion of the Design Engineer (for the post-development condition), without needing to provide supporting documentation.

5.5.3 Hydraulic Design Standards

Computational procedures for the hydraulic design of stormwater conveyance systems (pipes and swales) shall follow methods and procedures outlined in the *NRCS National Engineering Handbook*, Part 640:Hydrology (Ref. 5), *The Federal Highway Administration's Urban Drainage Design Manual*, HEC-22 (Ref. 2), *PennDOT Design Manual* Part 2, Chapter 10 (Ref. 17), *The Pennsylvania Stormwater Best Management Practices Manual* (Ref. 1), or other manual of engineering practice.

5.5.4 Open Channels and Swales

Where possible, vegetated surface channels and swales should be used for stormwater conveyance. When designed appropriately, surface swales can be used to help mitigate peak runoff rates, runoff volume, and stormwater quality. For specific information on design options and plant materials, see References 1 and 21.

The use of properly designed, graded and turfed drainage swales is encouraged in lieu of structural storm sewers. In addition to carrying the required discharge without excessive erosion, consideration should always be given to designing vegetation-lined swales to provide increased surface contact time and enhanced infiltration characteristics.

Figure 5.3. Vegetated Swale Filters Street Run-off

Recommended Standards

5.5.5 Pipe Systems

If open channels or swales are not an option due to steep slopes or other limiting factors, piped systems shall be used for stormwater conveyance. Stormwater conveyance shall occur in underground piped systems. The following pipe materials, bedding, and backfill standards shall be used for piped conveyance systems.

5.5.5.1 Pipe Materials

Materials used in the construction of storm sewers shall be constructed of reinforced concrete, ductile iron, or corrugated polyethylene, or when approved by the municipal engineer, corrugated metal. The most cost-effective materials shall be permitted that conform to local site conditions and reflect the relevant operations, maintenance, and system character of the municipal stormwater system. Specifications referred to, such as ASTM or AWWA, etc., should be the latest revision in effect at the time of application.

1. The following apply to reinforced concrete pipe:
   a. Circular reinforced concrete pipe and fittings shall meet the requirements of ASTM C76.

   b. Elliptical reinforced concrete pipe shall meet the requirements of ASTM C507.

   c. Joint design and joint material for circular pipe shall conform to ASTM C443.

   d. Joints for elliptical pipe shall be bell and spigot or tongue and grove sealed with butyl, rubber tape, rubber ring gaskets, or external sealing bands conforming to ASTM C877.

   e. All pipe shall be Class III unless loading conditions call for stronger pipe (i.e., higher class).

   f. The depth of cover over the concrete pipe shall be as designated by the American Concrete Pipe Association in Table 5.4 below.

Commentary

the addition of higher densities of development (16 - 37% impervious) due to the increased pollutant removal capability.

Commentary

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Table 5.4. Minimum Depth of Cover Over Concrete Pipe

Pipe diameter (inches)	AST (Class)	Minimum cover (surface to top of pipe – inches)
12	III IV V	17 12 7
15	III IV V	16 11 7
18	III IV V	16 10 6
24	III IV V	15 6 6
30	III IV V	10 6 6
36 and above	III IV	6 6

Minimum depth of coverage as designated by the American Concrete Institute

2. Ductile iron pipe shall conform to ANSI/AWWA C151/A21.51.

   Joints shall conform to ANSI/AWWA C111/A21.11 or ANSI/AWWA C115/A21.15, as appropriate.

   Pipe shall be designed in accordance with ANSI/AWWA C150/A21.50. The outside of the pipe shall be coated in accordance with ANSI/AWWA C151 A21.51 and the inside lined in accordance with ANSI/AWWA C104/A21.4.

   Ductile iron pipe shall be installed in accordance with AWWA C600.

3. Corrugated polyethylene pipe shall conform to AASHTO M252 for three thorough ten (10) inches (standard drainage too big, and AASHTO mpg for 1,050 mm to 1,200mm diameter pipe), AASHTO M294 for sizes twelve (12) inches to 36 inches in diameter.

   Materials shall conform to ASTM D3350, Standard Specification for Polyethylene Plas-

Recommended Standards

tics Pipe and Fittings Materials. Pipe joints and fittings shall be compatible with the pipe material and shall conform to the same standards and specifications as the pipe material. Pipe couplers shall not cover less than one full corrugation on each section of pipe.

Installation shall be in accordance with ASTM D2321, Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications. Backfill material shall be placed in six (6)-inch lifts and compacted to 95% minimum dry density, per AASHTO T99. In areas of high ground water tables, design engineers shall check for flotation.

4. Corrugated metal pipe shall meet the requirements and be installed in accordance with the standards that follow:

   a. In areas with acid waters, engineers may specify the use of aluminum alloy pipe. In neutral/alkaline waters, aluminum, aluminum-coated steel Type 2, and polymeric-coated steel may be used. In all cases, the environmental limitations outlined in Table 5.5 must be met.

      Water pH and resistivity values must fall within the ranges in Table 5.5. Samples should be measured in accordance with ASTM G51 and G57. Avoid sampling water during storm events or for two days following a storm to ensure more typical readings. If there are severe corrosive conditions (pH 4), fiber-bonded steel pipe should be used.

Table 5.5. Environmental Limits for Corrugated Metal Pipe

Pipe Type	pH	Resistivity Values (ohm-cm)
Aluminum	4-9	>500
Aluminum-coated type 2	5-9	>1500
Polymeric coated	5-9	>1500
Fiber bonded	<4	-

   b. If the design flow velocity is greater than ten (10) feet per second, a one-half (1/2) bituminous coating and paved invert shall be provided in accordance with ASTM A849 (AASHTO M190).

   c. Minimum depth of coverage shall be as specified in Table 5.6.

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Table 5.6. Minimum Depth of Cover for Corrugated Metal Pipe

Pipe Diameter (inches)	Minimum cover Top of pipe to bottom of flexible pavement or top of rigid pavement (inches)
12 – 48	12 inches
54 inches or more	Per manufacturers recommendations

d. Corrugated aluminum pipe shall conform to the requirements of ASTM B745 (AASHTO M196) for Types I, II, IR, IIR, and III.

e. Corrugated Aluminum-coated steel Type 2 pipe shall conform to the requirements of ASTM A760 (AASHTO M36) for Types I, II, IR, IIR, and III, and have an aluminum one-ounce type 2 coating as specified in ASTM A929 (AASHTO M274)

f. Corrugated polymeric-coated steel pipe shall conform to the requirements of ASTM A762 (AASHTO M36) for Types I and II and have a polymeric 10/10 coating as specified in ASTM A742 (AASHTO M246).

g. Corrugated fiber-bounded steel pipe shall conform to the requirements of ASTM A760 (AASHTO M36) for Types I and II and have an aramid fiber composite coating as specified in ASTM A885. In addition, the pipe shall be bituminous coated as specified in ASTM A849 (AASHTO M190).

h. Corrugated metal pipe shall be fabricated with annual corrugations by riveted lap joint construction or with helical corrugations and a continuous weld or lock seam extending from end to end of each length of pipe.

i. Connecting bands shall be manufactured in accordance with ASTM A760 (Steel) or B745 (Aluminum) and have the same base metal and coating as the corrugated metal pipe. All pipe ends shall be annularly reformed a minimum of two corrugations.

j. Fittings and end sections shall be of the same base metal and coating as the corrugated metal pipe.

k. Corrugated metal pipe shall be installed per ASTM A798 (Steel) or ASTM B788.

l. Maximum cover and structural design of corrugated metal pipe shall be per ASTM A796 (Steel) of ASTM B790.

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5.5.5.2 Pipe Bedding and Backfill

Pipe bedding and backfill shall be provided as illustrated in Figure 5.4 and as described below:

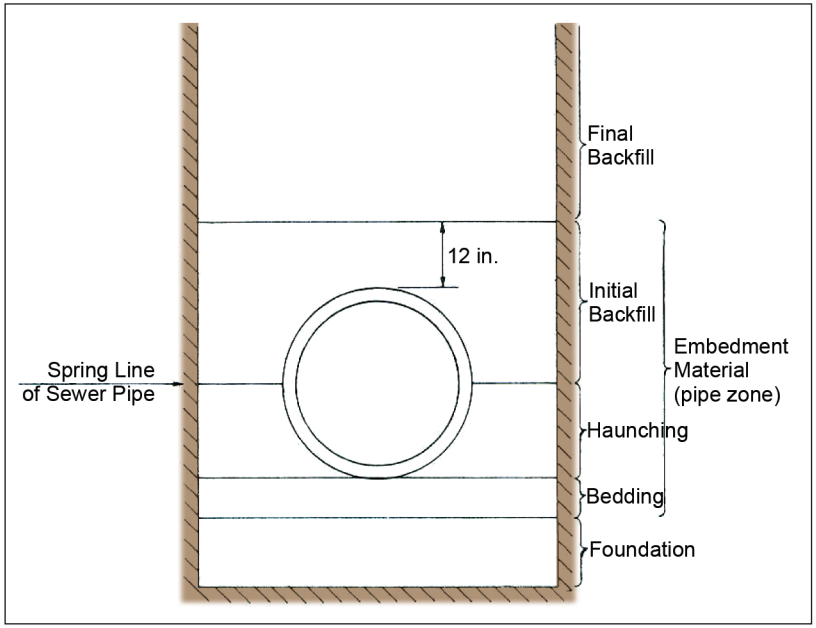

Figure 5.4. Pipe Bedding

Foundation - The foundation shall be excavated in natural material unless existing soils at this level have high organic content or are highly compressible.

Bedding - A minimum of 6 inches of bedding material to be provided. Bedding to be a well-graded, uncompacted stone that will provide adequate pipe support without damaging the pipe surface (typically less than 0.75 inches in diameter).

Haunching - Haunching shall extend to the pipe spring line, and shall consist of crushed stone or sand, or a well-graded granular material of intermediate size (typically less than 0.75 inches in diameter). Sand shall not be used if the pipe zone area is subject to a fluctuating groundwater table or where there is a possibility of the sand migrating into the pipe bedding material.

Commentary

Pipe bedding and backfill is critical to pipe's ability to safely support soil loads within the trench. The function of each of the five bedding zones are as follows.

The foundation provides the base for the pipe-soil system. The designer should be most concerned with providing a stable base. Highly organic or compressible soils are not suitable for the foundation area.

Bedding material provides the interface between the pipe and its foundation, and has an important influence on the distribution of the reaction against the bottom of the sewer pipe. The condition of the bedding influences the ultimate strength and function of the pipe. Uncompacted AASHTO #8 coarse aggregate or similar material serves well as bedding material.

The soil placed at the sides of the pipe from the bedding up to the spring line is the haunching. The care with which this material is placed is critical to the performance of the pipe. Poorly compacted material in this area will result in a concentration of reaction at the bottom of the pipe. PennDOT 2A coarse aggregate or similar material meets the requirements of haunching material.

Commentary

Initial backfill is the material that covers the pipe, and its function is to protect the pipe from damage by subsequent backfill and to ensure a uniform distribution of load over the top of the pipe. PennDOT 2A or similar stone serves well as initial backfill in the pipe zone.

Final backfill is not critical to the pipe, and does not affect its performance. The most significant issue with final backfill is settlement. Where settlement is critical (like under paved surfaces) final backfill material should be composed of select material that is easily densified. In areas not under pavement or traffic loads, excavated material can be used as final backfill.

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Initial Backfill - The initial backfill shall extend from the spring line to 12 inches above the pipe crown. This material shall be carefully tamped to compact the stone but not damage the pipe. For flexible pipe, initial backfill shall be a material that will develop a uniform and relatively high density with little compactive effort. Clay materials shall not be used for initial backfill.

Final Backfill - Under-paved areas, final backfill shall be a uniformly graded, granular material that is easily densified to minimize future settlement. This material shall be placed in 4-to 8-inch lifts and compacted to 95% SPD.

Under unpaved areas, final backfill may consist of excavated material, placed in 8-inch lifts and compacted to a near pre-excavation density that will minimize the risk of future settlement. However, soils with a high organic content, or a high shrink-swell rating shall not be used as final backfill.

Trench width shall be as follows.

- For pipe smaller than thirty (30) inches in diameter,
  Pipe Dia + 2 feet

- For pipe equal to or larger than thirty (30) inches in diameter,
  Pipe Dia + 3 feet

Trench backfilling shall be done in such a way as to prevent dropping of material directly on top of a sewer pipe through any significant vertical distance. When placing material with a bucket, the bucket shall be lowered so that the shock of falling earth will not cause damage to the pipe.

Bedding and backfill for any pipe material not covered by this manual shall be installed in accordance with manufacturer's recommendations.

5.5.6 Inlets, Catch Basins, Manholes, and Outlets

1. Inlets, catch basins, and manholes shall be designed in accordance with PA DOT standards. Bicycle-safe grates shall be used.

2. Inlet spacing depends on the inlet capacity and gutter flow spread. However, in no case shall inlets be spaced more than four-hundred (400) feet apart.

   Inlet capacity shall be established based on procedures for pavement drainage in *Urban*

Recommended Standards

Drainage Design, Hydraulic Engineering Circular (HEC) Number 22, U.S. Department of Transportation, Federal Highway Administration, 1996 or more current edition.

3. Manholes shall be precast concrete or concrete block, coated with two coats of Portland cement or mortar outside the manhole. Masonry brick may be used to make vertical adjustments to rims, as long as the adjustments are twelve (12) inches or less. In acidic soils, all manholes shall have two (2) coats of black bitumastic waterproofing applied per the manufacturer's instructions.

4. If precast manhole barrels and cones are used, they shall conform to ASTM Specification C478, with round rubber gasketed joints conforming to ASTM Specification C923. Both ASTM specifications are incorporated herein by reference. Maximum absorption shall be 9% in accordance with ASTM Specification C478, Method A.

5. If precast manholes are used, the top riser section shall terminate less than one (1) foot below the finished grade and the manhole cover shall be flush with the finished grade.

6. Manhole frames and covers shall be of cast iron, conforming to ASTM Specification A48, Class 30, incorporated herein by reference, and be suitable for H-20 loading capacity. Manhole covers in remote locations may have a locking device.

7. Outlet grates, fences, and other safety features for stormwater management facilities shall conform with PA DOT standards where appropriate.

8. The channel should be, insofar as possible, a smooth continuation of the pipe. The pipe may be laid through the manhole and the top half removed by saw cut. The completed channel should be U-shaped. The channel height shall be three-fourths of the diameter of the pipe.

9. The bench should provide good footing for a workman, and a place where minor tools and equipment can be laid. It must have a slope of four 4-8%.

5.6 PROHIBITIONS

5.6.1 Non-Stormwater Discharges

Any drain or conveyance, whether on the surface or subsurface, which allows any non-stormwater discharge, including sewage, process wastewater, and wash water to enter the waters of this Commonwealth, is prohibited.

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Discharges, which may be allowed if they do not significantly contribute to pollution to the waters of this Commonwealth, are identified in Table 5.7. In the event that the Municipality or DEP determines that any of the discharges identified in Subsection 701.B, significantly contribute to pollution of the Waters of this Commonwealth, the Municipality or DEP will notify the responsible person(s) to cease the discharge.

Table 5.7. Allowable Stormwater Discharges

-Discharges from fire fighting activities	-Flows from riparian habitats and wetlands
-Potable water sources, including dechlorinated water line and fire hydrant flushings	-Uncontaminated water from foundations or from footing drains
-Irrigation drainage	-Lawn watering
-Air conditioning condensate	-Dechlorinated swimming pool discharges
-Springs	-Uncontaminated groundwater
-Water from crawl space pumps	-Water from individual residential car washing
-Pavement wash waters where spills or leaks of toxic or hazardous materials have not occurred (unless all spill material has been removed) and where detergents are not used	-Routine external building wash down (which does not use detergents or other compounds)

5.6.2 Roof Drains

Roof drains and sump pumps shall be disconnected from structural storm sewer system where possible. These discharges shall be directed to cisterns, vegetated areas (lawn or garden areas) or to other infiltration BMP's.

5.6.3 Alteration of Stormwater Best Management Practices and Facilities

No person shall modify, remove, fill, landscape, or alter any stormwater facility or practice that has been approved as a part development plan without the written approval of the municipality.

5.7 OPERATION AND MAINTENANCE

Stormwater management facilities shall be regularly maintained to ensure that they func-

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tion at design capacity, and to prevent health hazards associated with debris buildup and stagnant water. An operations and maintenance plan identifying specific maintenance maintenance and operation requirements for all stormwater BMP's shall be prepared for all projects which include water quantity or water quality best management practices. For projects requiring the preparation of a post construction stormwater management plan, the operations and maintenance plan shall be included as part of said plan.

Maintenance and upkeep responsibility for stormwater facilities depends on facility ownership. If the storm drains, catch-basins, culverts, and /or other features of the stormwater system are part of a public drainage system, then the municipality or an appropriate public entity shall be responsible for for maintenance and upkeep. If part or all of the residential stormwater management system is privately owned, then the privately owned portion of the system must be privately maintained.

In cases where there is a common ownership of property that is not part of a publicly owned drainage system, a homeowner's association or similar permanent entity may be established as the agent responsible for upkeep, absent an agreement with the municipality or other appropriate public entity.

5.8 EROSION AND SEDIMENT CONTROL

All development applications which involve grading or excavation shall conform to the requirements of Title 25, Chapter 102 of the Pennsylvania State Code, and implemented and enforced by the Pennsylvania Department of Environmental Protection. In addition, the following standards shall be followed

1. No changes shall be made in the contour of the land; no grading, excavating, removal, or destruction of the topsoil, trees, or other vegetative cover of the land shall be commenced within a proposed subdivision or land development tract until such time that a plan for minimizing erosion and sedimentation control has been reviewed by the County Conservation District or the Pennsylvania Department of Environmental Protection and approved by the municipal authority, unless there has been a determination by the County Conservation District or the Pennsylvania Department of Environmental Protection that erosion and sedimentation plans are not necessary.

2. The following measures are effective in minimizing erosion and sedimentation and shall be included where possible in the context of the development plan.

    a. Minimize the disturbed area and the duration of exposure to a practical minimum;

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b. Preserve significant natural features and minimize cut-and fill-operations.;

c. Preserve and restore natural vegetation where possible;

d. Stabilize disturbed soils by permanent vegetation and/or by engineered erosion control and drainage measures as soon as practical in the development process, but no later than 14 days after disturbance occurs;

e. Protext exposed critical areas during development with temporary vegetation and/or mulching;

f. Effectively mitigate and control the increased surface runoff during and after development;

g. Use debris basins, sediment basins, and silt traps to contain sediment in the runoff water until the disturbed area is stabilized;

h. Establish basin and perimeter controls at the commencement of the work on the site;

i. Protect and stabilize earth storage piles within thirty (30) days; and

j. Install earth or paved interceptors and diversions at the top of cut or fill slopes where there is a potential for erosive surface runoff.

3. In order to prevent pollution of any watercourse and to reduce erosion of soil, sediment control devices shall be installed prior to any grading, filling, or excavation. Such devices shall be designed to retain sediment on the site.

4. Within thirty (30) days after completion of grading, all surfaces disturbed by vegetation removal, grading, haul roads, or other construction activity that alters natural vegetative cover, are to be revegetated to control erosion, unless covered with impervious or other improved surfaces authorized by approved plans. Erosion controls may include any combination of engineered or vegetative measures.

5.9 EXISTING WETLANDS

No subdivision or land development shall involve uses, activities, or improvements that

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would entail encroachment into, the regarding of, or the placement of fill in wetlands in violation of State or Federal regulations. Applicants must submit evidence that if wetlands are present on the site, the Pennsylvania Department of Environmental Protection and the U.S. Army Corps of Engineers have been contacted to determine the applicability of State and Federal wetland regulations. Municipal approval shall be contingent on full compliance with any requirements of any regulatory agency, and no action of the municipal planning body shall be relied on in lieu of a permit issued by the appropriate agency.

5.10 FLOODPLAINS

Floodplain areas shall be established and preserved on all development sites. In addition, floodplain areas shall be delineated on development plans as provided below:

a. A one-hundred (100-year floodplain shall be established for all watercourses and shall be delineated by one of the following methods:

    1. A FEMA flood Insurance Study.
    2. A floodplain study prepared by an agency of the county, State, or U.S. Government.
    3. A floodplain report or study prepared and certified to by a Professional Engineer registered in the Commonwealth of Pennsylvania duly qualified by education and experience to perform such duties.

b. Whenever a floodplain boundary is located within or along a lot, the plan shall include the boundary of the floodplain, along with the elevation or location dimensions from the centerline of the watercourse; a plan note that the floodplain shall be kept free of structures, fill, and other encroachments; and a plan note that floor elevations for all structures adjacent to the floodplain shall be two (2) feet above the one-hundred (100)-year flood elevation.

The above provisions shall not be construed to prohibit the following construction activities within floodplains:

a. Stormwater management facilities;
b. Stream improvements whose sole purpose is to improve aquatic habitat and that are approved by the Pennsylvania Fish Commission;
c. Farm ponds;
d. Flood-proofing and flood hazard reduction structures to protect existing buildings;
e. Water-oriented uses (except buildings), e.g., docks, piers, boat launching ramps, hatcheries, etc.;
f. Water monitoring devices;

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g. Culverts, bridges, and their approaches for floodplain crossings by streets, access drives, and driveways; and
h. Other fill activities as authorized under a permit issued by the U.S. Army Corps of Engineers, Pennsylvania Department of Environmental Protection, or other authorizing agency.

State regulations for encroachments within floodplains are contained at Title 25, Chapter 105 of the Pennsylvania State Code.

Any subdivision or land development proposal, which includes encroachments into a Federally mapped floodplain, must include evidence that the applicant has contacted and gained approval for said encroachments from the Pennsylvania Department of Environmental Protection (Waterways, Wetlands, and Erosion Control Division), and the Federal Emergency Management Agency.

5.11 ENFORCEMENT AND PENALTIES

5.11.1 Right of Entry

Following advance written notice and due process, municipal officials shall have the right to enter private property to inspect the condition of stormwater structures and facilities.

5.11.2 Inspection

SWM BMPs shall be inspected by the facility owner according to the following list of frequencies:

1. Annually for the first five (5) years.

2. Once every three (3) years thereafter.

3. During or immediately after the cessation of a ten (10)-year or greater storm.

5.11.3 Enforcement

It shall be unlawful for a person to undertake any regulated activity except as provided in an approved SWM Site Plan. It shall also be unlawful for a person to fail to take any regulatory action required by ordinance.

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It shall be unlawful to alter or remove any control structure required by the Post-Construction Stormwater Management Plan.

Inspections regarding compliance with the SWM Site Plan are a responsibility of the municipality.

5.11.4 Penalties

(This is a place holder. Municipalities should ask their solicitors to provide appropriate wording for this section.)

Commentary

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Appendix 5.A Definitions

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Infiltration rates are measured in units of length / time.

Agricultural Activities -- The work of producing crops and raising livestock, including tillage, plowing, disking, harrowing, pasturing and installation of conservation measures. Construction of new buildings or impervious area is not considered an agricultural activity.

Applicant -- A landowner or developer who has filed an application for approval to engage in any regulated activities.

BMP (Best Management Practice) -- Activities, facilities, measures, or procedures used to manage the volume, rate, and quality of stormwater runoff.

Carbonate -- A sediment formed by the organic or inorganic precipitation of mineral compounds characterized by the fundamental chemical ion CO3, the principal element in limestone and dolomite strata.

Channel -- A perceptible natural or artificial waterway, which periodically or continuously contains moving water having a definite bed and banks, which confine the water.

Check Storm -- The magnitude and temporal distribution of precipitation of a particular extreme probability of occurrence (e.g., 100-year storm) and duration (e.g., typically 24 hours), used to check how stormwater management and conveyance systems will function under extreme flooding conditions. The check storm is typically a 100 year, 24 hour precipitation event.

Closed Or Undrained Depression -- In a Karst geologic area a distinct bowl-shaped depression in the land surface; size and amplitude are variable; drainage is internal. It differs from a sinkhole in that the ground surface is unbroken and usually occurs in greater density per unit area.

Dam -- An artificial barrier, together with its appurtenant works, constructed for the purpose of impounding or storing water or another fluid or semifluid, or a refuse bank, fill or structure for highway, railroad or other purposes which does or may impound water or another fluid or semifluid.

Design Capture Volume -- The difference between the pre-development and post-development runoff from a 1-year, 24-hour design rainfall event for a specific development site.

Design Storm -- The magnitude and temporal distribution of precipitation from a storm event measured in probability of occurrence (e.g., a 5-year storm) and duration (e.g., 24 hours), used in the design and evaluation of stormwater management systems.

Detention Basin -- An impoundment structure designed to manage stormwater runoff by temporarily storing the runoff and releasing it at a predetermined rate.

Developer -- A person, partnership, association, corporation, or other entity, or any responsible person therein or agent thereof, that undertakes any Regulated Activity of this ordinance.

Development Site -- The specific tract of land for which a regulated activity is proposed.

Appendix 5.A Definitions (cont.)

Drainage Conveyance Facility -- A Stormwater Management Facility designed to transmit stormwater runoff and to include streams, channels, swales, pipes, conduits, culverts, storm sewers, etc.

Drainage Easement -- A right granted by a landowner to a grantee, allowing the use of private land for stormwater management purposes.

Drainage Permit -- A permit issued by the township governing body after the drainage plan has been approved. Said permit is issued prior to or with the final township approval.

Drainage Plan -- The documentation of the stormwater management system, if any, to be used for a given development site.

Drainage Way -- The natural or man-made path of surface water from a given area.

Erosion -- The movement of soil particles by the action of water, wind, ice, or other natural forces.

Erosion and Sediment Pollution Control Plan -- A plan that is designed to minimize accelerated erosion and sedimentation.

Existing Conditions -- The initial condition of a project site prior to the proposed construction.

Extended Detention Release Volume -- The portion of the capture volume not managed through natural or engineered infiltration or consumptive re-use techniques. This volume is released to receiving waters over a 48 to 72 hour period to minimize downstream impacts.

First Flush -- The initial surface runoff resulting from a rainfall event which usually picks-up dry pollutant deposition on surfaces and washes it into receiving waters. The first flush is usually considered to be the first one-half inch of surface runoff, resulting from a rainfall event.

Flood -- A general but temporary condition of partial or complete inundation of normally dry land areas from the overflow of streams, rivers, and other waters of this Commonwealth.

Floodplain -- Any land area susceptible to inundation by water from any natural source or delineated by applicable Department of Housing and Urban Development, Federal Insurance Administration Flood Hazard Boundary -- mapped as being a special flood hazard area.

Floodway -- The channel of the watercourse and those portions of the adjoining floodplains that are reasonably required to carry and discharge the 100-year frequency flood. Unless otherwise specified, the boundary of the floodway is as indicated on maps and flood insurance studies provided by FEMA. In an area where no FEMA maps or studies have defined the boundary of the 100-year frequency floodway, it is assumed -- absent evidence to the contrary - that the floodway extends from the stream to 50 feet from the top of the bank of the stream.

Freeboard -- A vertical distance between the elevation of the design high-water and the top of a dam, levee, tank, basin, or diversion ridge. The space is required as a safety margin in a pond or basin.

Grassed Waterway -- A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from cropland.

Appendix 5.A Definitions (cont.)

Groundwater Recharge -- Replenishment of existing natural underground water supplies.

Hydropedology -- The science that soil moisture and how water moves through soils and subsoils.

Impervious Surface -- A surface that prevents the percolation of water into the ground.

Impoundment -- A retention or detention basin designed to retain stormwater runoff and release it at a controlled rate.

Infiltration Rate -- The infiltration rate of a soil is related to the soil's final infiltration capacity and represents the rate at which water enters the soil/air interface at the top of the soil profile. Infiltration rates are measured in units of length / time.

Inlet -- A surface connection to a closed drain; a structure at the diversion end of a conduit; the upstream end of any structure through which water may flow.

Interceptor -- A channel, berm, or dike constructed across a slope for the purpose of intercepting stormwater, reducing the velocity of flow, and diverting it to outlets where it may be disposed.

Karst -- A type of topography that is formed over limestone, dolomite, or gypsum by bedrock solution, and that is characterized by closed depressions or sinkholes, caves, and underground drainage (from AGI, Glossary of Geology, 1972).

Land Development -- (1) the improvement of one lot or two or more contiguous lots, tracts, or parcels of land for any purpose involving (a) a group of two or more buildings, or (b) the division or allocation of land or space between or among two or more existing or prospective occupants by means of, or for the purpose of streets, common areas, leaseholds, condominiums, building groups, or other features; (2) any subdivision of land; (3) development in accordance with Section 503(1.1) of the Pennsylvania Municipalities Planning Code.

Land/Earth Disturbance -- Any activity involving grading, tilling, digging, or filling of ground or stripping of vegetation or any other activity that causes an alteration to the natural condition of the land.

Land Use -- The primary application employed in an area.

Licensed Professional -- See Registered Professional.

Main Stem (Main Channel) -- Any stream segment or other runoff conveyance facility used as a reach in the Spring Creek hydrologic model.

Natural Conservation Areas -- A natural area protected during development for its water quality or recharge enhancing abilities.

Outfall -- Point where water flows from a conduit, stream, or drain.

Outlet -- Points of water disposal from a stream, river, lake, tidewater or artificial drain.

Appendix 5.A Definitions (cont.)

PA DEP -- Pennsylvania State Department of Environmental Protection.

Penn DOT -- Pennsylvania State Department of Transportation.

Peak Discharge -- The maximum rate of stormwater runoff from a specific storm event.

Percolation Rate -- The rate at which water moves through a soil profile. Percolation rates are measured in units of time / length.

Pipe -- A culvert, closed conduit, or similar structure (including appurtenances) that conveys stormwater.

Point Discharge -- Any discernible, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, or conduit from which stormwaster is or may be discharged, as defined in state regulation at PA Code Title 25, Chapter 92.1.

Qualified Municipal Representative -- A professional engineer licensed in the Commonwealth of Pennsylvania and duly appointed by the subject municipality as their representative. In the event that a Stormwater Utility is formed, all references to the Municipal Engineer shall be considered to also imply the Stormwater Utility Engineer.

Recharge Volume -- The volume of water that is required to be recharged from developed sites.

Registered Professional -- An individual registered in and licensed by the State of Pennsylvania, including land surveyors, landscape architects, architects, engineers, and geologists.

Regulated Activity -- Any land disturbance activity that requires the preparation of a Stormwater Management Plan.

Retention Basin -- An impoundment in which stormwater is stored and not released during the storm event. Stored water may be released from the basin at some time after the end of the storm.

Return Period -- The average interval, in years, within which a storm event of a given magnitude can be expected to recur. For example, the 25-year return period rainfall has a 4% probability of occurring in any given year.

Runoff -- Any part of precipitation that flows over the land surface.

Safe Passage -- The routing of peak runoff events, usually the 100-year design event, safely through a structure without failure of that structure.

Scour -- Generally refers to the change in a channel configuration provoked by sediment imbalance, due to natural or man made causes, between the supply and transport capacity of the channel.

Sediment Basin -- A barrier, dam, retention or detention basin located and designed to retain rock, sand, gravel, silt, or other material transported by water.

Sheet Flow -- Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Appendix 5.A Definitions (cont.)

Sinkhole -- A localized, gradual or rapid sinking of the land surface to a variable depth, occurring in areas of carbonate bedrock; generally characterized by a roughly circular outline, a distant breaking of the ground surface and downward movement of soil into bedrock voids.

Spillway -- A depression in the embankment of a pond or basin that is used to pass peak discharge greater than the maximum design storm controlled by the pond.

Stabilization -- The proper placing, grading and/or covering of soil, rock or earth to ensure their resistance to erosion, sliding or other movement.

Storm Sewer -- A system of pipes and/or open channels that convey intercepted runoff and stormwater from other sources, but excludes domestic sewage and industrial wastes.

Stormwater -- The surface runoff generated by precipitation reaching the ground surface.

Stormwater Management Facility -- Any structure, natural or man-made, that, due to its condition, design, or construction, conveys, stores, or otherwise affects stormwater runoff. Typical stormwater management facilities include, but are not limited to, detention and retention basins, open channels, storm sewers, pipes, and infiltration structures.

Subarea -- The smallest drainage unit of a watershed for which stormwater management criteria have been established in the Stormwater Management Plan.

Surface Waters of the Commonwealth -- Any and all rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs, and other bodies or channels of conveyance of water on the land surface, or parts thereof, whether natural or artificial, within or on the boundaries of the Commonwealth of Pennsylvania, but excluding water at facilities approved for wastewater treatment such as wastewater treatment impoundments, cooling water ponds and constructed wetlands used as part of a wastewater treatment process.

Swale -- A natural low-lying stretch of land or minor man made conveyance channel, which gathers or carries surface water runoff.

SWM -- Stormwater management.

Topography -- The general configuration of a land surface or any part of the earth's surface, including its relief and position of its natural and man-made features. The natural or physical surface features of a region, considered collectively as to its form.

Undetained Area -- An area of a site that cannot be routed to a stormwater management facility because of its location; generally small areas around access drives or below stormwater management facilities.

Volume Credits -- A deduction from the required volume or amount. In this ordinance it implies a reduction in the volume of water to be treated or otherwise managed as a part of the stormwater impact mitigation plan.

Watercourse -- A channel or conveyance of surface water, such as a stream or creek, having defined bed and banks, whether natural or artificial,

Appendix 5.A Definitions (cont.)

with perennial or intermittent flow.

Water Quality Volume -- Volume of runoff required to be controlled from a site in a water quality BMP.

Waters of the Commonwealth -- Any and all rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs, and other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of the Commonwealth of Pennsyvlania, but excluding water at facilities approved for wastewater treatment such as wastewater treatment impoundments, cooling water ponds and constructed wetlands used as part of a wastewater treatment process.

Watershed -- The entire region or area drained by a river or other body of water, whether natural or artificial, a drainage basin or sub-basin.

Waters of the Commonwealth -- Any and all rivers, streams, creeks, rivulets, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs, and all other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth.

Water Table -- Upper surface of a layer of saturated material in the soil.

Wetland -- Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs, ferns, and similar areas.