

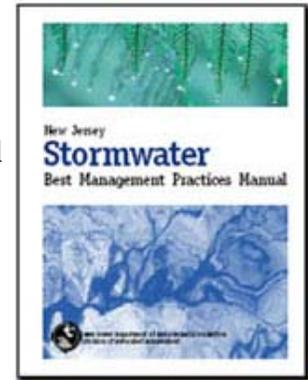


Stormwater and Nonpoint Source Pollution

njstormwater.org

NJ Stormwater Best Management Practices Manual

The Stormwater Management rules, N.J.A.C. 7:8 specify stormwater management standards that are mandatory for new major development. The New Jersey Stormwater Best Management Practices Manual (BMP manual) is developed to provide guidance to address the standards in the proposed Stormwater Management Rules, N.J.A.C. 7:8. The BMP manual provides examples of ways to meet the standards contained in the rule. The methods referenced in the BMP manual are one way of achieving the standards. An applicant is welcome to demonstrate that other proposed management practices will also achieve the standards established in the rules. The BMP Manual is developed by the New Jersey Department of Environmental Protection, in coordination with the New Jersey Department of Agriculture, the New Jersey Department of Community Affairs, the New Jersey Department of Transportation, municipal engineers, county engineers, consulting firms, contractors, and environmental organizations.



The BMP manual has been drafted to assist review agencies and the regulated community. The methods in the BMP manual can be utilized without need for additional documentation to address the performance standards in the rule. The Department anticipates providing guidance on additional best management practices and new information on already included practices as research and development occurs in this field.

Technical information regarding updates of the New Jersey Stormwater Best Management Practices Manual will be available at www.njstormwater.org.

Future versions of the New Jersey Stormwater Best Management Practices Manual will reflect the technical updates found on the website. Notices regarding future versions of the manual will be also be found at this www.njstormwater.org.

Future versions of the manual are expected to occur at most once a year.

If you have any question or comments on the content of this Manual, please e-mail your questions and comments to: swbmpmanual@dep.state.nj.us

BMP MANUAL - April 2004

- [Cover and Contents](#): Includes the cover pages, Notes on Technical Updates, Acknowledgements, and Table of Contents.

- ▶ [Chapter One](#): Impacts of Development on Runoff discusses the impact of development on the quality and quantity of stormwater runoff.
- ▶ [Chapter Two](#): Low Impact Development Techniques provides information how to use structural and nonstructural to provide lower impact development.
- ▶ [Chapter Three](#): Regional and Municipal Stormwater Management Plans presents guidance on the development of regional and municipal stormwater management plans.
- ▶ [Chapter Four](#): Stormwater Pollutant Removal Criteria provides guidance on how to meet the water quality performance standards.
- ▶ [Chapter Five](#): Computing Stormwater Runoff Rates and Volumes presents the mathematical methods for the stormwater runoff rates, volumes, and the stormwater quality and quantity design storms. This chapter provides information computations for unconnected impervious areas, and also contains an overview of various stormwater pollutant loading models.
- ▶ [Chapter Six](#): Groundwater Recharge discusses the groundwater recharge methodology, the groundwater recharge design storm, and the details of the New Jersey Groundwater Recharge Spreadsheet (NJGRS).
 - [Download the NJGRS in Excel 97 format](#)
 - [Download the NJGRS in Excel 2002 format](#)
- ▶ [Chapter Seven](#): Landscaping provides information on vegetation and landscaping for stormwater management measures.
- ▶ [Chapter Eight](#): Maintenance and Retrofit of Stormwater Management Measures provides information to be included and considered in a maintenance plan, and discusses retrofit of stormwater management facilities.
- ▶ [Chapter Nine](#): provides general information on Structural Stormwater Management Measures
 - [Chapter 9.1](#) Standard for Bioretention Systems
 - [Chapter 9.2](#) Standard for Constructed Stormwater Wetlands
 - [Chapter 9.3](#) Standard for Dry Wells
 - [Chapter 9.4](#) Standard for Extended Detention Basins
 - [Chapter 9.5](#) Standard for Infiltration Basins
 - [Chapter 9.6](#) Standard for Manufactured Treatment Devices
 - [Chapter 9.7](#) Standard for Pervious Paving Systems
 - Chapter 9.8 Standard for Rooftop Vegetated Cover (reserved)
 - [Chapter 9.9](#) Standard for Sand Filters
 - [Chapter 9.10](#) Standard for Vegetative Filters

- [Chapter 9.11](#) Standard for Wet Ponds
- [Appendix A](#): Low Impact Development Checklist provides information to assist reviewers and designers in the demonstration that nonstructural stormwater management measures have been implemented in a project.
 - [Download Appendix A](#) in Word Format.
- [Appendix B](#): Municipal Regulations Checklist provides information to assist municipalities in incorporating nonstructural stormwater management measures into the master plan, land use and zoning ordinances.
- [Appendix C](#): Sample Municipal Stormwater Management Plan provides an example as well as guidance on the municipal plan required to be developed by every municipality.
 - [Download Appendix C](#) in Word Format.
- [Appendix D](#): Model Municipal Stormwater Control Ordinance for Municipalities provides a sample stormwater ordinance consistent with the requirements of the Stormwater Management Rules.
 - [Download Appendix D](#) in Word Format.

The documents and maps linked to this page are available in Adobe Acrobat "pdf" format only. You will need a "pdf" reader such as the free [Adobe Acrobat Reader](#) to view these files.

[Back to Home Page](#)

Comments or suggestions on the Stormwater web site? Please contact [John Laurita](#).

[contact dep](#) | [privacy notice](#) | [legal statement](#)



department: [watershed management](#) | [water quality](#) | [njdep home](#) | [about dep](#) | [index by topic](#) | [programs/units](#) | [dep online](#)
statewide: [njhome](#) | [my new jersey](#) | [people](#) | [business](#) | [government](#) | [departments](#) | [search](#)

Copyright © State of New Jersey, 1996-2004
Department of Environmental Protection
P. O. Box 402
Trenton, NJ 08625-0402

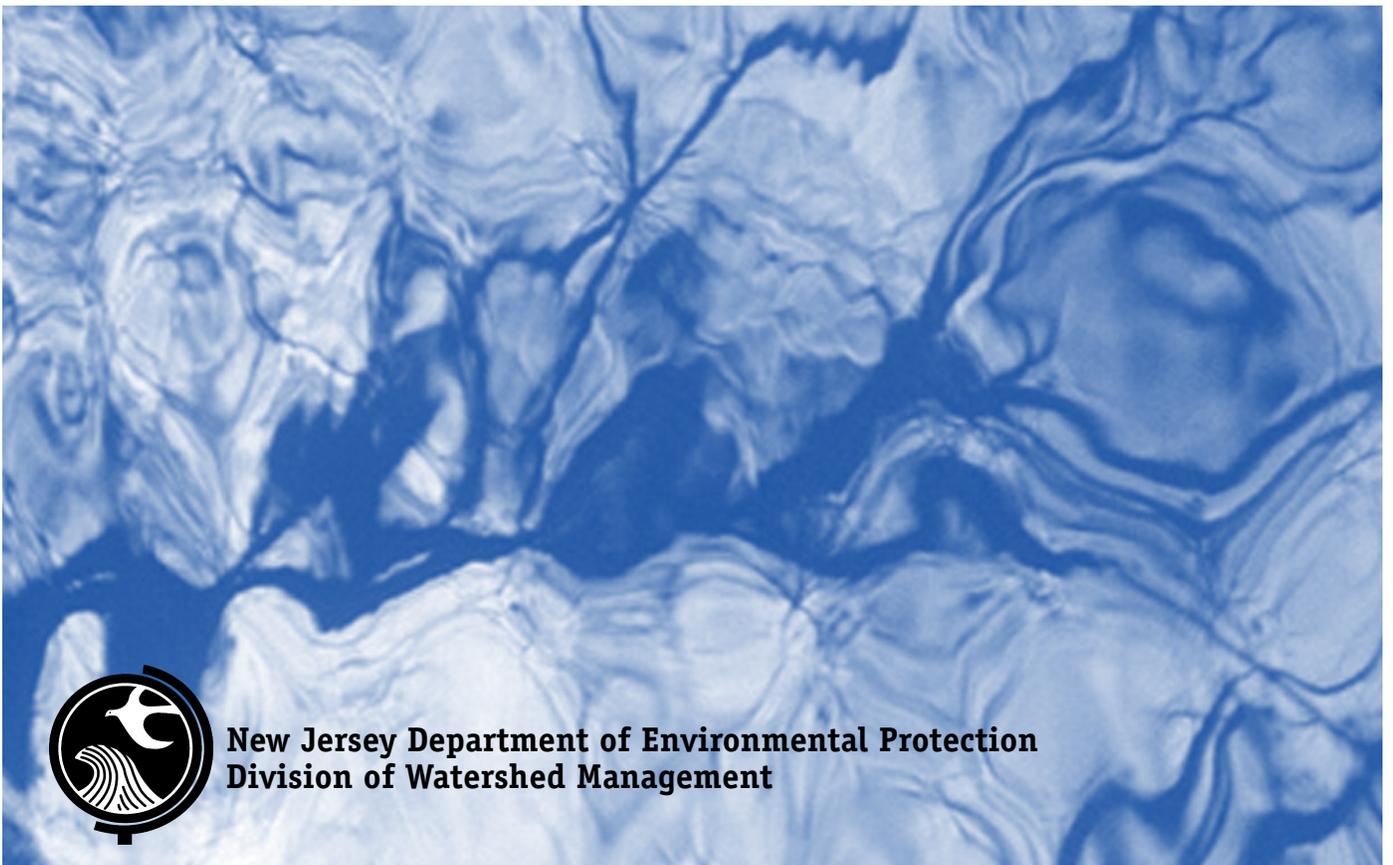
Last Updated: April 23, 2007



New Jersey

Stormwater

Best Management Practices Manual



New Jersey Department of Environmental Protection
Division of Watershed Management

New Jersey Stormwater Best Management Practices Manual

April 2004

State of New Jersey

James E. McGreevey, Governor

Department of Environmental Protection

Bradley M. Campbell, Commissioner

Land Use Management

Ernest P. Hahn, Assistant Commissioner

Division of Watershed Management

Larry Baier, Director

In cooperation with

New Jersey Department of Agriculture

New Jersey Department of Community Affairs

New Jersey Department of Transportation



New Jersey Department of Environmental Protection

Division of Watershed Management

PO Box 418

Trenton, NJ 08625-0418

Updates and Future Versions of the Stormwater BMP Manual

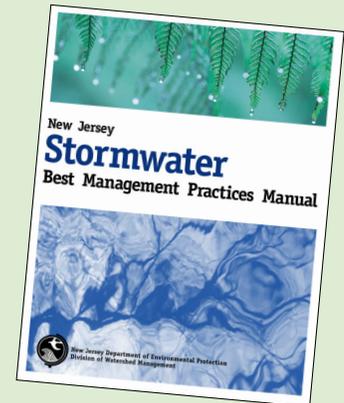
Technical information regarding updates of the New Jersey Stormwater Best Management Practices Manual will be available at www.njstormwater.org

Future versions of the New Jersey Stormwater Best Management Practices Manual will reflect the technical updates found on the website.

Notices regarding future versions of the manual will be posted at this website.

Future versions of the manual are expected to occur at most once a year.

www.njstormwater.org



Acknowledgements

Participating State Departments

This manual was developed in coordination with the New Jersey Department of Agriculture, New Jersey Department of Community Affairs, and New Jersey Department of Transportation.

The Department of Environmental Protection would like to thank the offices and individuals listed below for their assistance and contributions to the New Jersey Stormwater Best Management Practices Manual.

Project Manager

Elizabeth Semple, NJDEP – Division of Watershed Management

Principal Authors

Sandra A. Blick, NJDEP, Division of Watershed Management

Fred Kelly, Natural Resources Conservation Service

Joseph J. Skupien, P.P., P.E., Storm Water Management Consulting, P.A.

Co-authors

Bruce Friedman, NJDEP – Division of Water Quality

Steve Jacobus, NJDEP – Division of Watershed Management

Gene McColligan, NJDEP – Division of Watershed Management

Hunter Birkhead, P.E., P.P, NJDA – State Soil Conservation Committee

Jim Morris, Rutgers University, Cook College Office of Continuing Professional Education

Christopher Obropta, P.E., PhD., Rutgers Cooperative Extension

Paul Schiariti, P.E., Mercer County Soil Conservation District

Kaveh Zomorodi, PhD., Dewberry

Chris Miller, Natural Resources Conservation Service

THE DEPARTMENT WOULD ALSO LIKE TO THANK the Best Management Practices Manual Technical Committee and the Mosquito Control Subcommittee for their assistance in the development of the technical standards in this manual:

Best Management Practices Manual Technical Committee

David Ahdout, NJDOT – Division of Design Services
Michael Baier, NJDCA – Division of Codes and Standards
Sandra A. Blick, NJDEP, Division of Watershed Management
Hunter Birckhead, P.E., P.P, NJDA – State Soil Conservation Committee
Kiong Chan, NJDOT – Division of Design Services
Robert Colburn, Land Improvement Contractors of America, NJ Chapter
Joseph D’Abundo, P.E., NJ State Association of County Engineers
Anthony DiLodovico, Schoor DePalma, Inc.
Nicole Einthoven, NJDOT – Division of Design Services
Bruce Friedman, NJDEP – Division of Water Quality
Madhu Guru, P.E., NJDEP – Land Use Regulation Program
Steve Jacobus, NJDEP – Division of Watershed Management
Michael Kaminski, NJDOT
Fred Kelly, Natural Resources Conservation Service
Vincent J. Mazzei, Jr., P.E., NJDEP – Land Use Regulation Program
Gene McColligan, NJDEP – Division of Watershed Management
Brian McLendon, NJDEP – Division of Water Quality
Frank J. Minch, NJDA – State Soil Conservation Committee
Richard A. Moralle, P.E., P.P., C.L.S., C.M.E., Society of Municipal Engineers, T & M Associates
Manish Patel, P.E., NJDEP – Office of Innovative Technology
Frank S. Scarantino, P.E., P.P, NJ State Association of County Engineers, Society of Municipal Engineers
John Showler, NJDA – State Soil Conservation Committee
Joseph J. Skupien, P.P., P.E., Storm Water Management Consulting, P.A.
Lad Szalaj, NJDOT – Division of Design Services
Victoria Thompson, Monmouth County Mosquito Extermination Commission
Fritz Wise, NJDEP – Division of Water Quality

Best Management Practices Manual Mosquito Control Subcommittee

Hadley C. Foster, Morris County Mosquito Extermination Commission
John Kranz, Middlesex County Mosquito Extermination Commission
Daniel Rice, Morris County Mosquito Extermination Commission

THE DEPARTMENT WOULD ALSO LIKE TO THANK the Best Management Practices Manual Advisory Committee for their input and advice during the development of the manual:

Best Management Practices Manual Advisory Committee

Michael S. Bennett, P.E., Hatch Mott McDonald
Tracy Carluccio, Delaware Riverkeeper Network
Thomas H. Cahill, P.E., Cahill Associates
Frank Doyle, RSIS – Site Improvement Advisory Board
Valerie Hrabal, P.E., RSIS -Site Improvement Advisory Board, Keller Kirkpatrick
Don Johnson, P.E., Montgomery Township Special Projects Engineer

Best Management Practices Manual Advisory Committee continued

David Lamm, P.E., Natural Resources Conservation Service
Paul Pogorzelski, P.E., Van Cleef Engineering Associates
Gene Santana, P.E., Michael Baker Jr. Engineers, formerly from Act Engineers
Ramesh Rajagopal, P.E., Gannett Fleming, Inc.
Maya van Rossum, Delaware Riverkeeper

THE DEPARTMENT WOULD ALSO LIKE TO THANK the following individuals for their technical input and assistance during the development of the manual:

Roger T. Bannerman, Wisconsin Department of Natural Resources
Jeremiah Bergstrom, C.L.A., A.S.L.A., TRC Omni Environmental Corporation
Stewart Comstock, P.E., Maryland Department of the Environment
James F. Cosgrove, Jr., P.E., TRC Omni Environmental Corporation
Karl Dauber, P.E., Michael Baker Jr. Engineers
Mark Gallagher, Princeton Hydro, LLC
Geoffrey M. Goll, P.E., Princeton Hydro, LLC
Jeffrey L. Hoffman, P.G., NJDEP – New Jersey Geological Survey
Richard R. Horner, Ph.D., University of Washington
Robert Limbeck, Delaware River Basin Commission
Eric H. Livingston, Florida Department of Environmental Protection
William C. Lucas, TRC Omni Environmental Corporation
Richard H. McCuen, Ph.D., University of Maryland
Robert E. Pitt, Ph.D., P.E., University of Alabama
Thomas R. Schueler, Center for Watershed Protection
H. Earl Shaver, Auckland Regional Council, New Zealand
Eric W. Strecker, P.E., GeoSyntec Consultants
Stephen J. Souza, Ph.D., Princeton Hydro, LLC
John A. Thonet, P.E., P.P., Thonet Associates
Paul I. Welle, P.E., Schnabel Engineering

THE DEPARTMENT WOULD ALSO LIKE TO THANK the staff at the Rutgers University, Cook College Office of Continuing Professional Education, as well as the following individuals for administrative and research assistance:

Robin Paulin, P.E., Somerset County Engineering Department
Benjamin B. Witherell, Water Resource Management

Finally, a special thanks to our copy and style editor Nadene Rehnby at Hands On Publications.

Manual References

The information presented in each chapter of the Best Management Practices Manual was developed both from published sources and through detailed technical discussions held at numerous BMP Manual Technical, Mosquito Control, and Advisory Committee meetings hosted by the NJDEP. The information and conclusions developed at these meetings reflect the technical knowledge of the committee members, which was derived from their own experience and both published and unpublished sources of stormwater management information. Therefore, the NJDEP would like to thank all of the private, public, and academic researchers, practitioners, and experts, including those not specifically noted in the chapters' References sections, who have contributed to the current, extensive body of stormwater management knowledge upon which this manual has been based.

Contents

Acknowledgements	iii
Chapter 1: Impacts of Development on Runoff	1.1
Chapter 2: Low Impact Development Techniques	2.1
Chapter 3: Regional and Municipal Stormwater Management Plans	3.1
Chapter 4: Stormwater Pollutant Removal Criteria	4.1
Chapter 5: Computing Stormwater Runoff Rates and Volumes	5.1
Chapter 6: Groundwater Recharge (<i>April 2004</i>)	6.1
Chapter 7: Landscaping	7.1
Chapter 8: Maintenance and Retrofit of Stormwater Management Measures	8.1
Chapter 9.0: Structural Stormwater Management Measures	9.0.1
Chapter 9.1 Standard for Bioretention Systems	9.1
Chapter 9.2 Standard for Constructed Stormwater Wetlands	9.2
Chapter 9.3 Standard for Dry Wells	9.3
Chapter 9.4 Standard for Extended Detention Basins	9.4
Chapter 9.5 Standard for Infiltration Basins	9.5
Chapter 9.6 Standard for Manufactured Treatment Devices	9.6
Chapter 9.7 Standard for Pervious Paving Systems	9.7
Chapter 9.8 Standard for Rooftop Vegetated Cover	<i>Reserved</i>
Chapter 9.9 Standard for Sand Filters	9.9
Chapter 9.10 Standard for Vegetative Filters	9.10
Chapter 9.11 Standard for Wet Ponds	9.11
Appendix A: Low Impact Development Checklist	A-1
Appendix B: Municipal Regulations Checklist	B-1
Appendix C: Sample Municipal Stormwater Management Plan	C-1
Appendix D: Model Stormwater Control Ordinance for Municipalities (<i>April 2004</i>)	D-1

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 1

Impacts of Development on Runoff

This chapter describes the adverse impacts unmanaged land development can have on groundwater recharge and stormwater runoff quality and quantity both at and downstream of a development site. The chapter also reviews the fundamental physical, chemical, and biological aspects of the rainfall-runoff process and how they can be altered by development. In doing so, the chapter demonstrates the need for the NJDEP Stormwater Management Rules at N.J.A.C. 7:8, which have been developed to directly address these adverse impacts. In addition, the chapter seeks to increase understanding of these physical, chemical, and biological processes in order to improve the design of structural and non-structural measures mandated by the Rules' groundwater recharge, stormwater quality, and stormwater quantity requirements.

Runoff Quantity

Development can dramatically alter the hydrologic response of an area and, ultimately, an entire watershed. Prior to development, native vegetation can either directly intercept precipitation or evapotranspire that portion that has infiltrated into the ground back into the atmosphere. Development can remove this beneficial vegetation and replace it with turf grass lawns and impervious roofs, driveways, parking lots, and roads, thereby reducing the site's pre-developed evapotranspiration and infiltration rates. In addition, clearing and grading can remove surface depressions that store rainfall. Construction activities may also compact the soil and diminish its infiltration rate, resulting in increased rates and volumes of stormwater runoff from the development site.

Impervious areas directly connected to gutters, channels, and storm sewers can transport runoff more quickly than natural, vegetated conveyances. This shortening of the transport or travel time quickens the rainfall-runoff response of the site, causing flow in downstream waterways to peak faster and higher than under natural or predeveloped site conditions. These increases can create new and aggravate existing downstream flooding and erosion problems and can increase the quantity of sediment and other pollutants in the waterways.

Filtration of runoff and removal of pollutants by natural surface and channel vegetation is eliminated by storm sewers that discharge runoff directly into waterways. Increases in impervious area can also decrease

opportunities for infiltration and reduce stream base flow and groundwater recharge. Reduced base flows and increased peak flows produce greater fluctuations between normal and storm flow rates, which can increase channel erosion and adversely impact aquatic organisms and habitats. Reduced base flows can negatively impact the hydrology of adjacent wetlands and the health of biological communities that depend on these base flows.

To address these impacts, planners, engineers, reviewers, and other participants in the design of stormwater management measures must rethink traditional approaches to both land development itself and the environmental problems it can cause. New approaches such as those described in this manual must be taken. For example, nonstructural stormwater management principles provide a prevent-minimize-mitigate approach that is preferred by the NJDEP Stormwater Management Rules. Under these Rules, nonstructural stormwater management techniques are a requirement for new land development projects. Nonstructural stormwater management measures, also known as Low Impact Development Best Management Practices (LID-BMPs), include reduction of impervious cover, maintenance of natural vegetation, and reduction of nutrient inputs. LID-BMP techniques can significantly reduce and even prevent the negative effects of land development on stormwater runoff described above. Nonstructural stormwater management practices are covered in detail in *Chapter 2: Low Impact Development Techniques*.

During heavy rainfall, many land developments increase the rate or volume of stormwater runoff, even those with well-designed LID techniques. Historically, this increased runoff was managed through state and/or local regulations that required peak runoff rates leaving a site after development to be equal to those that existed prior to development. It was believed that if the peak rate of runoff was maintained, the downstream waterways could assimilate the runoff in the same manner as before development. This control was accomplished using detention and retention basins that store and then gradually release the runoff.

However, this control methodology failed to account for the increased volume of runoff caused by land development. Watershed studies in New Jersey have demonstrated that this additional volume resulted in extended peak rates and increases in non-peak flows that increased flooding and erosion problems downstream. These same watershed studies determined that, by reducing peak post-development site runoff to rates less than pre-developed site conditions throughout the watershed, the volume of post-development runoff was redistributed and pre-development peaks were maintained or reduced throughout the watershed.

The Stormwater Management Rules incorporate these peak flow reduction requirements, which are similar to those previously published in the NJDEP Flood Hazard Area Control Act Rules and the New Jersey Department of Community Affairs (NJDEA) Residential Site Improvement Standards (RSIS).

Runoff Quality

In addition to increases in runoff volume, land development often results in the accumulation of pollutants on the land surface that runoff can mobilize and transport to streams. New impervious surfaces and cleared areas created by development can accumulate a variety of pollutants from the atmosphere, fertilizers, animal wastes, and leakage and wear from vehicles. Pollutants can include metals, suspended solids, hydrocarbons, pathogens, and nutrients. Common pollutants found in stormwater runoff are shown in Table 1-1.

In addition to increased pollutant loading, land development can adversely affect water quality and stream biota in more subtle ways. For example, stormwater falling on impervious surfaces or stored in detention or retention basins can become heated and raise the temperature of the downstream waterway, adversely affecting cold water fish species such as trout. Development can remove trees along streambanks that normally provide shading, stabilization, and leaf litter that falls into streams and becomes food for the aquatic community.

Table 1-1: Typical Stormwater Pollutants

Pollutant	Typical Concentration
Total suspended solids ^a	80 mg/l
Total phosphorus ^b	0.30 mg/l
Total nitrogen ^a	2.0 mg/l
Total organic carbon ^d	12.7 mg/l
Fecal coliform bacteria ^c	3600 MPN/100ml
E. Coli bacteria ^c	1450 MPN/100ml
Petroleum hydrocarbons ^d	3.5 mg/l
Cadmium ^e	2 ug/l
Copper ^a	10 ug/l
Lead ^a	18 ug/l
Zinc ^e	140 ug/l
Chlorides ^f (winter only)	230 mg/l
Insecticides ^g	0.1 to 2.0 ug/l
Herbicides ^g	to 5.0 ug/l
<p>Notes</p> <ol style="list-style-type: none"> 1. Data sources: ^a Schueler (1987), ^b Schueler (1995), ^c Schueler (1997), ^d Rabanal and Grizzard (1996), ^e USEPA (1983), ^f Oberts (1995), ^g Schueler (1996). 2. Concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Mean or median runoff concentrations from stormwater hotspots are higher than those shown. 3. Units: mg/l = milligrams/liter ug/l = micrograms/liter MPN = Most Probable Number 	

The following sections provide basic information on the most common pollutants associated with stormwater runoff from a broad range of land uses.

1. Solids/Floatables

Solids/floatables are primarily a surface water pollution concern. They are defined by the NJDEP as wastes or debris floating, suspended or otherwise contained in wastewater or waters of the state (N.J.A.C. 7:22A-1.4 et seq.). These materials include debris such as bottles, jars, cans, cardboard boxes, paper bags, newspapers, plastic containers and wrappings, condoms, hypodermic needles, leaves, and branches.

Solid/floatable materials are wastes that are inadvertently or purposefully disposed of either on land or directly into stormwater conveyances. Runoff transports this material to receiving waters where it can disperse, float, wash ashore onto beaches or embankments, or settle onto waterway bottoms. Solid/floatable material can create odors, aesthetic problems, and even toxic or corrosive gases that can emanate from bottom mud deposits.

2. Sediment

Sediment is one of the most significant pollutants created by development and transferred by its runoff. Sediments consist largely of soil materials eroded from uplands as a result of natural processes and human activities.

The greatest sediment loads are exported during the construction phase of land development. Adequate sediment and erosion control must be installed and maintained at the site to prevent the delivery of large quantities of sediment into downstream waterways and water bodies. Other pollutants such as nutrients and organic matter attached to the sediment can also be delivered. Requirements for appropriate erosion controls are available in the Standards for Soil Erosion and Sediment Control in New Jersey available from the State Soil Conservation Committee (SSCC) or local Soil Conservation Districts.

Sediment and other nonpoint source pollution from agricultural sources is also a major contributor to water quality problems in the state. Sediment from croplands clogs lakes, road ditches, canals, and culverts, particularly during and just after active tilling.

High concentrations of suspended sediment in streams and lakes cause many adverse consequences including increased turbidity, reduced light penetration, reduced prey capture for sight-feeding predators, clogged fish gills/filters, and reduced angling success. Additional impacts can result after sediment is deposited in slower moving waters. These include the smothering of benthic communities, alterations in the composition of the bottom substrate, and the rapid filling-in of small impoundments that create the need for costly dredging and reductions in the overall aesthetic value of the water resource. Sediment is also an efficient carrier of toxins and trace metals. Once deposited, pollutants in these enriched sediments can be remobilized under suitable environmental conditions and threaten benthic life.

3. Nutrients

Phosphorus and nitrogen are nutrients used by plants during photosynthesis. Phosphorus in natural waters occurs as phosphate in three classifications: orthophosphates (P₀₄), polyphosphates (polymers of phosphoric acid), and organically bound phosphates. The most common forms of nitrogen are gaseous (N₂), ammonia (NH₃ or NH₄), nitrite (NO₂), nitrate (NO₃), and nitrogen bound in organic compounds. Pollution from inorganic phosphorus (orthophosphates) and inorganic nitrogen (nitrates and ammonia) are of chief concern in New Jersey.

In general, undeveloped land produces relatively few nutrients; agricultural, residential, industrial, and commercial areas produce more nutrient loadings. In rural and residential areas, substantial amounts of nutrients originate from commercial fertilizers, manure from livestock feeding operations, or dairy farming. Fertilizer spread on lawns and farmland during the winter can contribute nutrients to runoff in the springtime. Pet wastes contribute nutrients to runoff in residential areas. Detergents and raw sanitary waste also contribute to nutrient loading.

The action of phosphates and nitrates can be quite different. Although both can be transported by groundwater, phosphorus often combines with fine soil particles and remains locked in the soil until it is either utilized by plant life or eroded away with the soil. In the latter case, the phosphorus will flow along with the soil particles as suspended sediment. Nitrates in the soil remain much more soluble. During the late winter and occasionally in midseason following exceptionally heavy rainfall, nitrates may pass below the root zone into the groundwater. This movement of nitrates into groundwater may cause a public health hazard because high nitrate concentrations in drinking water can cause infant methemoglobinemia (Blue Baby Syndrome).

Under normal conditions, phosphorus and nitrogen are not generally regarded as problem chemicals. However, in excessive amounts, phosphorus and nitrogen present a problem by over-stimulating plant growth within the aquatic environment. When excessive concentrations (especially phosphorus) pass into surface fresh waters, they can contribute to eutrophication in slower moving water bodies and to dense algal growths on substrates within flowing water systems.

The greatest risk of eutrophication is in small agricultural ponds, urban lakes, and impoundments that have retention times of two weeks or more. Under optimal growing conditions, these lake systems can experience chronic and severe eutrophic symptoms such as surface algal scums, water discoloration, strong odors, depressed oxygen levels (as the bloom decomposes), release of toxins, and reduced palatability of fishery resources. High nutrient levels also promote the growth of dense mats of green algae that attach to rocks and cobbles in shallow, unshaded headwater streams. This phenomenon is present in many residential areas with recreational water bodies bordered by extensive, improperly fertilized lawn.

Coastal waters and estuaries in New Jersey also suffer from increased incidences of phytoplankton blooms, e.g., Barnegat Bay has been the site of several algal bloom problems including brown tide. Concern exists that this problem is caused, in part, by inputs from nutrient-enriched fresh waters; however, the relationship between high nutrient levels and algal production is extremely complex and is not fully understood.

4. Pesticides

Pesticides, which include insecticides, herbicides, rodenticides, and fungicides, are among the few toxic substances deliberately introduced to the environment. These substances are used routinely for agricultural purposes and in residential and commercial property maintenance to biochemically affect specific unwanted organisms. However, these substances can produce unintended toxic effects on ecosystems and human life by contaminating soil, water, and air. Numerous acute and chronic effects on humans and other organisms are associated with pesticide exposure. Pesticides can enter an organism through inhalation, ingestion, or skin contact. They have caused decreases in aquatic populations either directly, through damage to the food chain by decreasing reproductive success, or indirectly, by reducing oxygen levels in the water through a reduction in the populations of higher plants and phytoplankton. Some pesticides, such as DDT, dieldrin, and chlordane, are no longer in use but persist in the food chain and in the human body. Other commonly used pesticides, such as malathion, are suspected carcinogens and are hazardous more through direct contact than indirect contact via the food chain.

Pesticides are carried in stormwater from application sites by becoming dissolved or suspended in runoff or by binding to particulate matter carried in runoff. These pesticides can contaminate surface or groundwater through infiltration devices or overflow. The fate and transport of pesticides are dependent on their physical and chemical properties and their chemical interactions with the environment. Processes that determine the path of pesticides in the environment are primarily photolysis (degradation in light), hydrolysis (degradation in the presence of water), and sorption reactions that are dependent on the chemical nature and solubility of the pesticide and the percentage of particulate and organic matter present in the sediment. Some pesticides, such as aldicarb, are highly soluble in water and are easily flushed into aquatic ecosystems or groundwater. Pesticides with low solubility may accumulate in sediments by adhering to particulate matter. Adsorption and absorption increase with the amount of organic matter present. These factors and the resistance to degradation of certain pesticides (expressed as the half-life) increase the persistence of these substances in the environment.

5. Metals

The permissible concentrations of metals in water are established directly by numerical criteria under the surface and groundwater quality standards and indirectly by standards under the Safe Drinking Water Act. Concentrations of metals found in water can have adverse effects upon public health as well as upon aquatic biota. Lead, arsenic, copper, cadmium, mercury, and some forms of chromium are all metals of concern.

Metals can occur naturally in soil or result from human activity. The quantities of metals leaching into water from natural sources are influenced largely by the water's pH. Acid rain and the low pH water often found in swamps may increase the solution of metals into water. Although mercury and copper have been shown to cause serious health problems, lead is of primary public health concern. It has a cumulative, toxic neurological effect and may be particularly harmful to children. One of the principal sources of lead in stormwater runoff has been the tetraethyl lead in gasoline, but pollution from this source is rapidly declining due to stringent federal controls over lead in gasoline.

6. Road Salt

Road salt, primarily composed of sodium chloride (common salt), has the potential to impair land vegetation, water quality, and aquatic ecosystems. This material is commonly used throughout the state as a low-cost substance for melting snow and ice. Road salt entering stormwater runoff generally originates from salt stockpiles or from salt application to roadways and other impervious surfaces. Precipitation falling on salted surfaces creates runoff containing dissolved salt. The increasing amount of urban and suburban development in New Jersey has resulted in increased roadways and other impervious surfaces such as parking lots, which has increased the use of road salt.

The primary problem with road salt is the contamination of ground and surface waters, which may render them unusable or require expensive treatment procedures. Increased sodium chloride concentrations in water create aesthetically displeasing drinking water and interfere with pristine manufacturing processes. High levels of sodium consumed in drinking water can elevate blood pressure and impair kidney function in susceptible individuals.

Because of salt's long residence time, salt water often tends to build up concentration in groundwater. Due to a seasonal effect, the highest levels of chloride ions appear in the summer months. This effect is attributed to the slow movement of groundwater (reacting to winter applications) and high summer evapotranspiration rates.

Excessive salt or saline input to fresh surface waters can cause significant use impairment. The input of highly concentrated saline water into fresh water lakes can retard springtime mixing. The density of the bottom layer of water increases, thereby overriding the normal thermal density gradients responsible for

vertical mixing. This saline buildup can decrease oxygen levels and cause high mortality among bottom-dwelling organisms. Increased salt loading to bays and estuaries can alter natural saline concentrations and disrupt shellfish reproduction and fish spawning. Surface water effects are dependent on the concentrations of sodium chloride entering the system, the amount of dilution, and the sensitivity of the aquatic ecosystem.

Aside from contaminating surface and groundwater, high levels of sodium chloride can kill roadside vegetation and corrode infrastructure such as bridges, roads, and stormwater management devices. In addition, some industrial operations can be impaired by an increase in the salinity of intake water.

7. Petroleum Hydrocarbons

Petroleum hydrocarbons in water are considered very harmful to natural biota. In addition, some constituents are carcinogenic and toxic to humans. No numerical criteria exist for petroleum hydrocarbons in ground or surface water quality standards. In both cases and in most waters, the basic criterion is “none noticeable.”

Additional requirements for surface water prohibit hydrocarbons on aquatic substrata, along the shore in quantities detrimental to the natural biota, and where they would render waters unsuitable for their designated uses. The same standards are generally applicable to oil and grease, which, except for petroleum hydrocarbons, are not considered especially dangerous. Control efforts are mainly directed toward hydrocarbons.

Although the hydrocarbons harmful to water quality are mostly liquid at ambient temperatures, they are absorbed and adsorbed onto solid particles of sediment so rapidly that they are found mainly as particulates in runoff. Only considerable masses of oil will remain in liquid form in the larger storm drains. Petroleum hydrocarbons are also biodegradable in an aerobic environment, although at a relatively slow rate.

8. Pathogens

Pathogens (viral and bacterial) and non-pathogenic bacteria are found in the intestinal tracts of humans and other warm-blooded animals and are excreted with fecal wastes. A number of human diseases can be transmitted by runoff contaminated by fecal sources. Some well-documented bacterial agents include the *Salmonella* group responsible for typhoid fever, paratyphoid fever, and intestinal fever; the *Shigella* group causing bacillary dysentery; *Vibrio cholerae* responsible for cholera; and *Escherichia coli* (*E. coli*) causing gastroenteritis. In humans, gastroenteritis is the leading waterborne infectious disease in the United States. Deficient water treatment and groundwater contamination of wells are responsible for most of the outbreaks (65 percent) and cases (63 percent). The ingestion of shellfish harvested from contaminated waters can lead to disease as well.

Human fecal contamination is primarily a sewage treatment problem complicated by cross-connections or interconnections between sanitary and storm sewers, where combined sewer overflows degrade surface waters and where faulty, improperly sized, or improperly located septic systems contaminate groundwater. Animal fecal material from livestock operations, domestic pet populations, and concentrated wildlife populations contaminate surface waters via overland runoff and stormwater sewer discharges. Groundwater contamination occurs in areas with very permeable soils and/or high groundwater tables and where sinkholes, fractured rock, and well casings provide possible entry routes.

It is generally accepted that urban runoff will exceed desired bacterial limits. When considering stormwater contributions to the flow in a combined sewer system, the importance of stormwater control for bacterial water quality should be considered.

While not directly responsible for disease, fecal coliform bacteria have traditionally served as the microbiological indicators for the potential presence of waterborne pathogens. Enterococci appear to be a more accurate indicator than coliform bacteria, especially in saltwater where their resistance time and

survival rate is similar to that of pathogenic bacteria. Research is being conducted on the use of bacteriophages as viral indicators. Until regulations are revised, however, the state will continue to rely on traditional indicators (total and fecal coliforms) as well as enterococci.

Compared to other pollutants, bacteria and pathogens have relatively low residence times in the environment. Survival in surface waters varies with environmental factors such as temperature, light intensity, salinity, nutrient levels, bacteriophages and predation, absorption, sedimentation, and the presence of toxic substances.

Bacteria and viruses, when introduced to the subsurface environment, can undergo a natural die-off, be retained in the soil, or be transported to groundwater. Survival rates of both bacteria and viruses decrease with increasing temperature, decreasing soil moisture, and increasing competition with native soil microflora. Bacteria can be effectively retained in soils by the filtering action of fine particle soils with small pore size. The finer the soil grain, the greater its capability to filter out microorganisms. Adsorption, however, is the principal mechanism by which viruses are retained in the soil, and it can be a factor for retaining bacteria. Adsorption may be temporary; viruses may remain on the soil particle and be returned to subsurface flow during intense rainfall.

Groundwater is less likely to be contaminated by bacteria than surface waters. Bacteria and pathogens are generally filtered, adsorbed by soil, or dead before reaching the groundwater.

There is presently limited information that specifically addresses the survivability and transport of bacteria in stormwater runoff. The exact distances bacteria would be transported vary with soil properties, climate, and vegetation.

Parasites are an additional concern under this general category of pollutants. A number of infectious diseases are transmissible to humans via ordinary parasites. Common causes of these diseases are dog and cat parasites such as roundworms and hookworms shed in animal feces. The intimate relationships that household pets have with people, combined with the large pet population, greatly increase the potential for transmission of pathogens. This also appears to be true for bacteria and viruses, many of which have long survival times when infected pet waste is washed into receiving waters via stormwater.

Two relatively common protozoa that cause intestinal disorders in humans are also of great concern. The first is *Cryptosporidium Spp.*, which often causes diarrhea and may be accompanied by fever, abdominal pain, nausea, constipation, and/or weight loss. Most infections occur after contact with infected people. The other is *Giardia Spp.*, which causes many of the same symptoms as cryptosporidiosis. Its major reservoirs appear to be water and food contaminated by infected animals and people. A worrisome feature of these organisms is their resistance to environmental influences and disinfectants.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 2

Low Impact Development Techniques

As described in Chapter 1, land development can have severe adverse stormwater impacts, particularly if the land is converted from woods, meadow, or other natural condition to a highly disturbed area with large percentages of impervious and non-native vegetated covers. Such impacts typically include an increase in stormwater runoff volume, rate, velocity, and pollutants and a corresponding decrease in the quality of runoff and stream flow. Frequently, management of these impacts has focused on collecting and conveying the runoff from the entire site through a structural conveyance system to a centralized facility (e.g., detention basin, wet pond) where it is stored and treated prior to discharge downstream. In effect, such practices first allow the adverse runoff impacts to occur throughout the site and then provide remedial and/or restorative measures immediately prior to releasing the runoff downstream.

Since the 1960s, the range of remedial measures provided in centralized treatment facilities has increased from merely 100-year peak flow attenuation to the range of peak flow, volume, and nonpoint source pollutant controls required by New Jersey's current Stormwater Management Rules at N.J.A.C. 7:8. This has required modifications to established methods of runoff computation and the development of alternative treatment methods to be used in centralized facilities.

However, with the increasing emphasis on nonpoint source pollution and concerns over the environmental impacts of land development, it has become necessary to develop effective alternatives to the centralized conveyance and treatment strategy that has been the basis for much of the stormwater management systems and programs in the state. New strategies must be developed to minimize and even prevent adverse stormwater runoff impacts from occurring and then to provide necessary treatment closer to the origin of those impacts. Such strategies, known collectively as Low Impact Development or LID, seek to reduce and/or prevent adverse runoff impacts through sound site planning and both nonstructural and structural techniques that preserve or closely mimic the site's natural or pre-developed hydrologic response to precipitation. Rather than responding to the rainfall-runoff process like centralized structural facilities, low impact development techniques interact with the process, controlling stormwater runoff and pollutants closer to the source and providing site design measures that can significantly reduce the overall impact of land development on stormwater runoff. As such, low impact development promotes the concept of designing with nature.

Effective low impact development includes the use of both nonstructural and structural stormwater management measures that are a subset of a larger group of practices and facilities known as Best Management Practices or BMPs. As noted above, the BMPs utilized in low impact development, known as LID-BMPs, focus first on minimizing both the quantitative and qualitative changes to a site's pre-developed hydrology through nonstructural practices and then providing treatment as necessary through a network of structural facilities distributed throughout the site. In doing so, low impact development places an emphasis on nonstructural stormwater management measures, seeking to maximize their use prior to utilizing structural BMPs.

Nonstructural BMPs used in low impact development seek to reduce stormwater runoff impacts through sound site planning and design. Nonstructural LID-BMPs include such practices as minimizing site disturbance, preserving important site features, reducing and disconnecting impervious cover, flattening slopes, utilizing native vegetation, minimizing turf grass lawns, and maintaining natural drainage features and characteristics. Structural BMPs used to control and treat runoff are also considered LID-BMPs if they perform these functions close to the runoff's source. As such, they are typically smaller in size than standard structural BMPs. Structural LID-BMPs include various types of basins, filters, surfaces, and devices located on individual lots in a residential development or throughout a commercial, industrial, or institutional development site in areas not typically suited for larger, centralized structural facilities.

Finally, low impact development promotes the view of rainwater as a resource to be preserved and protected, not a nuisance to be eliminated. For example, with low impact development, roof runoff can be captured and stored in rain barrels for plant watering or other uses. Runoff can also be directed to small on-lot bioretention or infiltration basins, also known as rain gardens, to provide both runoff treatment and landscape enhancements.

Unfortunately, low impact development techniques and strategies are considered by some to be applicable only to land development sites with limited impervious cover. However, it has been clearly demonstrated that low impact development techniques can be applied to virtually any development site, regardless of impervious coverage, to produce enhanced site designs and "lower" stormwater impacts.

The use of nonstructural and structural LID-BMPs can be a significant improvement over the more centralized approach to stormwater management traditionally used in New Jersey. Even in those instances where centralized structural BMPs are still required to fully provide downstream areas with effective pollution, erosion, and flood protection, LID-BMPs can help to reduce the number and/or size of such facilities, further reducing site disturbance. And, in certain instances, it may be possible to satisfy all stormwater management requirements through the use of nonstructural LID-BMPs alone, thereby eliminating the need for any structural BMPs. In all instances, specific site and downstream conditions must be evaluated to determine the range of standard and low impact development BMPs that can be utilized at a land development site.

It is also important to note that, since low impact development typically relies on an array of nonstructural and relatively small structural BMPs distributed throughout a land development site, ownership and maintenance of the various BMPs may be similarly distributed over an array of property owners. As such, it is vital to have public understanding of and support for the various LID-BMPs officially authorized for use in a particular municipality. Such understanding and support must include an appreciation for the role that the LID-BMPs play in the site's or watershed's stormwater management program and a commitment to preserve and maintain them. Additional information regarding this issue is presented in the *Additional Considerations* section below.

The use of both nonstructural and structural BMPs in low impact development is governed by certain principles, objectives and requirements. A discussion of each of these factors is presented below, along with details of each type of LID-BMP. It should be noted that, while consideration of nonstructural stormwater management techniques at land development sites is required by the NJDEP Stormwater Management Rules at N.J.A.C. 7:8, the NJDEP believes that effective, state-wide use of such practices can be best achieved through municipal master plans and land development ordinances that mandate specific LID goals and authorize the use of specific LID-BMPs. For this reason, the Stormwater Management Rules require municipalities to review their master plans and ordinances in order to incorporate LID practices into their land development regulations to the maximum extent practicable. A detailed discussion of the NJDEP Stormwater Management Rules is presented below, along with guidelines on the development of municipal LID regulations and the selection of practical and reliable LID-BMPs.

Nonstructural Stormwater Management Strategies

As described above, effective low impact development includes the use of both nonstructural and structural stormwater management measures known as LID-BMPs. Of the two, nonstructural LID-BMPs play a particularly important role. The proposed NJDEP Stormwater Management Rules at N.J.A.C. 7:8 require in Section 5.2(a) that the design of any development that disturbs at least 1 acre of land or increases impervious surface by at least 1/4 acre must incorporate nonstructural stormwater management strategies “to the maximum extent practicable.” Such a development is defined in the Rules as a “major development.” As such, nonstructural LID-BMPs are to be given preference over structural BMPs. Where it is not possible to fully comply with the Stormwater Management Rules solely with nonstructural LID-BMPs, they should then be used in conjunction with LID and standard structural BMPs to meet the Rules’ requirements.

More precisely, to achieve the Rules’ design and performance standards, Subchapter 5 of the NJDEP Stormwater Management Rules requires the maximum practical use of the following nine nonstructural strategies at all major developments:

1. Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss.
2. Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces.
3. Maximize the protection of natural drainage features and vegetation.
4. Minimize the decrease in the pre-construction “time of concentration.”
5. Minimize land disturbance including clearing and grading.
6. Minimize soil compaction.
7. Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers, and pesticides.
8. Provide vegetated open-channel conveyance systems discharge into and through stable vegetated areas.
9. Provide preventative source controls.

In addition, Subchapter 5 further requires an applicant seeking approval for a major development to specifically identify which and how these nine nonstructural strategies have been incorporated into the development’s design. Finally, for each of those nonstructural strategies that were not able to be incorporated into the development’s design due to engineering, environmental, or safety reasons, the applicant must provide a basis for this contention.

While the nonstructural stormwater management strategies listed above represent a wide range of both objectives and practices, Strategies 1 through 8 can be directly addressed through the use of specific nonstructural LID-BMPs that can be grouped into four general categories:

1. Vegetation and Landscaping;
2. Minimizing Site Disturbance;
3. Impervious Area Management; and
4. Time of Concentration Modifications.

Information on the specific nonstructural LID-BMPs included in each of these categories is presented below. A Nonstructural Stormwater Management Checklist is provided in Appendix A to assist applicants and reviewers in demonstrating that the Stormwater Management Rules' nine nonstructural stormwater management strategies have been utilized throughout the land development site to the maximum extent practicable.

Prior to utilizing any of the specific nonstructural LID-BMPs described below, applicants are urged to review the land development regulations of the municipality and/or agency from which they are seeking development approval. Despite low impact development being a relatively new aspect of stormwater management, many municipalities and agencies have already incorporated low impact development goals and strategies into their own regulations and, with the advent of the NJDEP Stormwater Management Rules, those that haven't will be required to do so. Therefore, additional nonstructural strategies and/or specific nonstructural LID-BMPs aside from those described in this chapter may have already been incorporated into a municipality's land development regulations or will be in the near future. In light of the site specific nature of LID-BMPs, these regulations may also discourage or prohibit the use of specific LID-BMPs for engineering, safety, or maintenance reasons. Consideration should also be given to having a pre-design meeting and/or site walk with pertinent regulators and technical reviewers to review local regulations and optimize the site's nonstructural stormwater management design.

Finally, engineers and site designers should recognize the importance of accurately computing existing or predeveloped runoff at a land development site. While this is an important computation at all development sites, it is particularly important at those sites where nonstructural LID-BMPs will be utilized. This is because, to a large degree, these nonstructural measures will utilize and/or mimic the predeveloped site's rainfall-runoff response. As such, accurate computation of predeveloped hydrologic conditions is vital to successful LID-BMP use. It is recommended that engineers and site designers consult with regulatory entities, such as the State, municipality, or local soil conservation district, regarding predeveloped hydrologic conditions.

1. Vegetation and Landscaping

As a nonstructural LID technique, the management of existing and proposed vegetation at a land development site can significantly reduce the site's impact on downstream waterways and water bodies. As discussed in detail in Chapter 5, pervious vegetated areas reduce runoff volumes and peaks through infiltration, surface storage, and evapo-transpiration. Vegetated areas also provide a pervious surface for groundwater recharge, particularly during dormant or non-growing seasons. In addition, vegetation can remove pollutants from the runoff flowing through it through both filtration and biological uptake.

Information regarding three key nonstructural LID-BMPs that utilize vegetation and landscaping to manage stormwater runoff are presented below. A review of this information demonstrates how the features of all three are closely inter-related.

A. Preservation of Natural Areas

The preservation of existing natural vegetated areas is a nonstructural LID-BMP that must be considered throughout the design of a land development. This is especially true for areas with significant hydrologic functions such as forested areas, riparian corridors, and high groundwater or aquifer recharge capabilities. When applying for development approval from a regulatory agency or board, a plan showing natural vegetated areas on the pre-developed site, along with a narrative and photographs describing each area's vegetated and hydrologic characteristics, should be included in the application package. The narrative should also discuss the alternatives and choices made to preserve the natural vegetated areas.

In addition to identifying natural areas to be preserved at a development site, specific legal and/or procedural measures must be specified to ensure that such areas remain preserved in the future. This may include the establishment of easements or deed restrictions on specific portions of a parcel or lot that prohibit any disturbance or alteration. Other measures may not designate a particular portion of a parcel or lot but instead mandate through deed restrictions that an overall percentage of the parcel or lot must remain in natural, vegetated cover. This method allows greater flexibility but can be used only where the exact location of the preserved natural area is not critical to the success of the development's stormwater management system. In either case, the amount of natural area to be preserved must be the maximum amount feasible.

B. Native Ground Cover

Research has demonstrated that areas covered with turf grass typically generate more runoff than other types of vegetation. This is especially true when comparing grass areas with naturally wooded areas or forests. Therefore, in keeping with the goals of nonstructural LID-BMPs contained in the NJDEP Stormwater Management Rules, the amount of lawns and other grass areas at land development sites should be minimized. Instead, alternative vegetation, particularly native plants, should be used to revegetate disturbed site areas.

The use of native plants can provide a low-maintenance alternative to turf grass, resulting in lower fertilizer and water needs. The use of native ground cover, shrubs, and trees instead of turf grass can create infiltration characteristics similar to those of natural areas. These plants can also provide better habitat and create food sources for songbirds and small animals. Native landscaping can also be used to provide property screening, summer shade, and year-round landscaping interest.

In addition to revegetating site areas disturbed by construction, native plants can be used to improve or enhance the hydrologic characteristics of existing site areas. Such areas may include existing agricultural fields, developed areas, access roads, and other previously disturbed portions of the site as well as degraded natural areas. Naturally wooded areas or forests should also be restored or reestablished at land development sites wherever practical. This is also consistent with the goals of nonstructural LID-BMPs. In doing so, it is often necessary to provide stable interim vegetative cover in such restored areas.

In selecting native vegetation, consideration should be given to height, density, and other growth patterns, visual appearance, anticipated use of the planted area, and fertilizer, irrigation, and other maintenance needs. Additional information on native vegetation and landscaping is presented in Chapter 7.

C. Vegetative filters and Buffers

Both native ground cover and grass areas can provide a vegetated buffer to help filter stormwater runoff and provide locations for runoff from impervious areas to re-infiltrate. As described above, water flowing as sheet flow across a vegetated area is slowed, filtered and, depending on soil conditions, given the opportunity to re-infiltrate into the soil. Dense vegetative cover, long flow path lengths, and low surface slopes provide the most effective vegetated filters. Maximizing the use of such nonstructural LID-BMPs

helps demonstrate compliance with the nonstructural stormwater management requirements of the NJDEP Stormwater Management Rules.

Vegetative filters and buffers can be created by preserving existing vegetated areas over which runoff will flow or by planting new vegetation. Vegetative filters located immediately downstream of impervious surfaces such as roadways and parking lots can achieve pollutant removal, groundwater recharge, and runoff volume reduction. Vegetated buffers adjacent to streams, creeks, and other waterways and water bodies can also help mitigate thermal runoff impacts, provide wildlife habitat, and increase site aesthetics. Further information and detailed design procedures for vegetative filters are presented in Chapter 9.

2. Minimizing Land Disturbance

Minimizing land disturbance at a development site is a nonstructural LID-BMP that can be used during all phases of a land development project. Similar to the preservation of natural areas (see *1. Vegetation and Landscaping* above), minimizing land disturbance can help reduce post-development site runoff volumes and pollutant loads and maintain existing groundwater recharge rates and other hydrologic characteristics by preserving existing site areas. However, as a strategy, minimizing land disturbance can also be applied during a project's construction and post-construction phases.

Minimum disturbance begins during the project's planning and design phases by fitting the development into the terrain, as opposed to changing the terrain to fit the development. Also known as site fingerprinting, minimal disturbance techniques are first applied during the planning and design stages to evaluate existing site characteristics and constraints. The goal of this process is to limit clearing, grading, and other land disturbance necessary for buildings, houses, roadways, parking lots, and other proposed features and facilities. Roadway and building patterns that match the existing land forms and limit the amount of required clearing and grading should be chosen.

Site-specific conditions such as slope, soil type, drainage area, and other site conditions and constraints must be considered, including the identification of effective groundwater recharge and runoff storage areas. Wherever feasible, development should be concentrated on soils with low permeability rates to minimize the increase in runoff and to retain high permeability areas for groundwater recharge. The selection of the location of the development due to the soil type can have a significant impact on the resulting increases in runoff. Existing runoff storage areas should also be preserved to help retain the site's hydrologic character. Strict adherence to a minimum land disturbance strategy during a development's planning and design stages can also be an effective way to minimize soil compaction at those sites where there is a potential for it to occur.

In addition, the identification and evaluation of site constraints such as wetlands, Karst topography, and floodplains are critical to the effective implementation of LID designs. For example, additional analysis and provisions are applicable for development in Karst areas. It is interesting to note that the New Jersey Geological Survey's recommendations for Karst areas presented below are very similar to those for low impact development:

1. Do not concentrate flows.
2. Minimize grading.
3. Build within landscape (design around existing topography).
4. Do not alter natural drainage areas.
5. Minimize the amount of imperviousness.
6. Increased structural loads at the site can contribute to ground failures.
7. Changes to existing soil profile, including cuts, fills, and excavations, should be minimized.

Additional information on development in Karst areas can be found in Appendix A-10 of the New Jersey Department of Agriculture's Soil Erosion and Sediment Control Standards or from either the State Soil Conservation Committee (SSCC) at (609) 292-5540 or the New Jersey Geological Survey (NJGS) at (609) 292-2576. Information may also be available from the local Soil Conservation District or municipal engineer.

As noted above, land disturbance can also be minimized during a project's construction and post-construction stages. For example, during a development's construction phase, construction areas, access roads, and material and equipment storage areas can be minimized and strictly regulated. In addition, lighter-weight, rubber-tired construction equipment can be used whenever possible, with their movements limited to a few repetitive routes. Construction can also be phased to minimize the site area that will be disturbed at any given time. To help ensure compliance, such practices and requirements should be included in soil erosion and sediment control plans, construction plans, and contract documents.

Following construction, limits can be placed on the expansion of homes, buildings, driveways, parking, and other disturbed areas through deed restrictions, approving resolutions, owners' agreements, and zoning ordinances. Specific portions or percentages of a parcel or lot can be designated to remain undisturbed through deed restrictions or easements. As such, it can be seen that minimizing land disturbance should not only be one of the first nonstructural LID-BMPs applied to a land development's design, but it should also be continually reapplied throughout the life of the project.

It should also be noted that, in addition to the measures described above for minimizing soil compaction, measures can be taken to remediate a soil compaction problem. If compaction should be a problem, the Standards for Soil Erosion and Sediment Control in New Jersey recommends that, prior to topsoil and seed application, the surface of all compacted areas be scarified 6 to 12 inches.

3. Impervious Area Management

Impervious areas in a watershed have been cited in studies as an indicator of stream health. Increases in watershed imperviousness have been linked in these studies to degradation of water quality, especially in areas where the impervious surface is directly connected to a water body. Increases in impervious cover in a watershed can be directly correlated to increased runoff volumes and rates as well as waterway velocities, erosion, and flooding. Impervious areas can also accumulate nonpoint source pollutants that can significantly impact waterways when washed off by runoff.

Fortunately, comprehensive management of impervious areas at a land development site can help reduce the impervious area impacts described above. This section discusses the nonstructural LID-BMPs that can reduce the volume and peak rate of runoff from impervious surfaces by limiting their total area or disconnecting them from the site's stormwater conveyance system. Reductions in impervious area translate into more surface storage, infiltration and groundwater recharge, less stormwater runoff, and reduced storm sewer construction, maintenance, and repair costs. It is important to note that all reductions in the amount and dimensions of impervious surfaces at a land development site must also recognize safety and the level of use of the impervious surfaces.

A. Streets and Sidewalks

Street Widths: Street widths are typically based on traffic density, emergency vehicle movement, and the need for roadside parking. Street widths in residential areas are specified in Subchapter 4: Streets and Parking of the Residential Site Improvement Standards at N.J.A.C. 5:21 (RSIS). In such developments, efforts should be made to utilize the minimum pavement or cartway width consistent with the Standards. Similarly, in all other development types, the widths of all streets should be evaluated to demonstrate that the proposed width is the narrowest possible consistent with safety and traffic concerns and requirements.

Street Features: The design of certain streets or portions thereof may include features or areas that can be covered with pervious material, landscaped, and/or designed to receive runoff. For example, traffic calming measures such as circles, rotaries, medians, and islands can be vegetated or landscaped. Such features reduce the amount of impervious cover and provide an opportunity to store and possibly infiltrate runoff from adjacent impervious street surfaces. When curbs are necessary to maintain traffic safety and/or meet existing regulations, street runoff may be directed to these features through curb cuts.

Sidewalks: Sidewalk requirements within residential areas are also specified in Subchapter 4 of the RSIS and are based on the street type and development intensity. Municipal regulations often dictate the requirements for sidewalks in non-residential development to provide safe pedestrian movement. Pedestrian traffic patterns considered when determining the placement of sidewalks include the presence of schools, shopping centers, recreational facilities, handicap access, and public transportation facilities. Sidewalks can be made of pervious material, such as porous pavement or concrete, or designed to provide runoff storage and infiltration in their stone base. Where impervious material is used, sidewalks can be disconnected from the drainage system, which allows some of the runoff from them to re-infiltrate in adjacent pervious areas. Additional details regarding unconnected impervious surface is presented below.

B. Parking and Driveway Areas

Similar to street widths, the size of parking areas and driveways contributes to the total amount of impervious surface at a development site. In New Jersey, parking area and driveway requirements are typically mandated by municipal regulations and, in the case of residential areas, the RSIS. In Section 4.14, the RSIS states:

Alternative parking standards... shall be accepted if the applicant demonstrates these standards better reflect local conditions. Factors affecting minimum number of parking spaces include household characteristics, availability of mass transit, urban vs. suburban location, and available off-site parking resources.

As such, the RSIS provides flexibility in selecting parking and driveway size, provided that supporting local data is available.

The RSIS further states:

When housing is included in a mixed-use development, a shared parking approach to the provision of parking shall be permitted.

From the above, it can be seen that a mix of residential and nonresidential uses at a development site can share parking areas, thereby reducing the total parking area and impervious cover. The RSIS also allows a reduction in the standard 18 foot parking space length provided that room is provided for overhang by the vehicle. The overhang area can then be vegetated to further reduce (and possibly help disconnect) impervious surfaces. Non-residential developments can use these same ideas where permitted by local regulations.

At all development sites, consideration should be given to constructing some or all driveways and parking areas from pervious paving material. This is particularly true for overflow parking areas as well as driveways (and other access roadways) that are used relatively infrequently by maintenance and emergency vehicles. See below and Chapter 9 for more information on pervious paving materials. Parking can also be located underground or beneath buildings, which can help reduce the site's overall impervious coverage. Finally, parking decks can reduce overall impervious coverage by concentrating the total required parking area into a smaller footprint.

C. Pervious Paving Materials

Pervious paving materials can be used at many site locations to replace standard impervious pavement. These locations may include parking spaces, driveways, access roadways, and sidewalks. Pervious material can include pavers (interlocking concrete blocks or bricks), porous pavement (concrete or asphalt), gravel, and reinforced lawn. While brick pavers, concrete block pavers, and gravel are themselves impervious, their use can reduce impervious areas by providing gaps between individual pieces through which runoff can reach a pervious base course and/or subsoil. Turf blocks (open cells made of concrete, plastic, or composite materials that are filled with soil and planted with grass) may also be utilized to replace traditionally paved areas. Porous concrete and porous asphalt are generally considered fully pervious and may be viable options for areas that need to be fully paved. Municipal regulations must be reviewed to determine whether the use of pervious paving materials is permissible at a development site. It may also be appropriate to discuss the use of pervious paving materials with local officials and Soil Conservation Districts.

In selecting the type of pervious paving material to be used at a development site, consideration must be given to anticipated character and intensity of use of the material's surface. This will include the type, weight and size of vehicle, and the traffic rate and frequency. For example, due to their non-monolithic character, pavers, turf blocks, and gravel can achieve significant infiltration but may not be able to withstand regular traffic loads. As such, these materials may be more appropriate for overflow parking areas and emergency or maintenance access roads. Since its monolithic character is similar to standard impervious paving, porous pavement will have more general use, provided that adequate subsurface drainage is available. In all cases, consideration must be given to the effects of snow plowing and other maintenance activities. Additional information regarding pervious paving is available in Chapter 9.

D. Unconnected Impervious Areas

Unconnected impervious areas are impervious surfaces that are not directly connected to a site's drainage system. Instead, runoff from an unconnected impervious area is allowed to sheet flow from the impervious area across a downstream pervious surface, where it has the opportunity to re-infiltrate into the soil, thereby reducing the total runoff volume. An unconnected impervious surface may be on-grade (e.g., a parking lot) or above-grade (e.g., a roof). While impervious area disconnection is most applicable to low density development where pervious open space is readily available to accept impervious area runoff, opportunities to utilize unconnected impervious area can usually be found even at highly impervious development sites.

In most circumstances, impervious areas can be considered unconnected under the following conditions:

1. All runoff from the unconnected impervious area must be sheet flow.
2. Upon entering the downstream pervious area, all runoff must remain as sheet flow.
3. Flow from the impervious surface must enter the downstream pervious area as sheet flow or, in the case of roofs, from downspouts equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.
4. All discharges onto the downstream pervious surfaces must be stable and nonerosive.
5. The shape, slope, and vegetated cover in the downstream pervious area must be sufficient to maintain sheet flow throughout its length. Maximum slope of the downstream pervious area is 8 percent.
6. The maximum roof area that can be drained by a single downspout is 600 square feet.

Methods to compute the resultant runoff volumes and peak runoff rates from unconnected impervious areas are presented in Chapter 5 of this manual. This includes parameters and procedures for determining the effective size of the downstream pervious area that receives the runoff from an unconnected impervious area.

Curb requirements included in the RSIS and many municipal regulations are often cited as a limiting factor in the use of unconnected impervious areas. However, residential curb requirements in the current RSIS provide flexibility to limit curbing, and also allow the use of curb cuts to disconnect impervious areas. The RSIS states in Section 4.3 (d):

Curb requirements may be waived by the appropriate municipal approving agency, and shoulders and/or drainage swales used when it can be shown that: shoulders are required by CAFRA; soil and/or topography make the use of shoulders and/or drainage swales preferable; and/or the community desires to preserve its rural character by using shoulders and/or drainage swales instead of curbs.

In addition, the top of the curbing may be set level with the impervious and downstream pervious surfaces to allow sheet flow from one to the other. Similar opportunities to use level curbs and/or curb cuts may also exist at nonresidential developments.

It is important to note that, in designing and utilizing unconnected impervious areas, consideration must be given, on a case-by-case basis, to sensitive or limiting geographic conditions such as Karst topography and rough, irregular topography.

E. Vegetated Roofs

Vegetated roofs, also known as green roofs, are an innovative way to reduce impervious surfaces at development sites in New Jersey. They have been used successfully in several European countries, including Germany. A vegetated or green roof consists of a lightweight vegetated planting bed that is installed on a new or existing roof. This enables the roof to retain precipitation on and within the planting bed and on the surface of the vegetation. This stored water is later released through evapotranspiration, thereby reducing the volume of runoff from the roof. The exact amount of rainfall storage (and runoff reduction) will depend upon the depth and porosity of the planting bed and, to a lesser degree, the type and density of vegetation.

Vegetated roofs can be implemented using specialized commercial products. A common arrangement consists of an impervious synthetic underdrain system that allows drainage of water from the roof surface (known as a geomembrane) and a 1 to 6-inch thick layer of lightweight planting media. The type of vegetation to be used should be based on access and maintenance requirements and secondary uses of specific roof areas. Except for periodic fertilization and watering, a meadow-like planting of perennial plants can require minimal maintenance.

When designing new systems or converting existing roofs to green roofs, adequate capacity and easy access to gutters, underdrains, downspouts, and other components of the roof's drainage system must be provided. Clogging of underdrains must be prevented through a combination of sound design and regular inspection and maintenance. Overflows must also be provided to address drainage system malfunctions and rainfalls that exceed the system's design storm. Green roofs will be most effective during the spring and summer growing season, with somewhat reduced effectiveness during the late fall and winter months. Depending on the type of vegetation selected and the amount of rainfall, there may be a need for occasional watering and perhaps fertilization of the vegetative cover. Therefore, special provisions must be provided to readily enable such activities.

The structural integrity of the roof and the building must support any loading resulting from the vegetation, soil, and rainfall stored in the rooftop. In general, the slope (horizontal to vertical) of the roof can vary between 12:1 and 4:1. Steeper roofs will usually require erosion protection to hold the planting media in place at least until the plants become established. The roof slope must not exceed 1:1. Relatively flat roofs require an underdrain layer, while steeper roofs can drain by gravity.

4. Time of Concentration Modifications

Time of concentration (T_c) is technically defined as “the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed.”¹ Stated more simply, it represents the time needed to drain runoff from an area. Changes in peak flow result from changes in T_c from drainage areas, with longer times yielding smaller peak runoff rates and shorter times causing greater ones. Site factors that affect a drainage area’s time of concentration include flow length, flow regime, surface roughness, channel shape, and slope.² Typically, land development modifies most if not all of these factors in ways that cause the time of concentration of a drainage area to be shorter (and, therefore the peak runoff rates to be greater) after development than prior to development.

However, during site design, it may be possible to avoid or minimize this decrease in time of concentration by controlling the various site factors that affect it. Considerations for three factors are presented below. In reviewing these considerations, it must be remembered that, although the time of concentration of a drainage area is computed for a specific flow path (as determined by the technical definition above), it is actually a representative time for an entire drainage area. As such, the modifications discussed below that pertain to sheet flow from a drainage area to a more defined conveyance system (such as a channel or storm sewer) must not only be applied along the specific T_c route, but throughout the entire area where the sheet flow is occurring.

For certain areas in New Jersey, such as those with Karst topography, the flat topography of the Pinelands and shore areas, and the rough terrain of the northwest, the development of a time of concentration may be difficult. In such cases, the designer should confer with the applicable review agencies in order to develop a representative T_c route and time.

A. Surface Roughness Changes

Based upon hydraulic theory, surface roughness coefficients used in sheet flow computations are based on the land cover of a drainage area, with areas of dense vegetation having generally higher coefficients (and longer times of concentration) than smoother surfaces such as paved or grassed areas. This surface roughness can also vary with season and degree of maintenance, particularly for turf grass areas. Therefore, site designers should preserve existing native vegetation or use native plants to restore disturbed areas (as discussed above in *1. Vegetation and Landscaping*) in order to increase surface roughness and time of concentration, and consequently reduce the peak flows from a drainage area.

B. Slope Reduction

As noted above, ground slope is another important factor in determining a drainage area’s time of concentration and peak discharge. Reducing slopes in graded areas can help minimize T_c reductions and peak flow increases. In addition, terraces and reduced slope channels can be constructed on a sloping area to provide additional travel time. Terraces can also be used to redirect runoff to flow along rather than across the slope, decreasing the slope and increasing the flow length and, subsequently, the time of concentration. Care should also be taken to ensure that the grading of vegetated areas is sufficient to allow for positive drainage as required by local or state regulations, particularly adjacent to buildings and other structures.

¹ USDA Soil Conservation Service Technical Release 55, June 1986, Urban Hydrology for Small Watersheds.

² Ibid.

C. Vegetated Conveyance

The use of vegetated conveyance measures such as channels and swales can increase the surface roughness along the T_c flow path and increase the overall T_c . Grade stabilization structures can also be added to further decrease the flow velocity. In addition, vegetated channels can provide opportunities for runoff treatment, runoff infiltration, and groundwater discharge. Such measures can replace conventional storm sewer systems in small drainage areas. Site specific conditions such as slope, soil type, drainage area, and site constraints must be considered in the design of a vegetated channel or swale. Additional requirements are presented in the Standards for Soil Erosion and Sediment Control in New Jersey. The local Soil Conservation District will review the project to ensure stability.

In designing vegetated conveyance measures, care should be taken to protect transitions to and from culverts from erosion caused by flow acceleration and turbulence. In addition, vegetated channels and swales should be constructed only in areas with sufficient sunlight to adequately maintain vegetation. The channels must also be able to drain and dry out between storm events. As an alternative to grasses, the channel could be planted with ground covers that tolerate frequent short-duration flooding. The vegetation must be tolerant of the hydrologic regime associated with the channel.

In the design of any site features to control or modify time of concentration, it should be noted that the effectiveness of the design may vary with runoff rate and, therefore, storm frequency. As a result, modifications to such factors as slope or surface roughness may have a significant effect on the time of concentration for a one-year storm event, but little or no effect on a larger 10 or 100-year event. Therefore, it may be necessary (and even prudent) to vary T_c with storm frequency, utilizing the longer one for the frequent events associated with stormwater quality and the shorter (and more conservative) one for the more extreme erosion and flood control storms. Care should also be taken when analyzing a time of concentration to ensure that the watershed it represents is relatively homogenous. Otherwise, the drainage area may need to be divided into subareas with a separate T_c computed for each.

Structural Stormwater Management Measures

In addition to the nonstructural LID-BMPs presented in the previous section, structural stormwater management measures can also be used to implement low impact development. Known as structural LID-BMPs, these structural measures are identified as low impact BMPs by storing, infiltrating, and/or treating runoff close to its source. Unlike typical structural BMPs that are centrally located along a site's drainage system, structural LID-BMPs are normally dispersed throughout a development site and, like the nonstructural LID measures discussed above, provide ways to more closely mimic the site's predeveloped hydrology than standard structural BMPs.

As structural facilities, however, the configuration, operation, and maintenance of structural LID-BMPs are similar to standard structural BMPs, although their location closer to the runoff source typically allows them to be smaller in size. An example of this relationship is the use of bioretention basins as structural LID-BMPs in a residential subdivision. Also known as raingardens, they are typically located on each lot in the subdivision and, as such, each receives considerably less runoff than would a single, centralized bioretention basin. Nevertheless, similar to the centralized bioretention basin, each basin would be designed and constructed in accordance with the technical standards presented in Chapter 9. Designers should take care to ensure that sufficient setbacks are provided to protect adjacent structures from impacts due to the anticipated functioning of LID-BMPs.

The integration of bioretention basins and other structural BMPs throughout a development site can be viewed as applying low impact development techniques. Many standard BMPs can be done at an LID scale. Drywells, infiltration systems, bioretention basins, and both surface and subsurface detention basins can all be downsized to address stormwater runoff close to its source, as opposed to a centralized location at the end of a stormwater collection and drainage system. Detailed design, construction, and maintenance information on various structural BMPs is presented in Chapter 9.

Preventative Source Controls

The most effective way to address water quality concerns is by preventing pollutants from being part of stormwater runoff. Pollution prevention techniques should be incorporated into site designs, especially at commercial and light industrial sites, to minimize the potential impact those activities may have on stormwater runoff quality. Preventative source controls, while more limited, can also be applied in residential development, particularly in preventing floatables (trash and debris) from entering storm sewer drainage systems.

Preventative source controls can prevent the accumulation of trash and debris in drainage systems by providing trash receptacles at appropriate locations throughout the site. The benefits are realized only if regular trash collection is provided; this should be included as part of the site maintenance plan. The installation of litter fences, especially at commercial properties, to prevent the blowing of litter off the site is another measure that addresses the accumulation of trash and debris. At industrial/commercial sites, maintenance plans should include regular sweeping or manual collection of litter. In residential developments, the inclusion of “pet waste stations” in the site design of dense housing developments such as apartment, townhouse and condominium communities prevents pollutants from entering the stormwater system. Pet waste stations should include bags for picking up pet waste and containers for pet waste disposal. Providing these stations will increase the likelihood that pet waste is properly disposed and prevent it from being washed into streams as part of stormwater runoff.

Site design features can also prevent the discharge of trash and debris into receiving streams. Storm drain inlets, trash racks, or structural BMPs are types of features that prevent the discharge of trash and debris. The New Jersey Pollutant Discharge Elimination System stormwater general permits issued under the Municipal Stormwater Regulation Program provide information on storm drain inlets that are designed specifically to prevent the discharge of large trash and debris from drainage systems by reducing the size of each individual clear space in both the grate and curb opening. Where allowed and consistent with the design standard, alternative devices may be substituted for these storm drain inlets.

Some site design features help to prevent or contain spills and other harmful accumulations of pollutants at industrial or commercial developments. These include roofs, overhangs, knee walls, berms, secondary containment, stormwater diversion devices, oil/grit separators and other manufactured treatment devices, and indoor storage. Specifically, berms and secondary containment can contain spills of fuels or other chemicals, and roofs and walls can prevent or minimize exposure of stormwater to activities and materials such as fueling and maintenance, trash, waste motor oil, storage or handling of landscape and garden chemicals (including fertilizers and pesticides) at retail stores, and storage or handling of raw materials, intermediate products, final products, and by-products at warehouses or manufacturing plants. Stormwater diversion devices, such as curbing and berms, can divert stormwater away from areas where it may come into contact with materials or activities that could affect stormwater quality. Oil/grit separators and other manufactured treatment devices may contain certain spills and treat stormwater that has come into contact with spills or residual material from spills. Also, the inclusion in the site design of adequate indoor storage of raw materials, intermediate products, final products, and by-products at commercial and industrial sites is the best method for preventing potential stormwater quality issues.

Stormwater as a Resource

Stormwater runoff from precipitation is often viewed as a nuisance. However, an increase in stormwater runoff is an indicator of reduced infiltration and recharge to groundwater. As such, this negative view of stormwater runoff must be corrected to more accurately consider stormwater as a resource vital to achieving more sustainable development.

For example, stormwater runoff from roofs can be captured for future re-use using a variety of collection and storage devices. These systems can be installed above or below ground. Above ground systems could be simple rain barrels that overflow onto a splash pad. Underground systems may be concrete structures requiring a pump to empty them or, if the topography allows it, they may drain by gravity. The size of this BMP depends on the contributing roof area. In commercial or high-density residential applications, roof water cisterns can be incorporated into landscaping features such as water fountains and ponds. Where space permits, underground cisterns can discharge to an infiltration trench.

It is important to note that all collection and storage devices must be emptied between storm events in order to be considered effective in reducing site runoff volumes. In addition, the total system storage volume must be evaluated to determine its effectiveness as a runoff volume control measure. Nevertheless, re-use of the collected stormwater in place of potable water from an onsite well or public water supply will help minimize the site's over environmental impacts, reduce site operating costs, and help achieve a more sustainable environment.

Additional Considerations

As described above, low impact development typically relies on an array of nonstructural and relatively small structural BMPs distributed throughout a land development site to manage stormwater runoff quantity and quality. This distributed approach to stormwater management contrasts with the more traditional use of centralized stormwater facilities in New Jersey. However, as discussed briefly at the beginning of this chapter, this distributed approach means that the responsibility for successful operation and maintenance of the various LID-BMPs will not be centrally located at a municipality or other government entity. Instead, such responsibility will be distributed over a variety of property owners with varying interests, knowledge, abilities, and resources. As such, it is vital to have public understanding of and support for the various LID-BMPs that a municipality authorizes for use in its stormwater management program and land development regulations. Such understanding and support must include both an appreciation for the necessary role that the LID-BMPs play in meeting a development site's stormwater obligations and a strong, enforceable commitment to preserve and maintain them.

This is particularly true for nonstructural LID-BMPs, which may rely on such techniques as preserving existing or planting new vegetation, minimizing building footprints, and limiting lot impervious cover and/or disturbance limits to effectively manage stormwater runoff and prevent downstream environmental and property damage. The Stormwater Rule at Section 5.3(c) requires the deed restriction of LID-BMPs since such practices may not be readily recognized by property owners as stormwater management measures or facilities, and they may be more prone to neglect, abandonment, or removal than centralized structural BMPs unless the property owners fully recognize, understand, and support their use.

Similar problems may also arise with structural LID-BMPs which, due to their smaller size and their location on individual lots much closer to homes than larger, centralized facilities, may be overlooked as vital stormwater management measures and similarly neglected or abandoned. In the worst case, a resident or property owner may remove a vital structural LID-BMP located on their property. Such action may occur due to an alternative need for the land (e.g., house addition, driveway expansion, storage shed), adverse aesthetic impacts, or excessive maintenance demands. Regardless of the reasons, a municipality may find it extremely difficult to have the eliminated LID-BMP either restored or replaced by a centralized facility.

Therefore, it is vital that each municipality critically evaluate the range of available nonstructural and structural LID-BMPs presented in this manual and elsewhere and authorize the use of only those that they can rely on to be properly operated, maintained, and preserved by their residents, property owners, and municipal employees. Failure to achieve such acceptance, operation, and maintenance can lead to flooding, erosion, and runoff pollution; damage to downstream waterways and property; and threats to public safety.

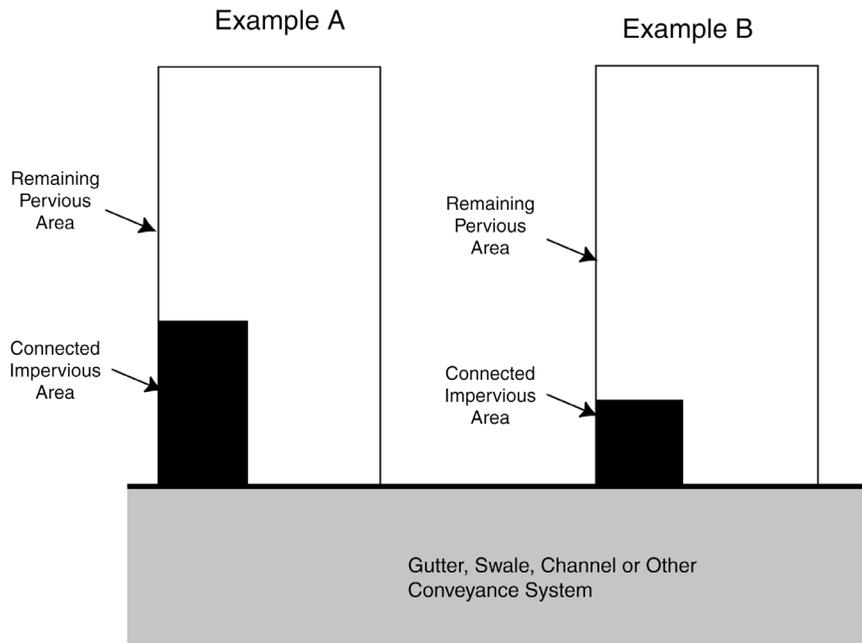
To assist in this evaluation, physical details and operation and maintenance requirements for a range of structural BMPs are presented in Chapter 9.

When evaluating LID-BMPs for authorization and incorporation into their land development ordinances and standards (as required by the NJDEP Stormwater Management Rules), a municipality should consider the following:

1. Permitting the use of certain LID-BMPs to manage the runoff from small, frequent storm events (such as those required by the NJDEP Stormwater Management Rules for groundwater recharge and stormwater quality), but prohibiting their consideration when addressing erosion and flood control requirements that typically involve larger, less frequent but more hazardous events. For example, a municipality may allow a site designer to use rain barrels and/or small, on-lot infiltration basins (also known as raingardens) to meet groundwater recharge and stormwater quality requirements, but may also require that such measures be ignored when meeting erosion and flood control standards.
2. Requiring deed restrictions or adopting ordinances that prohibit the alteration or elimination of on-lot LID-BMPs approved for use at a land development and officially identified as such. Such restrictions and ordinances should clearly define the right of the municipality to restore such LID-BMPs and the means by which it will be accomplished and financed.
3. Requiring deed restrictions or adopting ordinances that require land owners to properly maintain structural LID-BMPs located on their properties.
4. Requiring signage of LID-BMPs to indicate their function and use.
5. Preparing leaflets, brochures, and/or manuals for property owners on the function and importance of LID-BMPs and their maintenance and preservation. Similar efforts targeting such activities as proper septic system operation, recycling, lawn fertilization, and pet waste disposal have proven successful in many municipalities. Soil test kits and information regarding lawn fertilization are available for homeowners from the Rutgers Cooperative Extension.

Low Impact Development Example Calculations

Figure 2-1: Schematic of Lot with Connected Impervious Areas



Reduction of Runoff Volumes Due to Reduced Impervious Surfaces

Note: The computations were done by evaluating the runoff from the pervious and the impervious areas separately, and summing the volumes.

Example A

Given: A 32670 sf lot with 27470 sf lawn, HSG "B", CN = 61, 5200 sf impervious surface, CN = 98.

No impervious cover is disconnected

$P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inches

From the NRCS Runoff Equation, the following runoff volumes are generated:

2-year = 2444 cf
10-year = 5567 cf
100-year = 10175 cf

Example B

Given: A 32670 sf lot with 29870 sf lawn, HSG "B", CN = 61, 2800 sf impervious surface, CN = 98.

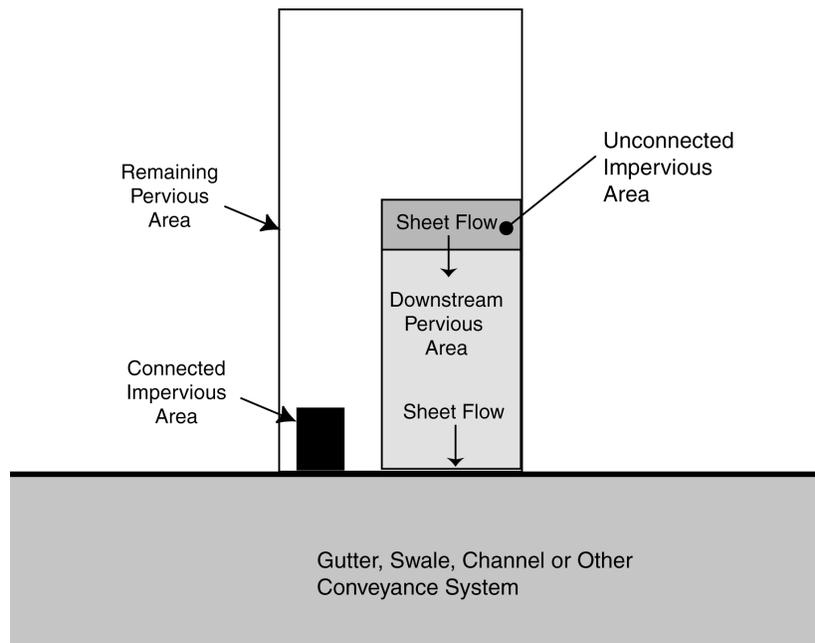
No impervious cover is disconnected

$P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inches

From the NRCS Runoff Equation, the following runoff volumes are generated:

2-year = 1927 cf
10-year = 4872 cf
100-year = 9336 cf

Figure 2-2: Schematic of Lot with Connected and Unconnected Impervious Areas



Changes in Runoff Volumes Due to Disconnection of Impervious Surfaces

Example C

Given: A 32670 sf lot with 29870 sf lawn, HSG "B", CN = 61, 2800 sf impervious surface of total impervious area, CN = 98.
2000 sf of impervious area discharges to 8900 sf of lawn, and 800 sf impervious area is directly connected
 $P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inches

**NRCS Method:

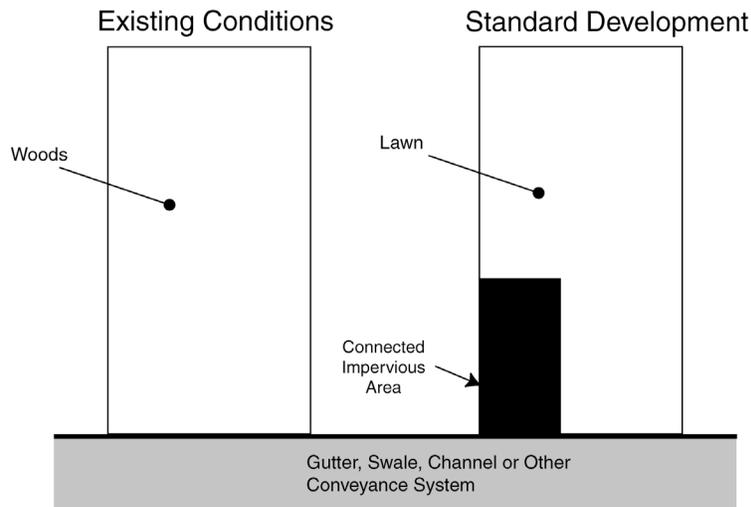
2-year = 1625 cf
10-year = 4515 cf
100-year = 8947 cf

Two-Step Method (discussed in Chapter 5):

2-year = 1650 cf
10-year = 4580 cf
100-year = 9055 cf

**Note: The computations were done by evaluating the runoff from the pervious, impervious, and unconnected impervious areas separately, and summing the volumes. The equation for Figure 2-4, shown in Appendix F of the USDA Urban Hydrology for Small Watersheds, was used for the volume of unconnected impervious areas.

Figure 2-3: Schematic of Existing Lot and Standard Development Lot



Comparison of Changes in Runoff Due to Low Impact Development Techniques

Predeveloped Condition

0.75 acre lot
 20,650 sf woods, HSG “B”
 12,020 sf woods, HSG “C”
 $P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inch

$T_c = 0.52$ hours
 125 lf sheet flow, 1.3% slope, $n = 0.40$
 135 lf shallow concentrated flow, 1.4% slope, unpaved

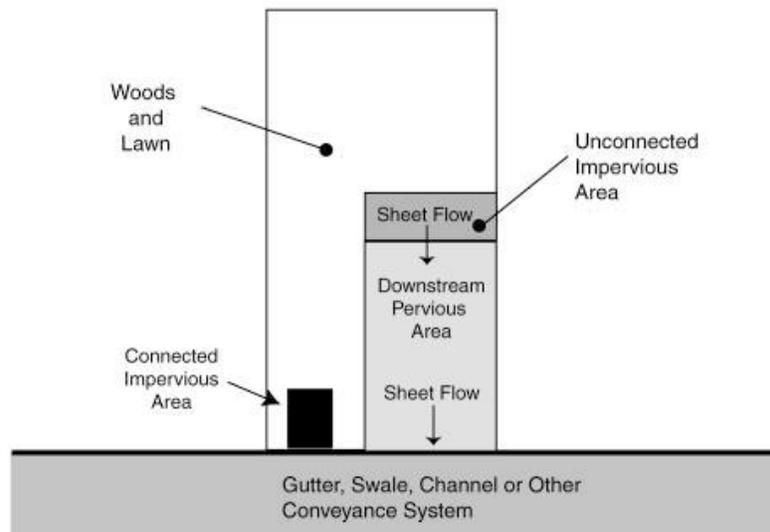
Postdeveloped Condition (Standard Development Lot)

0.75 acre lot
 5200 sf of total impervious area, directly connected, $T_c = 0.1$ hours
 $P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inch

Vegetated Area, $T_c = 0.32$ hours
 125 lf sheet flow, 1.6% slope, $n = 0.24$
 135 lf shallow conc flow, 1.4% slope, unpaved

Area (sf)	Land Use	HSG
17214	Lawn (good condition)	B
10256	Lawn (good condition)	C
3436	Impervious (directly connected)	B
1764	Impervious (directly connected)	C

Figure 2-4: Schematic of Lot With LID Techniques



Postdeveloped Condition (With LID Techniques)

0.75 acre lot, 2800 sf of total impervious area
 800 sf of impervious area, directly connected, $T_c = 0.1$ hours
 2000 sf of impervious area, unconnected, discharging to 8906 sf of lawn
 $P_2 = 3.3$ inches, $P_{10} = 5.2$ inches, and $P_{100} = 7.5$ inch

Nonstructural stormwater management strategies used: minimized land disturbance; minimized compaction; maximized the protection of vegetation; minimized the decrease in post-development time of concentration through retaining existing wooded area; and minimized and disconnected impervious cover.

Vegetated Area, $T_c = 0.52$ hours

125 lf sheet flow, 1.3% slope, $n = 0.40$

135 lf shallow conc flow, 2.1% slope, unpaved

Area (sf)	Land Use	HSG
17524	Woods (good condition)	B
1564	Lawn (good condition)	B
1876	Lawn (good condition)	C

Unconnected Impervious Area, $T_c = 0.23$ hours

100 lf sheet flow, 2.1% slope, $n = 0.24$

Note: The time of concentration was developed from the receiving pervious area alone.

Distribution of Pervious Areas Receiving Unconnected Impervious Area Runoff		
Area (sf)	Land Use	HSG
1562	Lawn (good condition)	B
7344	Lawn (good condition)	C

Peak Flow Rates and Volumes

	Existing Conditions	Proposed Conditions (Standard Development)	Proposed Conditions (Nonstructural Stormwater Management Strategies)	
			Two-Step Method	NRCS Method
2-year	0.15 cfs	0.48 cfs	0.29 cfs	0.27 cfs
	0.030 ac-ft	0.067 ac-ft	0.043 ac-ft	0.041 ac-ft
10-year	0.62 cfs	1.18 cfs	.81 cfs	.78 cfs
	0.093 ac-ft	0.150 ac-ft	0.116 ac-ft	0.109 ac-ft
100-year	1.35 cfs	2.19 cfs	1.61 cfs	1.58 cfs
	0.192 ac-ft	0.261 ac-ft	0.214 ac-ft	0.211 ac-ft

References

- Johnston, J. and Newton, J. 1992. *Building Green: A Guide for Using Plants on Roofs, Walls and Pavements*. London: The London Ecology Unit.
- Lieseche, H., et al. 1989. *Fundamentals of Roof-Greening (Grundlagen der Dachbegrünung)*. Platzer Verlag, Berlin, Germany. (Available in German language only).
- New Jersey Department of Agriculture. 1999. *Standards for Soil Erosion and Sediment Control in New Jersey*. New Jersey Department of Agriculture, Trenton, NJ.
- Osmundson, T. H. 1999. *Roof Gardens: History, Design, and Construction*, W.W. Norton & Co.
- Pennsylvania Association of Conservation Districts. 1998. *Pennsylvania Handbook for Best Management Practices in Urban Areas*. Harrisburg, Pennsylvania.
- Prince George's County. 2001. *Bioretention Manual*, Department of Environmental Resources, Prince George's County, Maryland.
- Schueler, T. R. 2000. "Is Rooftop Runoff Really Clean?" Article 8 in "The Practice of Watershed Protection" Published by Center for Watershed Protection, Ellicott City, Maryland. Original Source: Technical Note 25 from *Watershed Protection Techniques*, 1(2): 84-85.
- Tourbier, J. T. and R. Westmacott. 1981. *Water Resources Protection Technology—A Handbook to Protect Water Resources in Urban Development*. Washington, D.C.: The Urban Land Institute.
- Tourbier, J. T. and R. Westmacott. 1974. *Water Resources Protection Measures in Land Development*. Final Report prepared for the U.S. Department of the Interior, Water Resources Center, University of Delaware.
- University of Maryland. 1991. *Landscape Design to Reduce Surface Water Pollution in Residential Areas*, Cooperative Extension Services, University of Maryland, College Park, Maryland.
- U.S. Department of Agriculture. 1986. *Urban Hydrology for Small Watersheds*. Technical Release Number 55 (TR-55). National Technical Information Service.
- Velazquez, L. 2000. "Greenroofs.com" <http://www.greenroofs.com/>.
- Washington State Department of Ecology. 2000. *Stormwater Management for Western Washington, Volume V, Runoff Treatment BMPs*, Publication 99-15, Final Draft.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 3

Regional and Municipal Stormwater Management Plans

Regional Stormwater Management Plans

Regional stormwater management planning is a water resource management strategy that identifies and develops solutions to problems that can be managed most effectively on a regional basis. The product of this planning process, the regional stormwater management plan (RSWMP), spans the boundaries of individual properties, neighborhoods, municipalities, and even county borders. A plan may address an existing water quantity issue, such as localized flooding; an existing water quality issue, such as excess pollutant loading; or issues of water quantity and quality that may be generated by future development. Regional stormwater planning creates a combination of regulations and actions tailored to the specific needs of a drainage area, but it does not reduce environmental protection. Rather, it allows regulations more flexibility to match the concerns, conditions, and features of regions that are connected by a common drainage area.

Well-designed RSWMPs share common elements. First, they are collaborative. Adoption and implementation of an RSWMP depends on the cooperation of county and municipal governing bodies, regulatory agencies, and environmental organizations. Any plan designed without their active involvement and consent has dim prospects for adoption. Second, they focus on identifying and solving specific problems. Shared regional problems, such as recurring flooding, unswimmable lakes, reduced stream flows, or contaminated public water supplies, can drive the collaboration needed to trigger and sustain the planning and adoption process. Specific problems also lend themselves to specific, measurable, and quantifiable implementation steps. For example, an RSWMP can spell out the specific measures required to reduce pollutant loads determined by the TMDL (total maximum daily load) process. Third, an RSWMP's recommendations are based on sound engineering and science geared to local land use conditions. All measures included in an RSWMP must be supported by a rationale that includes a feasibility analysis for achieving specific objectives as well as a monitoring plan to gauge long-run effectiveness of each measure. Plans must be reviewed every five years at a minimum. Fourth and finally, RSWMPs include a strong emphasis on maintenance and monitoring to ensure long-term functioning of the structures, measures, and programs recommended by the plan.

Regional stormwater management planning represents a fundamental shift in thinking – and execution. Traditionally, stormwater has been planned for and managed on a site-by-site basis, with the combined effect of thousands of individual stormwater management decisions in one watershed creating unintended consequences. For example, a detention or retention basin may make perfect sense to manage stormwater for an individual property. Typically, these basins were designed to ensure that peak runoff rates from a site did not increase after the property was developed. However, when hundreds of such basins simultaneously retain and then release stormwater in a regional drainage area, they can actually increase flooding and downstream erosion by extending peak runoff rates and increasing non-peak flows. As development increase in a drainage area, this site-by-site planning failed to account for the increased volume of runoff caused by regional increases in development. To address these increased volumes, recent regulations, including the Stormwater Management Rules, require stormwater management plans to reduce peak flows leaving a site. The regulations are based on analyses that demonstrate how to prevent increases in the flows that cause both flooding and erosion. However, this statewide method for addressing flooding and erosion may not be the optimum solution for managing runoff for a specific drainage area. For example, an RSWMP may recommend longer detention times at the top of a watershed to release water more slowly into local streams, and the plan may call for reduced detention times in more urbanized sections of the watershed where storage space is limited.

RSWMPs optimize flexible use of stormwater management measures by providing the authority to create new, customized regulatory requirements and by setting priorities for actions that address the specific stormwater quality, quantity, and recharge objectives within the planning area. Although performance standards can be changed from those proposed in the Stormwater Management Rules, RSWMPs must avoid adverse impacts downstream of the planning area. Regional planning also creates more options for groundwater recharge. Local topography, geology, and soil conditions that restrict infiltration may present daunting design challenges for some sites and municipalities, while well-suited recharge sites may lie just up- or downstream. In each case, better solutions become available with regional planning.

Sizing an RSWMP

Determining the size of a drainage area is one of the first technical challenges in creating an RSWMP. Regional stormwater management is fundamentally a problem-centered planning process, so the size of an RSWMP drainage area may depend on the nature and location of previously identified local concerns such as water quality impairment, erosion damage, reduced stream flows, sedimentation, inadequate groundwater recharge, or flooding. RSWMPs are created to address existing problems or to anticipate and avoid future ones. Local interest groups may already have specific concerns that can be addressed with a regional plan. TMDL implementation plans may identify regional stormwater management plans as a long-term management measure to address impairment for a specific stream segment.

A build-out analysis may identify additional problems during the assessment portion of regional plan development. A regional plan developed for the Jackson Brook in Morris County, for example, was driven initially by flooding concerns, but it also proposes improvements to reduce pollutant loads projected under full development conditions. A regional plan proposed for the Mulhockaway Creek seeks to anticipate and address concerns about development in an environmentally sensitive area of the South Branch of the Raritan River. A plan proposed for the Cedar Grove Brook in Franklin Township is targeting water quality issues in an urbanized area just upstream from water supply intakes.

Available funding is a key variable in determining the size of a regional area for a plan. Budgets for developing RSWMPs typically exceed \$100,000 because they often require extensive collection and complex analysis of field data. Those costs tend to limit the size of the drainage area to be studied, and the regional plans completed or proposed in New Jersey tend to fall between 5 and 20 square miles. The budget for a

12-square-mile drainage area around the Mulhockaway Creek drainage area, for example, is projected at \$300,000. The budget to develop the plan for the 5-square-mile drainage area around Cedar Grove Creek was \$200,000. The cost of implementing an RSWMP, of course, depends on its findings and recommendations. If writing a plan can easily run into six figures, implementing one can easily exceed \$1 million if construction of large stormwater management structures is called for in the plan. These costs, however, are dependent on the goals and objectives of the plan and the specific conditions of the area; therefore, costs can vary significantly between regional stormwater management plans.

In New Jersey, with its history of municipal autonomy known as “home rule,” smaller drainage areas tend to be more politically feasible. Regional stormwater planning requires municipalities to align their zoning and development standards with the plan, so drainage areas that involve three or four neighboring municipalities with a common concern may have a realistic chance of aligning development standards to solve their shared problem. That possibility would likely diminish dramatically if the regional plan involves tens of municipalities lacking a common, immediate problem.

Beginning the Process

By law and by definition, the development of a regional stormwater management plan is a participatory process. In fact, N.J.A.C. 7:8-3, the regulations authorizing optional regional plans require the creation of a broadly representative regional planning committee as the first step in the process. That committee then designates a lead planning agency to marshal the technical and administrative resources required to develop and implement a regional plan.

From a technical standpoint, plan development begins with characterizing and assessing the drainage area by gathering and reviewing all relevant water quality and quantity information currently available. This requires scouring for all available data from sources including:

- state and Federal Emergency Management Agency (FEMA) floodplain maps;
- hydraulic analysis and stream cross section data from stream encroachment permits;
- topographic data from aerial photos with two-foot contours;
- water quality data from New Jersey Pollution Discharge Elimination System (NJPDES) permits or intake waters from local water treatment facilities; and
- monitoring data from the U.S. Geological Survey, the Environmental Protection Agency’s STORET database, the NJDEP, local health departments, environmental commissions, or watershed associations.

In New Jersey, local Soil Conservation Districts are a valuable source of field observations on streambanks, erosion, and scouring that can be collected only from walking along stream corridors. Additional information regarding local conditions may be available from the Division of Watershed Management and local environmental organizations. Recent watershed characterization studies, if available, also provide data to focus planning efforts on water quality issues.

If a watershed characterization study is not available, consider performing a relatively quick and inexpensive Geographic Information Systems (GIS) analysis that matches water supply sources with reported water quality degradations and potential pollutant sources.

The full range of steps and requirements for creating, implementing, and adopting an RSWMP are included in N.J.A.C. 7:8-3. A summary of those requirements is outlined in this chapter, including:

- a written statement from each public entity on the committee confirming the authority of each to develop and implement a stormwater management plan;
- a discussion of both the majority and minority positions, if portions of the plan do not represent a consensus of the committee;

- characterization and evaluation of the planning committee's drainage area;
- specific objectives for water quality, groundwater recharge, and water quantity for the planning committee's drainage area;
- specific performance standards for water quality, groundwater recharge, and water quantity for the committee's planning area; and
- stormwater management measures selected by the planning committee and an explanation of why they were chosen.

Steps to Create, Implement and Adopt an RSWMP

Planning the RSWMP Process

Because an RSWMP is both a technical planning procedure and a regulatory process, it requires active participation from organizations that would likely be affected by the plan. In fact, the first step in the RSWMP process is to create a regional stormwater management planning committee and select a lead planning agency for the express purpose of developing a regional plan. The committee is charged with soliciting information from the following interested groups and organizations:

- government agencies at all levels, including Soil Conservation Districts;
- local and regional environmental groups and organizations including lake associations, watershed associations, and environmental commissions;
- water supply and wastewater treatment utilities, authorities, and agencies, and watershed management planning agencies; and
- residents in the drainage area.

The planning committee must designate a lead planning agency to serve as the primary contact for the committee. The Lead Agency must submit a request for the recognition of the regional stormwater plan committee to the NJDEP. This request must include a draft work plan, schedule of activities, and the information used to invite organizations to participate in the planning committee. The NJDEP has 45 days to approve or deny the request or ask for more information.

Data Gathering and Priority Setting

Data gathering and priority setting can be the most expensive steps in the process because they often require time-intensive collection of field data on variables such as stream elevations, erosion hot spots, and water quality. To minimize the cost of gathering this data, the NJDEP encourages planners to make maximum use of existing information, including information on the department's GIS web site (www.state.nj.us/dep/gis) or developed through the watershed management process. This task is ideally suited for analysis and display on Geographic Information Systems, and all maps developed must meet New Jersey's digital data standards in N.J.A.C. 7:1D. The following items should be included in the assessment unless they are not pertinent to a specific analysis.

Maps

The maps must first clearly delineate the drainage area boundaries, showing both existing and projected land uses assuming full development under current zoning. The following layers of information should be included: soils, topography, flood hazard areas, well protection, and groundwater recharge areas. All water bodies designated as water quality-limited surface water as well as environmentally sensitive areas or special classifications should be identified, including river areas designated under the New Jersey Wild and Scenic

Rivers Act or the Federal Wild and Scenic Rivers Act. These maps must identify stormwater management structures, surface water intakes, and public water supply reservoirs in addition to features that are outside the regional planning areas but discharge or flow into the drainage area.

Key Stormwater Management Features

The assessment must include an inventory of all key stormwater management features, including slopes, swales, outfall structures, culverts, and impoundment areas pertinent to stormwater management and required for analyzing the drainage area. Often this data can be gathered only by physically walking stream corridors to record features such as stream widths, streambank conditions, pollutant sources, eroded areas, and other relevant data. This data collection requires trained eyes in the field and often accounts for a substantial portion of the cost of developing an RSWMP.

Modeling and Analysis

Analysis of the drainage area or a water quality, groundwater recharge and water quantity hydrologic and hydraulic model may need to be performed if new performance standards are being proposed. This analysis is critical to identifying the current or potential concerns that drive the entire plan. The analysis must include existing and projected land uses assuming full development under current zoning.

Relevant Current Regulations

The assessment must identify and evaluate existing municipal, county, state, federal, and other regulations related to stormwater management, groundwater recharge, and water quality and quantity, including programs to develop total maximum daily load (TMDLs).

Once the characterization and assessment of the drainage area is complete, the RSWMP must identify current stormwater-related water quality concerns and forecast future ones, assuming full development under current zoning. The inventory should include current and potential stormwater pollutant sources in the regional planning area including urban and suburban development, roads, storm sewers, agricultural or mining operations, and waterfront development. The New Jersey Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)) (Integrated List) is required by the Federal Clean Water Act to be prepared biennially and is a valuable source of water quality information. This combined report presents the extent to which New Jersey waters are attaining water quality standards, and identifies waters that are impaired. Sublist 5 of the Integrated List constitutes the list of waters impaired or threatened by pollutants for which one or more TMDLs are needed.

Once identified, these water-quality concerns must be ranked based on criteria determined by the planning committee. They can include: threat to public health, safety and welfare; damage to water supplies; risk of damage to the biological integrity of water bodies; mosquito control; groundwater depletion; or impacts to the ecosystem, among others.

If a TMDL has been adopted for any part of a water body in the planning area, these water-quality objectives must incorporate the loading reductions established in the TMDL for stormwater runoff. If any part of a water body is on Sublist 5 of the Integrated List due to stormwater-related impacts, the plan's objectives must specifically address those pollutants of concern.

Regional stormwater management plans must also identify and rank issues of water quantity and groundwater recharge as well as water quality. Thus, the broad goal of the plan is to eliminate, reduce, or minimize stormwater-related impacts associated with current and future land use. The minimum standard of protection is the level that would be achieved by conforming to New Jersey's Design and Performance Standards for Stormwater Management Measures when implemented throughout the regional stormwater management planning area.

Designing Regional Stormwater Solutions

An RSWMP must include design and performance standards to meet the New Jersey water quality, water quantity, and groundwater recharge standards in N.J.A.C. 7:8-3.5. However, because an RSWMP addresses concerns on a regional basis, the design and performance standards need not be uniform throughout the planning area if they satisfy N.J.A.C. 7:8-5 when considered as a whole. Any alternative standards must be at least as protective when implemented throughout the regional stormwater management planning area.

Once the objectives and performance standards have been identified, an RSWMP must outline the stormwater management measures needed to achieve the objectives. The plan may include the following guidelines for new or existing land uses or other measures: design and performance standards for storm water quality, stormwater quantity, or groundwater recharge for new development; modifications to existing stormwater management structural controls; elimination of illegal or illicit discharges; prevention or minimization of the exposure of pollutants to stormwater; or control of floatables. The plan may also include measures to enhance, protect, or preserve land or water areas for purposes of flood control, water quality protection, or conservation of natural resources. And, because many stormwater management concerns can be traced directly to the lifestyle choices of watershed residents, a plan may choose to emphasize public education programs that address root causes of water quantity and quality impacts.

Whatever measures are selected, the plan must include two important additional features. First, the plan must explain the committee's rationale for including the selected measure. The rationale should include a feasibility and cost/benefit analysis, an estimate of reduction in pollutant loads, and a projection of performance longevity. Second, the plan must specifically address maintenance requirements for each stormwater management measure, including preventative and corrective maintenance, a long-term maintenance implementation schedule, and clear identification of the organization or entity responsible for implementation and maintenance.

Implementation and Evaluation Strategies

The implementation strategy begins by identifying the agency assigned to coordinate plan implementation, including long-term monitoring requirements. The plan must identify the agency appointed to implement and monitor each measure in the plan along with a timetable for implementation. It must include a process to evaluate the entire plan at least once every five years and should include a budget that projects both long- and short-term costs for each measure. The strategy should identify possible current and potential funding sources to implement the RSWMP.

The long-term monitoring program should provide information about land use, water quality, water quantity, groundwater, and riparian and aquatic habitat conditions. Monitoring data may include information from watershed management agencies and monitoring programs operated by other agencies, including volunteer programs.

Once complete, an RSWMP will be submitted for review to the NJDEP and, if applicable, to the designated water quality management planning agency as an amendment to areawide water quality management plans. If the plan is approved, the NJDEP will propose to amend the areawide water quality management plan as outlined in N.J.A.C. 7:15-3.4(g). Any performance standards developed under an RSWMP adopted by the NJDEP in effect supersedes the minimum design and performance standards in N.J.A.C. 7:8-5 of the Stormwater Management Rules. NJDEP will use the plan requirements to review stormwater management requirements for activities currently regulated by the Freshwater Wetland Protection Act, Coastal Zone Management Rules, Flood Hazard Area Control Act Rules, New Jersey Pollution Discharge Elimination System Rules, and Dam Safety Standards. Each municipality in the regional stormwater management planning area must incorporate the applicable provisions of the plan into a new or amended municipal stormwater management plan. In addition, the stormwater management review for residential developments, which are based on the Residential Site Improvement Standards, will be based on the regional stormwater management plan. The requirements of the plan apply only to stormwater management criteria of other regulatory programs; additional requirements may be imposed as necessary under each program.

Municipal Stormwater Management Plans

A municipal stormwater management plan (MSWMP) documents the strategy of a specific municipality to address stormwater-related impacts. MSWMPs provide the structure and process for addressing stormwater management in the municipality. They are required by the Environmental Protection Agency's Phase II Stormwater Permitting Rules; the mandatory elements of the plan are described in the Stormwater Management Rules.

The municipal plan must address and achieve the goals of stormwater management discussed in N.J.A.C. 7:8-2. For new development, the plan must incorporate the performance standards for water quantity, water quality, and groundwater recharge in the Stormwater Management Rules at N.J.A.C. 7:8-5. If alternate standards have been established by an adopted regional stormwater management plan (RSWMP), the MSWMP must be consistent with it. A copy of the ordinances incorporating the performance standards must be included in the plan.

The MSWMP must be coordinated and consistent with other regulations on stormwater management issues such as those of the Soil Conservation Districts and the Residential Site Improvement Standards. The MSWMP may also address existing stormwater issues such as those identified in an RSWMP. In addition to specific design criteria, maintenance and safety requirements are a critical component. Preventative and corrective maintenance strategies must be included in the plan to ensure long-term effectiveness of stormwater management facilities. Safety standards discussed in Subchapter 6 of the Stormwater Management Rules must also be included in the MSWMP.

The plan must provide a view of the impacts of existing zoning and environmentally constrained areas on the municipality's landscape. In addition, the plan must include: maps of existing streams, groundwater recharge, and wellhead protection areas; build-out conditions based on existing zoning; and an evaluation of the existing master plan and land use ordinances that identifies areas to be amended to enable the implementation of nonstructural stormwater management techniques identified in the Rules. In order for the municipality to grant variances or exemptions from the design and performance standards for groundwater recharge and stormwater runoff quality and quantity, the municipality must provide a mitigation strategy in the MSWMP. The municipality should use the information provided in the plan to ensure that stormwater management objectives are completely addressed in the implementation of the municipal plan and ordinances.

MSWMPs are subject to review by county planning agencies to determine whether they meet the standards required by the Stormwater Management Rules. A copy of the proposed plan must also be sent to the Department of Environmental Protection, Division of Watershed Management. The county must approve, conditionally approve, or disapprove the plan in writing within 60 days. Generally, the plan becomes effective upon approval by the county; however, in the case of conditional approvals, the plan becomes effective after the municipality meets the conditions of approval.

A sample municipal stormwater management plan is provided in Appendix C.

Mitigation

Municipal stormwater management plans must incorporate design and performance standards that are as protective as those outlined in the Stormwater Management Rules or alternative standards in an adopted regional stormwater management plan. These design and performance standards focus on three areas: maintaining groundwater recharge from proposed development, minimizing the proposed development's impact on flooding, and minimizing the proposed development's water quality impact on state waters. Some projects have unique, site-specific conditions that prevent them from strict compliance with the performance standards. In order for the municipality to grant a waiver or exemption from strict compliance

with the groundwater recharge and stormwater runoff quality and quantity requirements, the MSWMP must include a mitigation process documented in a mitigation plan contained within the larger MSWMP.

The mitigation plan must identify the measures required to offset any potential impact created by granting the variance or exemption to the performance standards. Several strategies can be used to mitigate a development project and its impacts. Applicants can: identify, design, and implement a compensating measure to mitigate impacts; complete a project identified by the municipality as equivalent to the environmental impact created by the exemption or variance; or, provide funding for municipal projects that would address existing stormwater impacts.

The preferred option is to identify a mitigation project within the drainage area that directly compensates for the projected impact of the variance or exception. For example, because of natural site constraints, a proposed development might be unable to fully meet the groundwater recharge criteria, with the projected impact being an annual net loss of 50,000 cubic feet of groundwater recharge volume. In this case, a mitigation plan might require recovery of the lost recharge volume by capturing existing runoff from an impervious area on a site within the same drainage basin. Applicants can be directed to identify potential properties suitable for the mitigation project and secure the easements necessary to implement the projects.

Municipalities can plan for mitigation by identifying property owned by the municipality or by securing easements, as conditions of planning and zoning board approvals, that would allow implementation of future mitigation measures. Municipalities should develop a list of projects that need to be implemented throughout the municipality that would compensate for groundwater recharge, stormwater quality, and stormwater quantity impacts. Project mitigation is simplified when the municipality identifies and ranks a series of projects an applicant can select, especially on land owned or controlled by the municipality. The selection process should be clearly stated so the applicant and the municipality have predictability in the mitigation process. In its mitigation plan, a municipality can assign credits for proposed projects that address groundwater recharge and stormwater runoff quantity and quality problems within the drainage area.

If direct mitigation for the projected environmental impact is not feasible, an MSWMP may permit a non-equivalent project mitigation. Using the development example above, a mitigation plan may require a project that helps alleviate an existing impairment, such as fecal contamination in local streams, rather than one that compensates for the loss of groundwater recharge. Non-equivalent mitigation projects allow a municipality to target issues of greatest concern within a drainage area and secure the resources to correct them. In this example, the non-equivalent mitigation option might be pursued if close examination of local water resources indicates that fecal impairment is a more critical parameter in the receiving stream than small losses in groundwater recharge and baseflow. Clearly, the non-equivalent mitigation option must be cautiously approached; in this example, the long-term impacts of cumulative losses in groundwater recharge on the aquifer and baseflow must be carefully considered before granting a variance or exception.

The third, and least preferred, mitigation option is to require funding for specific projects within the municipality that would retrofit existing groundwater recharge and stormwater quality or quantity issues. In urban redevelopment areas, funding projects that address stormwater impacts on a regional basis, such as the development or implementation of regional stormwater management plans, may be more effective than a project that provides direct compensation for the performance standard. Planners implementing this option should ensure that the funding results in projects that provide adequate protection to compensate for the impact created by failing to strictly comply with the performance standards in the Stormwater Management Rules.

All mitigation plans and reviews should consider the location of mitigation projects in relation to the property where the projected damage will occur. For example, if a project is unable to achieve the stormwater quantity performance standards upstream of an inadequate culvert, a mitigation project downstream of that culvert would not offer similar protection. If the groundwater recharge is the major contributor to a wetlands area, the new project should continue to provide recharge to the wetlands area. A municipality can develop a mitigation plan that includes any or all of the options discussed above. Plans can

be as simple or as complex as the municipality chooses, provided they afford sufficient protection of the water resources. However, mitigation should not be an option until it is clearly demonstrated that on-site compliance is not practical.

Mitigation requirements should include a hierarchy of options that clearly offset the effect on groundwater recharge, stormwater quantity control, and/or stormwater quality control that was created by granting the variance or exemption. Mitigation must occur within the same drainage basin as that of the proposed development so that it provides benefits and protection similar to those that would have been achieved if the stormwater and recharge performance standards had been completely satisfied. Because these problems span political boundaries, mitigation projects could be located in adjacent municipalities within the drainage area with the cooperation of the municipalities, especially if a regional stormwater management plan has been developed for the drainage basin. The mitigation planning and approval process must ensure that long-term maintenance is achieved by clearly assigning responsibility for maintenance and by securing the funding and resources required to perform it.

Mitigation plans can differ greatly from municipality to municipality. As part of the mitigation plan development, consideration should be given to a specific municipality's water resource needs and ability to implement the plan. The following text is an example of a mitigation plan.

If a proposed development requests a variance or exemption from strict compliance with the groundwater recharge, stormwater quantity and stormwater quality requirements outlined in the Municipal Stormwater Management Plan and ordinances, the applicant must provide mitigation in accordance with the following:

1. A mitigation project must be implemented in the same drainage area as the proposed development. The project must provide additional groundwater recharge benefits, or protection from stormwater runoff quality and quantity from previously developed property that does not currently meet the design and performance standards outlined in the Municipal Stormwater Management Plan.
 - The applicant can select a project listed on the Municipal Stormwater Management Plan to compensate for the deficit from the performance standards resulting from the proposed project.
 - The applicant can obtain the necessary agreements to create a project to compensate for the deficit from the performance standards resulting from the proposed project.
 - The applicant must ensure the long-term maintenance of the project including the maintenance requirements under Chapters 8 and 9.
2. If a suitable mitigation site cannot be located in the same drainage area as the proposed development, as discussed under Option 1, the municipality may allow the applicant to provide funding to the municipality for an environmental enhancement project that has been identified in this Municipal Stormwater Management Plan. *[This option would be available only if the MSWMP includes a list of environmental enhancement projects that provide groundwater recharge, control flooding, or control nonpoint source pollution.]* The funding must be equal to or greater than the cost to implement the mitigation outlined above, including the costs associated with purchasing the property or easement for mitigation and the costs associated with the long-term maintenance requirements of the mitigation measure.

Build-Out

A build-out analysis allows a municipality to project future development based on existing zoning and land-use regulations. It develops a picture, projected visually on a map, of what will happen if land is developed to the maximum extent allowed by law. A build-out analysis is not only useful for communities with undeveloped land. Areas with significant redevelopment potential should be considered in developing a build-out analysis. Many urban and older suburban municipalities contain properties that are not developed to the full extent allowed under current zoning. For example, properties zoned for industrial use may contain residential developments. Or, a developer might assemble several small residential and retail properties for demolition and redevelopment as an office complex. A build-out analysis can identify those properties and project impacts of their potential redevelopment.

Each municipal stormwater management plan is required to include a build-out analysis with information about the municipality based on the HUC14 boundaries. A hydrologic unit code 14 (HUC14) is a specific drainage area defined by the U.S. Geological Survey. For every individual HUC14 area in the municipality, the full development impervious cover and the anticipated pollutant loading based on full development must be determined.

A build-out analysis has two phases. The first visually depicts changes on a map and is best performed using a Geographic Information System (GIS), which is a computerized system for developing, analyzing, and displaying locational data. GIS allows planners to combine data sources such as zoning maps, tax maps, HUC14, and topographic maps, into “layers” that can be displayed on one map.

- Begin by constructing a base map of your community that includes the municipal boundary, existing roads, surface water bodies, HUC14 boundaries, impervious cover, existing development by land use types, groundwater recharge areas, and wellhead protection area layers. Existing GIS information sources may be helpful in the development of this plan, such as the NJDEP-GIS website at <http://www.state.nj.us/dep/gis>. Counties, watershed associations, and universities may also have information useful for the development of the base map.
- Identify and delineate land that cannot be developed because of legal restrictions, physical constraints, or environmental sensitivity. Examples include lands in permanently preserved open space, public ownership, deed restrictions, utility easements, steep slopes, wetlands, floodplains, and Category 1 Waters with the associated special water resource protection areas.
- Identify and delineate developable land under current zoning and land use regulations, as well as land that is not currently developed or restricted as discussed above. Identify and delineate developed areas within the municipality that have significant redevelopment potential and that have not been developed to the maximum allowed. For these undeveloped and underdeveloped areas, determine maximum future development by projecting the largest number of housing units allowed in residential zones and the largest number of buildings and most intensive land uses in commercial and industrial zones.

The second phase quantifies the impact of the changes based on information provided by the maps. This includes calculations of percentage of impervious surfaces, number of housing units and their density, and remaining farmland and open space acreage. GIS can also assist in this computation by providing values for specific sets of layers such as the combination of the municipality, HUC14, and impervious area layers. This set of variables can provide the impervious cover for each HUC14 required by the Stormwater Management Rules. Values can be exported to other programs from GIS for more comprehensive computations, including the pollutant loading calculations also required by the regulations.

The pollutant load computation is a planning tool that helps municipalities evaluate anticipated pollutant loads from future development. Nonpoint source pollutant loads from current conditions should be compared to build-out conditions. If BMPs are required for the development of undeveloped or

underdeveloped areas by regulation, the implementation of BMPs and their impacts on loading should be incorporated into the analysis.

To calculate pollutant loads from land uses for both current and build-out conditions, the table of values below for total suspended solids, nitrogen, and phosphorus can be used for a broad perspective on a municipal level. To utilize the table, relate the zones on the zoning map to the listed land uses. Other pollutant loading values may also be used provided that the values are a better depiction of the municipality. Pollutant loads are required for each HUC14 in the municipality. For each land use within the HUC14, multiply the total acreage by the assigned load factor, which is given in pounds per acre per year. The total pollutant load for the HUC14 will be the sum of the loads for each land use.

Table 3-1: Pollutant Loads by Land Cover

Land Cover	TP load (lbs/acre/yr)	TN load (lbs/acre/yr)	TSS load (lbs/acre/yr)
High, Medium Density Residential	1.4	15	140
Low Density, Rural Residential	0.6	5	100
Commercial	2.1	22	200
Industrial	1.5	16	200
Urban, Mixed Urban, Other Urban	1.0	10	120
Agriculture	1.3	10	300
Forest, Water, Wetlands	0.1	3	40
Barrenland/Transitional Area	0.5	5	60

Note: References for Table 3-1 are provided at the end of this chapter.

The build-out analysis can go further than the requirements in the regulations. In addition to pollutant loads and impervious surfaces, the analysis can be used to assess open space plans, and to project school population and demand on municipal services. The build-out analysis can greatly benefit a municipality by envisioning its future so that steps can be taken to prevent unwanted impacts or plan for future needs. Finally, the build-out analysis should include a summary with critical findings, conclusions, and recommendations.

It is important to note that, although the pollutant loads for agricultural lands are higher than those for low density residential for the parameters in Table 3-1, converting agricultural lands to residential typically results in an increase in pollutant loads for metals and petroleum hydrocarbons; it is recommended that each municipality calculate build-out pollutant loads for each. Also, the total load of suspended solids due to stormwater runoff may decrease due to the conversion of agricultural lands to low density residential, but the percentage of impervious surfaces increases dramatically. If increases in stormwater runoff flows, due to the increase of impervious surfaces, are not managed properly, these high flows will increase stream bank erosion, thereby increasing sediment loads to the receiving waters.

Evaluation of Master Plan and Municipal Ordinances

The master plan and ordinances of the municipality must be analyzed as part of the requirements for the municipal stormwater management plan. They must be assessed to determine which aspects of the master plan and ordinances limit the use of nonstructural stormwater management strategies, as discussed in N.J.A.C. 7:8-5.3. These strategies include minimum disturbance, disconnection and minimization of impervious surfaces, pollution prevention techniques, and minimization of lawns. Elements of the plan and ordinances to be evaluated can include items such as minimum parking spaces, curbing, minimum lawn areas, and landscaping. Recommendations for revisions to the master plan and ordinances should be included in the MSWMP.

To fulfill the requirement that nonstructural stormwater management strategies be incorporated into local regulations and plans, as outlined in N.J.A.C. 7:8-5.3(b), municipal engineers and municipal planners must work together. This allows the municipality to address the issue cost-effectively using expertise already on staff.

In essence, this task requires that municipalities review and update their master plans (including the land use plan element), official maps, and development regulations (including zoning ordinance) to implement the principles of the nine nonstructural stormwater strategies in N.J.A.C. 7:8-5.3(b). *Chapter 2: Low Impact Development Techniques* can assist municipalities in the review of these documents to determine where changes should be made. A checklist is also provided in *Appendix B: Municipal Regulations Checklist – A Checklist for Incorporating Nonstructural Stormwater Management Strategies into Local Regulations*.

References

County of Morris, Department of Planning and Development. March 2001. Jackson Brook Watershed Stormwater Management Plan. Prepared by Killam Associates in association with Najarian Associates.

Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with the U.S. Environmental Protection Agency. Terrene Institute, Washington, pp 235-248.

Personal communication with Daniel Van Abs. October 25, 2002

Personal communication with Tavit O. Najarian. November 11, 2002.

Personal communication with Christopher Obropta. November 12, 2002, February 21 to March 5, 2003.

U.S. Environmental Protection Agency. March 2003. How to Do a Build-out Analysis. Green Communities Website. http://www.epa.gov/greenkit/build_out.htm.

References for Table 1: Pollutant Loads by Land Cover

Database of Total Phosphorus, Total Nitrogen, and Total Suspended Solids Export Coefficients

A database of literature values was assembled that includes approximately 4,000 values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the NJDEP took steps to identify appropriate export values by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches. From the remaining studies, total phosphorus, total nitrogen, and total suspended solids values were selected based on best professional judgment for eight land use categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the following reference list.

Export Coefficient Database Reference List

- Allison, F.E., E.M. Roller and J.E. Adams. 1959. Soil Fertility Studies in Lysimeters Containing Lakeland Sand. Tech. Bull. 1199, U.S. Dept. of Agriculture, Washington, D.C. p. 1-62.
- Apicella, G. 2001. Urban Runoff, Wetlands and Waterfowl Effects on Water Quality in Alley Creek and Little Neck Bay. TMDL Science Issues Conference, WEF Specialty Conference.
- Athayde, D. N, P. E. Shelly, E. D. Driscoll, D. Gaboury and G.B. Boyd. 1983. Results of the Nationwide Urban Runoff Program: Final Report. USEPA Water Planning Division. Washington, D.C.
- Avco Economic Systems Corporation. 1970. Storm Water Pollution from Urban Land Activity. Rep.11034 FKL 07/70, Federal Water Qual. Adm., U.S. Dept. of Interior, Washington, D.C. p. 325.
- Bannerman, R., K. Baun, M. Bohm, P. E. Hughes and D. A. Graczyk. 1984. Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, Report No. PB84-114164, U.S. Environmental Protection Agency, Region V, Chicago, IL.
- Bengtson, R.L. and C.E. Carter. 1989. Simulating Soil Erosion in the Lower Mississippi Valley with the CREAMS Model. From: Application of Water Quality Models for Agricultural and Forested Watersheds, edited by D.B. Beasley and D.L Thomas. Southern Cooperative Series Bulletin No. 338.
- Broadbent, F.E. and H.D. Chapman. 1950. A Lysimeter Investigation of Gains, Losses and Balance of Salts and Plant Nutrients in an Irrigated Soil. Soil Sci. Soc. Amer. Proc. 14:261-269.
- Carter, Gail P.. 1998. Estimation of Nonpoint Source Phosphorus and Nitrogen Loads in Five Watersheds in New Jersey's Atlantic Coastal Drainage Basin. Surveying and Land Information Systems, Vol. 58, no 3. pp. 167-177.
- CH2M Hill. 2000. Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality.
- Claytor, R.A. and T.R. Schueler. 1996. "Design of Stormwater Filtering Systems," The Center for Watershed Protection, Prepared for Chesapeake Research Consortium, Inc.
- Corsi, S.R., D.J. Graczyk, D.W. Owens and R.T. Bannerman. 1997. Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds of Wisconsin. USGS FS-195-97.

- Delaware Valley Regional Planning Commission. 1977. Average Pollutant Concentrations Associated with Urban Agriculture and Forest Land Use. Working Paper 5.01-1, Extent of NPS Problems.
- Eck, P. 1957. Fertility Erosion Selectiveness on Three Wisconsin Soils. Ph. D. Thesis, Univ. of Wisconsin, Madison, WI.
- F.X. Brown, Inc. 1993. Diagnostic-Feasibility Study of Strawbridge Lake. FXB Project Number NJ1246-01.
- Frink, C.R. 1991. Estimating Nutrient Exports to Estuaries. *Journal of Environmental Quality*. 20:717-724.
- Horner, R., B. W. Mar, L. E. Reinelt, J. S. Richey and J. M. Lee. 1986. Design of monitoring programs for determination of ecological change resulting from nonpoint source water pollution in Washington State. University of Washington, Department of Civil Engineering, Seattle, WA.
- Horner, R.R. 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division, Seattle, WA.
- Horner, Richard R., Joseph J. Skupien, Eric H. Livingston and H. Earl Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Prepared by the Terrene Institute, Washington, DC, in cooperation with the U.S. Environmental Protection Agency. EPA/840/B-92/002.
- Johnston, W.R., F. Ittihadieh, R.M. Daum and A.F. Pillsbury. 1965. Nitrogen and Phosphorus in Tile Drainage Effluent. *Soil Sci. Soc. Amer. Proc.* 29:287-289.
- Knoblauch, H.C., L. Kolodny and G.D. Brill. 1942. Erosion Losses of Major Plant Nutrients and Organic Matter from Collington Sandy Loam. *Soil Sci.* 53:369-378.
- Loehr, R.C. 1974. Characteristics and comparative magnitude of non-point sources. *Journal of WPCF* 46(11):1849-1872.
- Lopes, T.J., S.G. Dionne. 1998. A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S. Geological Survey, U.S. Department of Interior.
- Marsalek, J. 1978. Pollution Due to Urban Runoff: Unit Loads and Abatement Measure, Pollution from Land Use Activities Reference Group. International Joint Commission, Windsor, Ontario.
- McFarland, Anne M.S and L. M. Hauck. 2001. Determining Nutrient Export Coefficients and Source Loading Uncertainty Using In-stream Monitoring Data. *Journal of the American Water Resources Association*, pp. 223, 37. No. 1, February.
- Menzel, R. G., E. D. Rhoades, A. E. Olness and S. J. Smith. 1978. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. *Journal of Environmental Quality*, 7:401-406.
- Mills, W.B., D.B. Porcella, M.J. Unga, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie. 1985. Water Quality Assessment – A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water – Part I and II. EPA-600/6-85-002A&B.
- Minshall, N.E., M.S. Nichols and S.A. Witzel. 1969. Plant Nutrients in Base Flow of Streams in Southwestern Wisconsin. *Water Resources*. 5(3):706-713.
- Mundy, C., M. Bergman. 1998. Technical Memorandum No. 29, The Pollution Load Screening Model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases, Department of Water Resources, St. Johns River Water Management District.
- NCDWQ. 1998. Neuse River Basinwide Water Quality Plan, Chapter 5, Section A.
- Nelson, M.E. 1989. Predicting Nitrogen Concentrations in Ground Water An Analytical Model. IEP, Inc.

- Northeast Florida Water Management District. 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan. Appendix 4.
- Northern Virginia Planning District Commission. 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies. Prepared for the Metropolitan Washington Council of Governments.
- Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, NY.
- Omernik, J.M. 1976. The influence of land use on stream nutrient levels, U.S. EPA, January. EPA-60/3-76-014.
- Omni Environmental Corporation. 1991. Literature Search on Stormwater Pollutant Loading Rates. Literature cited from DVRPC 1977; Wanielista et al. 1977; Whipple and Hunter 1977; NVPDC 1980; USEPA 1983; Mills et al. 1985; Nelson 1989; Walker et al. 1989.
- Omni Environmental Corporation. 1999. Whippany River Watershed Program Stormwater Model Calibration and Verification Report.
- Overcash, M. R., F. J. Humenik and J. R. Miner. 1983. Livestock Waste Management, Vol. II, CRC Press, Inc., Boca Raton, FL.
- Pacific Northwest Environmental Research Laboratory. 1974. Relationships Between Drainage Area Characteristics and Non-Point Source Nutrients in Streams. Prepared for the National Environmental Research Center, August 1974.
- Panuska, J.C. and R.A. Lillie. 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. Research Management Findings, Bureau of Research, Wisconsin Department of Natural Resources, Number 38.
- Pitt, R.E. 1991. Nonpoint Source Water Pollution Management. Dep. Civil Eng., Univ. Alabama, Birmingham, AL.
- Polls, Irwin and Richard Lanyon. 1980. Pollutant Concentrations from Homogeneous Land Uses. Journal of the Environmental Engineering Division.
- Prey, J., D. Hart, A. Holy, J. Steuer and J. Thomas. 1996. A Stormwater Demonstration Project in Support of the Lake Superior Binational Program: Summary. Wisconsin Dept. of Natural Resources. (<http://www.dnr.state.wi.us/org/water/wm/nps/tpubs/summary/lakesup.htm>)
- Rast, W. and G.F. Lee. 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading -- Lake Response Relationships and Trophic State Indices., EPA-600/3-78-008.
- Reckhow, K.H., M.N. Beaulac and J.T. Simpson. 1980. Modeling of Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA 440/5-80-011. U.S. EPA, Washington, D.C.
- Ryding, S. and W. Rast. 1989. The Control of Eutrophication of Lakes and Reservoirs. Man and the Biosphere Series, United Nations Educational Scientific and Cultural Organization, Paris, France.
- Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for the Metropolitan Washington Council of Governments.
- Sonzogni, W.C. and G.F. Lee. 1974. Nutrient Sources for Lake Mendota - 1972. Trans. Wisc. Acad. Sci. Arts Lett. 62:133-164.
- Uchrin, C.G. and T.J. Maldanato. 1991. Evaluation of Hydrocarbons in Urban Runoff and in Detention Basins. Water Writes. Water Research Institute, Division of Coastal and Environmental Studies, Rutgers University.

- United States Geological Survey, U.S. Department of the Interior. 1998. Comparison of NPDES Program Findings for Selected Cities in the United States, USGS Fact Sheet, January.
- USEPA. 1987. Guide to Nonpoint Source Pollution Control. U.S. EPA, Criteria and Standards Division, Washington D.C.
- USEPA. 1993. Urban Runoff Pollution Prevention and Control Planning (handbook). EPA/625/R-93/004.
- USEPA. 2000. Watershed Analysis and Management (WAM) Guide for Tribes.
(<http://www.epa.gov/owow/watershed/wacademy/wam/>)
- Uttormark, P.D., J.D. Chapin and K.M. Green. 1974. Estimating nutrient loadings of lakes from non-point sources. (WRIL 160609). EPA-660/3-74-020. U.S. Environmental Protection Agency, Washington, D.C.
- Walker, J.F. 1989. Spreadsheet Watershed Modeling for Nonpoint Source Pollution Management in a Wisconsin Basin, Water Resources Bulletin, Vol. 25, no. 1, pp. 139-147.
- Wanielista, M.P., Y.A. Yousef and W.M. McLellon. 1977. Nonpoint Source Effects on Water Quality, Journal Water Pollution Control Federation, Part 3, pp. 441-451.
- Washington State Department of Ecology. 2000. Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements. Publication No. 99-11.
- Weidner, R.B., A.G. Christianson, S.R. Weibel and G.G. Robeck. 1969. Rural Runoff as a Factor in Stream Pollution. J. Water Pollution. Con. Fed. 36(7):914-924.
- Whipple, W. and J.V. Hunter. 1977. Nonpoint Sources and Planning for Water Pollution Control. Journal Water Pollution Control Federation. pp. 15-23.
- Whipple, W., et al. 1978. Effect of Storm Frequency on Pollution from Urban Runoff, J. Water Pollution Control Federation. 50:974-980.
- Winter, J.G. and H.C. Duthie. 2000. Export Coefficient Modeling to assess phosphorus loading in an urban watershed. Journal of American Water Resources Association. Vol. 36 No. 5.
- Zanoni, A.E. 1970. Eutrophic Evaluation of a Small Multi-Land Use Watershed. Tech. Completion Rep. OWRR A-014-Wis., Water Resources Center, Univ. of Wisconsin, Madison, WI.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 4

Stormwater Pollutant Removal Criteria

This chapter presents the criteria and methodologies necessary to determine the pollutant removal rates of stormwater management measures used individually and in series to meet the stormwater quality requirements of the Stormwater Management Rules at N.J.A.C. 7:8. According to these Rules, a “major development” project that creates at least 0.25 acres of new or additional impervious surface must include stormwater management measures that reduce the average annual total suspended solids (TSS) load in the development site’s post-construction runoff by 80 percent. This 80 percent requirement has been based, in part, upon Section 6217(g) of the 1990 Coastal Zone Management Act Reauthorization Amendments as enforced by the U.S. Environmental Protection Agency. In addition, these stormwater management measures must reduce the average annual nutrient load in the post-construction runoff by the maximum extent feasible. This requirement has been included in the Stormwater Management Rules because nutrients, consisting primarily of various forms of nitrogen and phosphorous, are recognized as a major class of stormwater pollutants from land development.

The stormwater management measures used to reduce the average annual TSS and nutrient loads can be structural and/or nonstructural in nature. To achieve the reduction requirements, they must be designed to treat the runoff from the stormwater quality design storm, a 1.25-inch/2-hour variable rate rainfall event. Details of the stormwater quality design storm are presented in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Details of nonstructural and structural stormwater management measures, also known as Best Management Practices (BMPs), are presented respectively in *Chapter 2: Low Impact Development Techniques* and *Chapter 9: Structural Stormwater Management Measures*.

TSS Removal Rates for Individual BMPs

As noted above, the Stormwater Management Rules require an 80 percent TSS reduction in the post-construction runoff from a land development site that increases impervious surface by 0.25 acres or more. This reduction is to be achieved by conveying the site's runoff through one or more onsite BMPs that have the ability to remove a portion of the TSS load. To demonstrate compliance with this requirement, the NJDEP has adopted official TSS removal rates for each of the BMPs described in detail in Chapter 9. These BMPs and their adopted TSS removal rates are presented below in Table 4-1. Different removal rates and BMPs may be utilized if supporting information is provided and accepted by the applicable review agencies.

It is important to note that the TSS removal rates shown in Table 4-1 have been based upon several sources of BMP research and monitoring data as well as consultation with numerous stormwater management experts. As demonstrated by that research, actual TSS removals at specific BMPs during specific storm events will depend upon a number of site factors and can be highly variable. As such, the TSS removal rates presented in Table 4-1 are considered representative values that are based upon a recognition of this variability and the state's need to develop and implement a statewide stormwater management program. Furthermore, the TSS removal rates are also considered to accurately represent the relative TSS removal efficiencies of the various BMPs listed in the table.

Table 4-1: TSS Removal Rates for BMPs

Best Management Practice (BMP)	Adopted TSS Removal Rate (%)
Bioretention System	90
Constructed Stormwater Wetland	90
Dry Well	Volume Reduction Only ¹
Extended Detention Basin	40 to 60 ²
Infiltration Structure	80
Manufactured Treatment Device	See N.J.A.C. 7:8-5.7(d) ³
Pervious Paving System	Volume Reduction Or 80 ⁴
Sand Filter	80
Vegetative Filter	60-80
Wet Pond	50-90 ⁵

¹ See text below.

² Final rate based upon detention time. See Chapter 9.

³ To be determined through testing on a case-by-case basis. See text below.

⁴ If system includes a runoff storage bed that functions as an infiltration basin. See Chapter 9.

⁵ Final rate based upon pool volume and detention time. See Chapter 9.

As shown in Table 4-1, a dry well and certain types of pervious paving do not have an adopted TSS removal rate. This is due to the fact that, as described in Chapter 9, a dry well is intended to infiltrate runoff only from a roof and other impervious area with minimal TSS loading. A pervious paving system without a runoff storage bed can reduce the runoff volume from standard paving, but is not used to treat runoff from other impervious areas. As such, these systems are not considered to be effective in reducing the overall TSS load from a development site. However, in recognition of their infiltration ability, both BMPs can be used to reduce the volume of development site runoff and, consequently, the size and cost of other onsite BMPs. Use of these “volume reduction” BMPs are illustrated in Example 4-2 below and described in detail in Chapter 5.

In addition, Table 4-1 also indicates that the adopted TSS removal rates for manufactured treatment devices must be determined on a case-by-case basis. Manufactured treatment devices are proprietary water quality devices that use a variety of stormwater treatment techniques. They have and continue to be developed by a variety of companies. As such, the actual TSS removal rate for a specific device will depend on a number of factors, and a single representative TSS removal rate cannot be developed. Instead, the NJDEP’s Division of Science, Research & Technology (DSRT) is responsible for certifying final pollutant removal rates for all manufactured treatment devices. This certification process is described in detail in Chapter 9.

Finally, as noted in Table 4-1, the adopted TSS removal rates for extended detention basins and wet ponds will vary depending on such specific features as detention time and permanent pool volume. Details for each BMP are also provided in Chapter 9.

TSS Removal Rates for BMPs in Series

The TSS removal rates specified in Table 4-1 for certain BMPs range as low as 40 percent, which indicates that these BMPs will not be able to meet the 80 percent TSS reduction requirement by themselves. As such, it will be necessary at times to use a series of BMPs in a treatment train to achieve the required 80 percent TSS removal rate. In such cases, the total removal rate of the BMP treatment train is based on the removal rate of the second BMP applied to the fraction of the TSS load remaining after the runoff has passed through the first BMP (Massachusetts DEP, 1997).

A simplified equation for the total TSS removal rate (R) for two BMPs in series is:

$$R = A + B - [(A \times B) / 100] \quad (\text{Equation 4-1})$$

Where:

R = Total TSS Removal Rate

A = TSS Removal Rate of the First or Upstream BMP

B = TSS Removal Rate of the Second or Downstream BMP

The use of this equation is demonstrated in Example 4-1 below.

Example 4-1: Total TSS Removal Rate for BMPs in Series

A stormwater management system consists of both a vegetative filter and an extended detention basin to collect and treat runoff from a small commercial parking lot. Runoff from the parking lot will sheet flow off the parking lot through the filter strip, which will have a turf grass surface cover, before being discharged to the extended detention basin. The extended detention basin will have a detention time of 18 hours.

From Table 4-1 and Chapter 9, the adopted TSS removal rates for these individual BMPs are:

Turf Grass Vegetative Filter = 60%

Extended Detention Basin with 18-Hour Detention Time = 50%

From Equation 4-1,

$$R = A + B - [(A \times B) / 100]$$

$$R = 60 + 50 - [(60 \times 50) / 100] = 110 - 30 = 80\% \text{ Total TSS Removal Rate}$$

It should be noted that the total TSS removal rate of the stormwater management system described in Example 4-1 above can also be computed by the following technique:

Initial TSS Load Upstream of Vegetated Filter Strip = 1.0

TSS Load Removed by Vegetated Filter Strip = 1.0 X 60% Removal Rate = 0.6

Remaining TSS Load Downstream of Vegetated Filter Strip = 1.0 - 0.6 = 0.4

TSS Load Removed by Extended Detention Basin = 0.4 X 50% Removal Rate = 0.2

Final TSS Load Downstream of Extended Detention Basin = 0.4 - 0.2 = 0.2

Total TSS Removal Rate = 1.0 - 0.2 = 0.8 or 80%

This technique can also be used in place of Equation 4-1 when there are more than two BMPs in series.

Guidelines for Arranging BMPs in Series

As described in Example 4-1, it may be necessary or desirable to use a series of BMPs in a treatment train to provide adequate TSS removal. In selecting the order or arrangement of the individual BMPs, the following general guidelines should be followed:

1. Arrange the BMPs from upstream to downstream in ascending order of TSS removal rate. In this arrangement, the BMP with the lowest TSS removal rate would be located at the upstream end of the treatment train. Downstream BMPs should have progressively higher TSS removal rates.
2. Arrange the BMPs from upstream to downstream in ascending order of nutrient removal rate. Similar to 1 above, the BMP with the lowest nutrient removal rate would be located at the upstream end of the treatment train in this arrangement. Downstream BMPs should have progressively higher nutrient removal rates.
3. Arrange the BMPs from upstream to downstream by their relative ease of sediment and debris removal. In this arrangement, the BMP from which it is easiest to remove collected sediment and debris would be located at the upstream end of the treatment train. In downstream BMPs, it should be progressively more difficult to remove sediment and debris.

In applying these guidelines, it is recommended that they generally be applied in the order presented above. As such, a series of BMPs would be preliminarily arranged in accordance with their relative TSS removal rates (Guideline 1). This preliminary arrangement would then be refined by the BMPs' relative nutrient removal rate (Guideline 2) and then their ease of sediment and debris removal (Guideline 3). Two or more

iterations may be necessary to select the optimum arrangement, which should also include consideration for site conditions and the abilities and equipment of the party responsible for the BMPs' maintenance.

Finally, it should be noted that, unless otherwise approved by the applicable reviewing agencies or specifically indicated in the certification of a specific manufactured treatment device, all manufactured treatment devices that achieve TSS removal primarily through swirling and/or baffles should be placed at the upstream end of a treatment train.

Sites with Multiple Discharge Points and Subareas

In general, if runoff is discharged from a site at multiple points, the 80 percent TSS removal requirement will have to be applied at each discharge point. However, the application of this requirement will depend upon the exact amount of physical and hydraulic separation between the various discharge points. If the runoff from two or more discharge points combine into a single waterway or conveyance system before leaving the site, these separate discharge points can be considered as a single one for purposes of computing TSS removal.

In addition, where there are multiple onsite subareas to a single discharge point, the removal rates for the subareas can be combined through a weighted averaging technique. It should be noted that the averaging of TSS removal rates is applicable only where the anticipated pollutant loadings from each of the subareas are similar. As such, the TSS removal rate for an onsite BMP receiving runoff from a commercial parking lot cannot be averaged with a second onsite BMP serving a lawn or landscaped area.

Example 4-2 below provides further explanations of the procedures described above for computing TSS removal rates at sites with both multiple discharge points and subareas.

Example 4-2: TSS Removal Rates at Sites with Multiple Discharge Points and Subareas

A 15-acre site has a ridge running through it from northeast to southwest. Five acres of the site drain in a southeasterly direction to Stream A, while the remaining 10 acres drain in a northwesterly direction to Stream B. Since Stream A and B do not join on the site, each portion of the site will have to be evaluated separately for compliance with the 80 percent TSS removal requirement.

Southeast Drainage to Stream A

The site runoff to Stream A will first be routed through a bioretention system.

The bioretention system TSS removal rate is 90 percent. This exceeds the 80 percent removal requirements and meets the TSS removal requirement for the southeast drainage area.

Northwest Drainage to Stream B

One acre of rooftop runoff from the stormwater quality design storm will be directed to dry wells, thereby reducing the drainage area to be served by other BMPs by 1 acre. The remaining 9 acres to Stream B are divided into two subareas of 2 and 7 acres, respectively. A vegetative filter will treat the runoff from one of the subareas, while a constructed stormwater wetland will treat the runoff from other. The anticipated pollutant loadings from each subarea are similar.

The TSS removal rate for a vegetative filter with meadow is 70 percent, which is not sufficient by itself to meet the 80 percent TSS removal requirement. However, the constructed stormwater wetland TSS removal rate is 90 percent, which exceeds the 80 percent TSS removal requirement. By averaging of removal rates, the use of these two BMPs may be sufficient to meet the 80 percent removal requirement for this portion of the site.

Two alternatives to address the TSS load in the runoff from the northwest portion of the site to Stream B are presented below.

OPTION A: The meadow vegetative filter will be used to treat the runoff from the 7 acre subarea, while the constructed stormwater wetland will be used in the 2 acre subarea.

Apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

$$7 \text{ Acres} \times 70\% \text{ TSS Removal for Vegetative Filter} = 4.9$$

$$2 \text{ Acres} \times 90\% \text{ TSS Removal for Wetland} = 1.8$$

$$\text{Total Acreage-Removal Rate} = 4.9 + 1.8 = 6.7$$

$$6.7 \text{ Total Acreage-Removal Rate} / 9 \text{ Acres} = 0.74 \text{ or } 74\% \text{ Average TSS Removal Rate}$$

Therefore, for Option A, the northwest portion of the site does not meet the 80 percent TSS removal requirement.

OPTION B: The vegetative filter will be used to treat the runoff from the 2 acre subarea, while the constructed stormwater wetland will be used in the 7 acre subarea.

Once again, apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

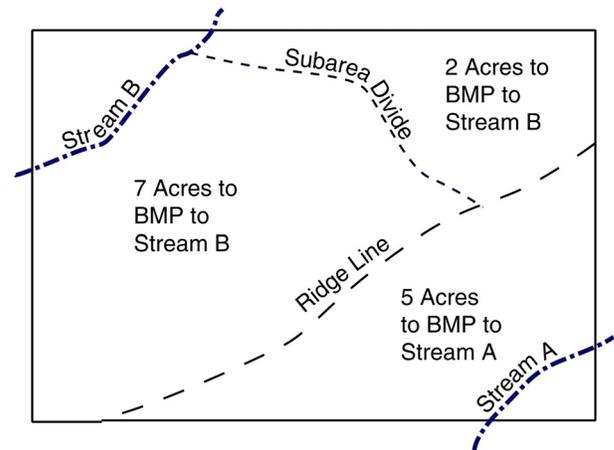
$$2 \text{ Acres} \times 70\% \text{ TSS Removal for Vegetative Filter} = 1.4$$

$$7 \text{ Acres} \times 90\% \text{ TSS Removal for Wetland} = 6.3$$

$$\text{Total Acreage-Removal Rate} = 1.4 + 6.3 = 7.7$$

$$7.7 \text{ Total Acreage-Removal Rate} / 9 \text{ Acres} = 0.86 \text{ or } 86\% \text{ Average TSS Removal Rate}$$

Therefore, for Option B, the northwest portion of the site does meet the 80 percent TSS removal requirement.



Nutrients

In addition to TSS removal, the Stormwater Management Rules also require the reduction of post-construction nutrients to the maximum extent feasible. In general, to demonstrate compliance with this requirement, a two step approach should be used. First, the input of nutrients to the drainage area should be limited as much as feasible. Second, when selecting a stormwater management measure to address the TSS removal requirement, the measure with the best nutrient removal rate that also best meets the site's constraints should be chosen. Details of each step in this approach are provided below.

Reducing Nutrient Input

A significant amount of nutrients are in stormwater runoff due to fertilization of lawns. As described in Chapter 2, lawns should be minimized in favor of other vegetated cover. Existing site areas with desirable vegetation communities should be left in a natural state and forested areas and meadows should be considered as alternatives to the standard lawn. Ground covers provide aesthetically pleasing, innovative landscapes that are adaptable to the local environment. These types of land cover reduce lawn area and the consequent need for fertilization. A landscape design that minimizes the use of lawn can be beneficial in preventing pesticides, as well as nutrients from fertilizers, from stormwater runoff.

Soil testing determines the soil nutrient level as well as pH. Using the test results to determine the appropriate application of lime and fertilizer required for lawn areas will increase efficient uptake and decrease associated costs of lawn maintenance as well as minimize nutrient input. Low or no phosphorous fertilizers may be adequate to maintain the health of the landscape after the vegetation has fully established. Soil test kits are available at most lawn and garden care centers as well as through the Rutgers Cooperative Extension county offices. Fertilization specifications must be included in the maintenance manual.

Pet waste is another source of nutrients in stormwater runoff. To prevent or minimize pet waste problems, residents must be required to pick up after their animal and dispose of the material in the toilet or garbage. Homeowner associations must include this condition in homeowner's agreements. Signage should be located strategically throughout the development to reinforce this criterion. Education is critical to successful pet waste management.

Nutrient Removal Rates

Site conditions and the need to reduce post-construction TSS by 80 percent are primary factors in the selection of appropriate BMPs for a development site. However, removal of nutrients such as phosphorous and the various forms of nitrogen must also be considered in this selection process. The chosen BMP must meet the TSS criteria, but must also maximize nutrient removal for the site. To assist with the selection of BMPs for nutrients, information regarding estimated nutrient removal rates is provided in Table 4-2.

Table 4.2 – Typical Phosphorous and Nitrogen Removal Rates for BMPs

Best Management Practice (BMP)	Total Phosphorous Removal Rate (%)	Total Nitrogen Removal Rate (%)
Bioretention Basin	60	30
Constructed Stormwater Wetland	50	30
Extended Detention Basin	20	20
Infiltration Basin	60	50
Manufactured Treatment Devices	See N.J.A.C. 7:8-5.7(d)	See N.J.A.C. 7:8-5.7(d)
Pervious Paving ²	60	50
Sand Filter	50	35
Vegetative Filter	30	30
Wet Pond	50	30

The nutrient removal rates presented in Table 4-2 should be considered typical values based upon data from a range of research studies. Due to the multiple forms and complex behavior of nutrients in stormwater runoff and the similarly complex processes by which nutrient loading is altered by BMPs, actual removal rates for specific BMPs and development sites may vary.

The nutrient removal data in Table 4-2 is intended to assist designers in the selection of appropriate BMPs to meet both the 80 percent TSS and maximum feasible nutrient removal requirements in the NJDEP Stormwater Management Rules. During this selection process, primary consideration should be given to achieving the Rules' 80 percent TSS removal requirement with one or more BMPs that are compatible with and responsive to site conditions and constraints, maintenance needs, and safety concerns. The selection process should then be further refined to achieve the Rules' maximum feasible nutrient requirement utilizing the structural BMP data in Figure 4.2 and, as necessary, other appropriate resources. In doing so, it should be remembered that many nonstructural BMPs can also help achieve the nutrient removal requirement, and must be considered prior to the use of structural BMPs.

The nutrient removal data in Table 4-2 can also be used to optimize existing BMP retrofits.

Additional Considerations

From the information presented in this chapter, it should be evident that BMPs are intended to reduce the pollutants in stormwater runoff. However, sometimes an unintended consequence of stormwater management facilities is their attractiveness to waterfowl, such as Canada geese. Canada geese are attracted to lawn areas adjacent to water bodies. As such, wet ponds and other stormwater management structures can appeal to these waterfowl, whose resulting fecal input can result in an increase in nutrient loading to systems that are intended to reduce such pollutants. As a result, adjustments to a BMP's design and/or maintenance plan may be necessary to discourage waterfowl from contributing pollutants to the stormwater measure. Additional guidance on Canada geese is available in Management of Canada Geese in Suburban Areas: A Guide to the Basics, available at http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/Goosedraft.pdf.

References

- Claytor, R. and T. Schueler. December. 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Ellicott City, MD.
- Center for Watershed Protection. March 2003. Impacts of Impervious Cover on Aquatic Systems – Watershed Protection Research Monograph No. 1. Ellicott City, MD.
- Desbonnet, A., P. Pogue, V. Lee, and N Wolff. 1994. Vegetated Buffers in the Coastal Zone – A Summary Review and Bibliography, Coastal Resources Center Technical Report No. 2064. University of Rhode Island Graduate School of Oceanography. Narragansett, RI.
- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Langan, T. National Stormwater BMP Database, NSW Statistical Summary 6-18-03 Tables.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Massachusetts Department of Environmental Protection. 1997. Stormwater Management Volume Two: Stormwater Technical Handbook.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.
- Strecker, E.W., M.M. Quigley, B. Urbonas. Results of Analyses of the Expanded EPA/ASCS National BMP Database.
- Winer, R. June 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition, Center for Watershed Protection.
- Wong, S.L. and R.H. McCuen. Design of Vegetated Buffer Strips for Runoff and Sediment Control.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 5

Computing Stormwater Runoff Rates and Volumes

This chapter discusses the fundamentals of computing stormwater runoff rates and volumes from rainfall through the use of various mathematical methods. To do so effectively, the chapter also describes the fundamentals of the rainfall-runoff process that these methods attempt to simulate. Guidance is also provided in the use of the Natural Resources Conservation Service, Rational, and Modified Rational Methods that are specifically recommended and/or required by the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. This guidance includes use of the methods to comply with the Rules' groundwater recharge, stormwater quality, and stormwater quantity requirements.

Fundamentals

The actual physical processes that convert rainfall to runoff are both complex and highly variable. As such, these processes cannot be replicated mathematically with exact certainty. However, through the use of simplifying assumptions and empirical data, there are several mathematical models and equations that can simulate these processes and predict resultant runoff volumes and rates with acceptable accuracy.

The selection of the appropriate model or equation depends upon a number of factors.

Desired Results

Some methods, such as the Rational Method, can be used to produce estimates of peak runoff rates, but cannot predict total runoff volumes. Other methods, conversely, can only produce estimates of total runoff volumes, while others, such as the Natural Resources Conservation Service (NRCS) methods, can accurately predict both total runoff volume and peak rate, and even entire runoff hydrographs.

Drainage Area Size

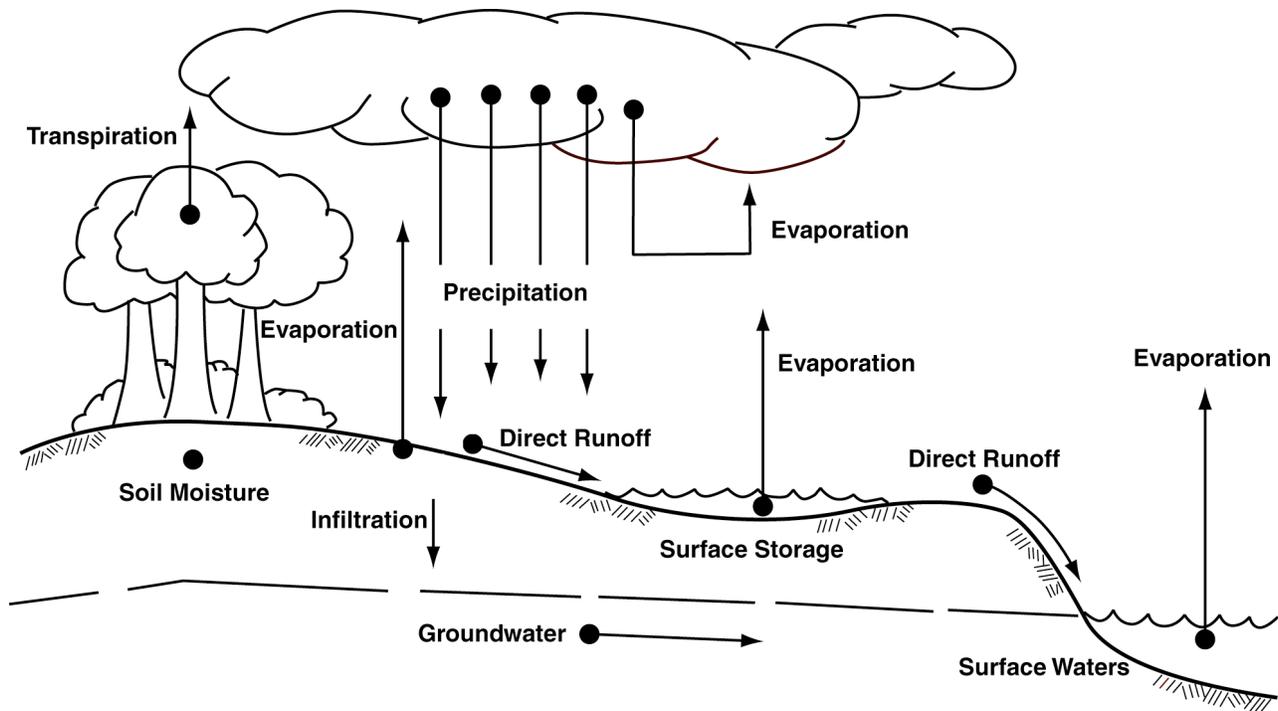
Due to their assumptions and/or theoretical basis, some methods can accurately predict runoff volumes or rates only for single drainage areas of 20 acres or less, while other methods can be applied to watersheds of 20 square miles or more with 100 or more subareas.

Data Availability

Simple methods, such as the Rational or Modified Rational Methods, require limited rainfall and drainage area data, while other, more sophisticated methods have extensive data needs, including long-term rainfall and temperature data as well as drainage area soils, subsoil, and ground cover information. In general, the more data-intensive models can produce more comprehensive runoff predictions.

In general, stormwater runoff can be described as a by-product of rainfall's interaction with the land. This interaction is one of several processes that the earth's water may go through as it continually cycles between the land and the atmosphere. In addition, stormwater runoff is only one of many forms water may take during one of these cycles, known scientifically as the hydrologic cycle. Shown in Figure 5-1 below, the hydrologic cycle depicts both the primary forms that water can take and the cyclical processes that produce them. In addition to runoff, these processes include precipitation, evaporation from surfaces or the atmosphere, evapotranspiration by plants, and infiltration into the soil or groundwater. As such, water that precipitates as rainfall can wind up or at least spend time on ground or plant surfaces, in the atmosphere, within the various soil layers, or in waterways and water bodies.

Figure 5-1: The Hydrologic Cycle



Source: Fundamentals of Urban Runoff Management.

In general, all runoff computation methods are, to some degree, mathematical expressions of the hydrologic cycle. However, most transform its cyclical character to a linear one, treating rainfall as an input and producing runoff as an output. During this transformation, each method uses mathematical approximations of the real rainfall-runoff processes to produce its estimates of runoff volume and/or rate. As described above, each method has its own complexity, data needs, accuracy, and range of results.

As the key input, rainfall is generally characterized by its size, intensity, and the frequency of its occurrence. The size of a rain storm is the total precipitation that occurs over a particular duration. How

often this size of storm is likely to reoccur is called its recurrence interval. For instance, a rainfall of certain duration that occurs, on average, once every 25 years would have an average recurrence interval of 25 years or be called a 25-year storm.

Since storms have been shown to be mathematically random events, their recurrence can also be specified as an annual probability. The equation for converting between recurrence interval and annual probability is:

$$\text{Annual probability (in percent)} = 100/\text{recurrence interval (in years)}$$

For example, the 25-year storm noted above could also be described as having a probability of 4 percent (=100/25) or a 4 percent chance of being equaled or exceeded in any given year. Similarly, a 2-year storm has a 50 percent chance (=100/2), a 10-year storm has a 10 percent chance (=100/10), and a 100-year storm has a 1 percent chance (=100/100) of being equaled or exceeded in a given year. Resultant runoff peak rates and volumes events can also be described in such terms.

Runoff volumes are influenced primarily by the total amount of rainfall. However, runoff rates resulting from a given rainfall, including the peak rate or discharge, are influenced primarily by the rainfall's distribution, which is how the rainfall rate or intensity varies over a period of time. Studies of rainfall records show that actual storm distributions and durations can vary considerably from event to event. A rainfall may be evenly distributed over a time period or can vary widely within that same period. Its duration can also be long or very short. These different types of rain events can produce extremely different runoff volumes and peak discharges.

Runoff computation methods deal with this rainfall variability in one of two general ways. Many methods, including the Rational and NRCS methods, rely on a hypothetical rain event known as a design storm for their rainfall input. This single, hypothetical storm event is based on a compilation of local or regional rainfall data recorded over an extended time period. To use a design storm, the user must make some assumptions about the antecedent ground and waterway conditions that exist at its start. Most runoff computations are based on average antecedent conditions, although wetter or drier conditions can also be used depending upon the user's interests and concerns.

Instead of compiling long-term rainfall data into a single design storm, other runoff computation methods address the variability of real rain events by analyzing a long series of them, computing runoff rate and volume estimates for each. While such methods need only the exact antecedent conditions that existed prior to the first storm, they must mathematically account for changes in ground and waterway conditions during intervening dry periods. Therefore, such methods are generally more complex than design storm methods and, obviously, require extensive rainfall data for the drainage area or watershed under analysis. Their results, however, are based on the actual long-term rainfall history of the watershed instead of a single, hypothetical design storm.

In addition to rainfall and antecedent conditions, other factors that can significantly affect both runoff volume and peak discharge are the hydrologic characteristics of the soils in the watershed and the type of surface that covers those soils. This cover may vary from pervious surfaces such as woods and grass to impervious surfaces such as roofs, roadways, and parking lots. Another factor that can greatly influence the peak runoff rate or discharge is the time of concentration (T_c). This is a measure of how quickly or slowly a watershed will respond to rainfall input and is usually measured as the time required for runoff to travel from the hydraulically most distant point in the watershed to the point of analysis at the watershed's lower end. Factors such as surface roughness, irregularity, length, and slope generally affect a watershed's T_c.

In summary, runoff computation methods attempt to mathematically reproduce or simulate the hydrologic cycle. They treat rainfall as an input, converting it into estimates of resultant runoff volume and/or rate. There are certain characteristics of both the rainfall event and the area upon which it falls that can influence the resulting runoff. These include:

1. High intensity rainfall will generally produce a greater peak discharge than a rainfall that occurs over a longer time period.
2. Highly porous or permeable soils that can rapidly infiltrate rainfall generally produce less runoff volume than soils with more restrictive infiltration.
3. Dense vegetation such as woodland intercepts and help infiltrates rainfall, thereby reducing runoff volumes and rates.
4. Conversely, impervious areas such as roadways and rooftops prevent infiltration and increase runoff volumes and rates.
5. Drainage areas with shorter times of concentration will have higher peak runoff rates than those with a longer T_c .

Runoff Computation Methods

As described in the Stormwater Management Rules, the NJDEP has specified that one of two general runoff computation methods be used to compute runoff rates and volumes. These are the NRCS methodology, which consists of several components, and the Rational Method (and the associated Modified Rational Method), which are generally limited to drainage areas less than 20 acres. A general description of each method is provided below.

NRCS Methodology

The USDA Natural Resources Conservation Service (NRCS) methodology is perhaps the most widely used method for computing stormwater runoff rates, volumes, and hydrographs. It uses a hypothetical design storm and an empirical nonlinear runoff equation to compute runoff volumes and a dimensionless unit hydrograph to convert the volumes into runoff hydrographs. The methodology is particularly useful for comparing pre- and post-development peak rates, volumes, and hydrographs. The key component of the NRCS runoff equation is the NRCS Curve Number (CN), which is based on soil permeability, surface cover, hydrologic condition, and antecedent moisture. Watershed or drainage area time of concentration is the key component of the dimensionless unit hydrograph.

Several runoff computation methods use the overall NRCS methodology. The most commonly used are the June 1986 *Technical Release 55 – Urban Hydrology for Small Watersheds* (TR-55), the April 2002 *WinTR-55 – Small Watershed Hydrology* computer program, and *Technical Release 20 – Computer Program for Project Formulation: Hydrology* (TR-20) published by the NRCS. The computer programs *HEC-1 Flood Hydrograph Package* and *HEC-HMS Hydrologic Modeling System* published by the U.S. Army Corps of Engineers' Hydrologic Engineering Center also contain components of the NRCS methodology. A complete description of the NRCS methodology can be found in the *NRCS National Engineering Handbook Section 4 – Hydrology* (NEH-4).

Rational Method

The Rational Method uses an empirical linear equation to compute the peak runoff rate from a selected period of uniform rainfall intensity. Originally developed more than 100 years ago, it continues to be useful in estimating runoff from simple, relatively small drainage areas such as parking lots. Use of the Rational Method should be limited to drainage areas less than 20 acres with generally uniform surface cover and topography. It is important to note that the Rational Method can be used only to compute peak runoff rates. Since it is not based on a total storm duration, but rather a period of rain that produces the peak runoff rate, the method cannot compute runoff volumes unless the user assumes a total storm duration. Complete descriptions of the Rational Method can be found in many hydrology and drainage textbooks.

Modified Rational Method

The Modified Rational Method is a somewhat recent adaptation of the Rational Method that can be used to not only compute peak runoff rates, but also to estimate runoff volumes and hydrographs. This method uses the same input data and coefficients as the Rational Method along with the further assumption that, for the selected storm frequency, the duration of peak-producing rainfall is also the entire storm duration. Since, theoretically, there are an infinite number of rainfall intensities and associated durations with the same frequency or probability, the Modified Rational Method requires that several of these events be analyzed in the method to determine the most severe. Similar to the Rational Method, there are several urban hydrology and drainage publications that contain descriptions of the Modified Rational Method, including Appendix A-9 of the *Standards for Soil Erosion and Sediment Control in New Jersey* published by the New Jersey State Soil Conservation Committee. Use of the Modified Rational Method should also be limited to drainage areas less than 20 acres with generally uniform surface cover and topography.

Design Storms

To fully comply with the NJDEP Stormwater Management Rules, stormwater runoff must be computed for three types of rainfall or storm events. These storms are associated with the groundwater recharge, stormwater quality, and stormwater quantity requirements in the Rules. A description of each storm and the techniques used to model it in the NRCS, Rational and Modified Rational methods are presented below.

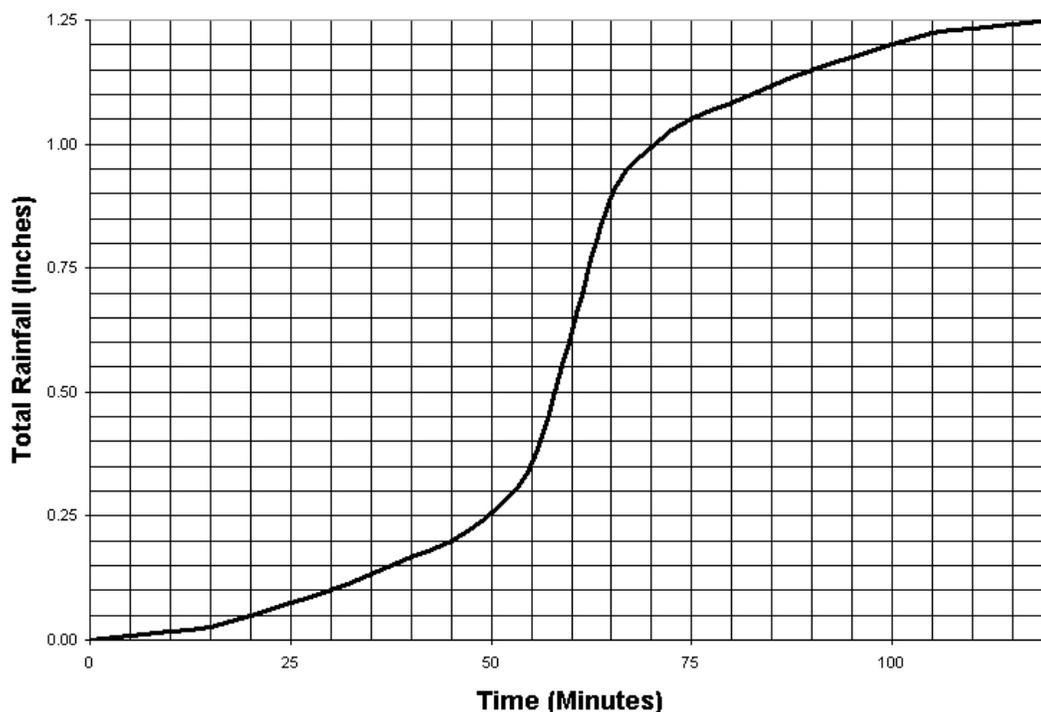
Groundwater Recharge Design Storm

As described in detail in *Chapter 6: Groundwater Recharge*, the NJDEP's groundwater recharge requirements are actually met through the analysis of a series of rainfall events derived from long-term New Jersey data. However, these events can also be expressed by an equivalent groundwater recharge design storm that represents the largest rainfall that must be controlled by a groundwater recharge facility. Due to the relatively small size of both the statistical rainfall series and the equivalent Design Storm, the NJDEP has developed specialized equations to compute the resultant runoff volume from each. The basis and use of these equations are described in detail in *Chapter 6: Groundwater Recharge*.

Stormwater Quality Design Storm

This is the rainfall event used to analyze and design structural and nonstructural stormwater quality measures (known as Best Management Practices or BMPs). As described in the Stormwater Management Rules, the NJDEP stormwater quality design storm has a total rainfall depth of 1.25 inches and a total duration of two hours. During its duration, the rain falls in a nonlinear pattern as depicted in Figure 5-2 below. This rainfall pattern or distribution is based on Trenton, New Jersey rainfall data collected between 1913 and 1975 and contains intermediate rainfall intensities that have the same probability or recurrence interval as the storm's total rainfall and duration. As such, for times of concentration up to two hours, the stormwater quality design storm can be used to compute runoff volumes, peak rates, and hydrographs of equal probability. This ensures that all stormwater quality BMPs, whether they are based on total runoff volume or peak runoff rate, will provide the same level of stormwater pollution control.

Figure 5-2: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm



The NJDEP stormwater quality design storm can be used to analyze and design stormwater quality BMPs based on the Rational, Modified Rational, or NRCS methods. Selection of the appropriate method will depend on the type of BMP selected and its required design data. BMPs that essentially store, treat, and slowly release the stormwater quality design storm runoff (such as extended detention basins, wet ponds, constructed stormwater wetlands, and sand filters) generally require a runoff volume at the very least and, ideally, an entire runoff hydrograph. This mandates the use of either the NRCS methodology or Modified Rational Method. However, BMPs that treat the stormwater quality design storm runoff as it is conveyed through them (such a filter strip, buffer or manufactured treatment device) generally require only a peak runoff rate. This can be computed using either the NRCS or Rational Methods. Further information on the use of these methods is presented below. When using either the Rational or Modified Rational Methods, it is important to remember their 20-acre drainage area limitations.

Table 5-1 was prepared for those using the NRCS methodology to compute stormwater quality design storm runoff peaks or hydrographs. It contains cumulative and incremental rainfall values for the stormwater quality design storm in five minute increments. These values can be used in computer programs such as TR-20, HEC-1, HEC-HMS, and other programs that both contain the NRCS methodology and allow user-specified rainfalls.

**Table 5-1: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm
Cumulative and Incremental Rainfall Distributions**

Time (minutes)	Cumulative Rainfall (inches)	Incremental Rainfall (inches)	Time (minutes)	Cumulative Rainfall (inches)	Incremental Rainfall (inches)
0	0.0000	0.0000	65	0.8917	0.2667
5	0.0083	0.0083	70	0.9917	0.1000
10	0.0166	0.0083	75	1.0500	0.0583
15	0.0250	0.0084	80	1.0840	0.0340
20	0.0500	0.0250	85	1.1170	0.0330
25	0.0750	0.0250	90	1.1500	0.0330
30	0.1000	0.0250	95	1.1750	0.0250
35	0.1330	0.0330	100	1.2000	0.0250
40	0.1660	0.0330	105	1.2250	0.0250
45	0.2000	0.0340	110	1.2334	0.0084
50	0.2583	0.0583	115	1.2417	0.0083
55	0.3583	0.1000	120	1.2500	0.0083
60	0.6250	0.2667			

Note: See Figure 5-1 for plot of cumulative rainfall distribution.

Figure 5-3 was prepared for those using the Rational Method to compute stormwater quality design storm runoff peaks. It presents the stormwater quality design storm as a rainfall intensity-duration curve that allows the user to determine the appropriate rainfall intensity for the selected time of concentration.

**Figure 5-3: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm
Rainfall Intensity-Duration Curve**



Finally, when using the Modified Rational Method to compute a stormwater quality design storm hydrograph, the entire 2-hour storm duration at an average intensity of 0.625-inches/hour can be used. Example 5-1 below demonstrates this procedure.

Important Note: While the stormwater quality design storm actually falls in a variable pattern, use of the 2-hour average rate described above and demonstrated in Example 5-1 is consistent with the assumptions of the Modified Rational Method. In addition, analysis and experience has shown that the structural BMPs that store and slowly release the stormwater quality design storm hydrograph (such as extended detention basins, wet ponds, bioretention facilities, constructed wetlands, and sand filters) are not particularly sensitive to rainfall pattern. If such sensitivity does exist for a particular BMP, the designer should use the NRCS methodology, which allows for consideration of the stormwater quality design storm's variable rainfall pattern.

Example 5-1: NJDEP 1.25-Inch/2-Hour Stormwater Quality Design Storm Hydrograph Computation with Modified Rational Method

Description: A 10-acre development site has a Rational C value of 0.78 and a time of concentration of 15 minutes. Construct a runoff hydrograph from the site for the 1.25-inch/2-hour stormwater quality design storm using the Modified Rational Method.

$$C = 0.78 \quad \text{Average } I = 1.25\text{-inches}/2\text{-hours} = 0.625 \text{ inches per hour}$$
$$\text{Area} = 10 \text{ acres} \quad T_c = 15 \text{ minutes} \quad \text{Storm duration} = 2 \text{ hours}$$

$$Q = \text{runoff rate (cubic feet per second)} = CIA$$

$$C = \text{Rational Method runoff coefficient}$$

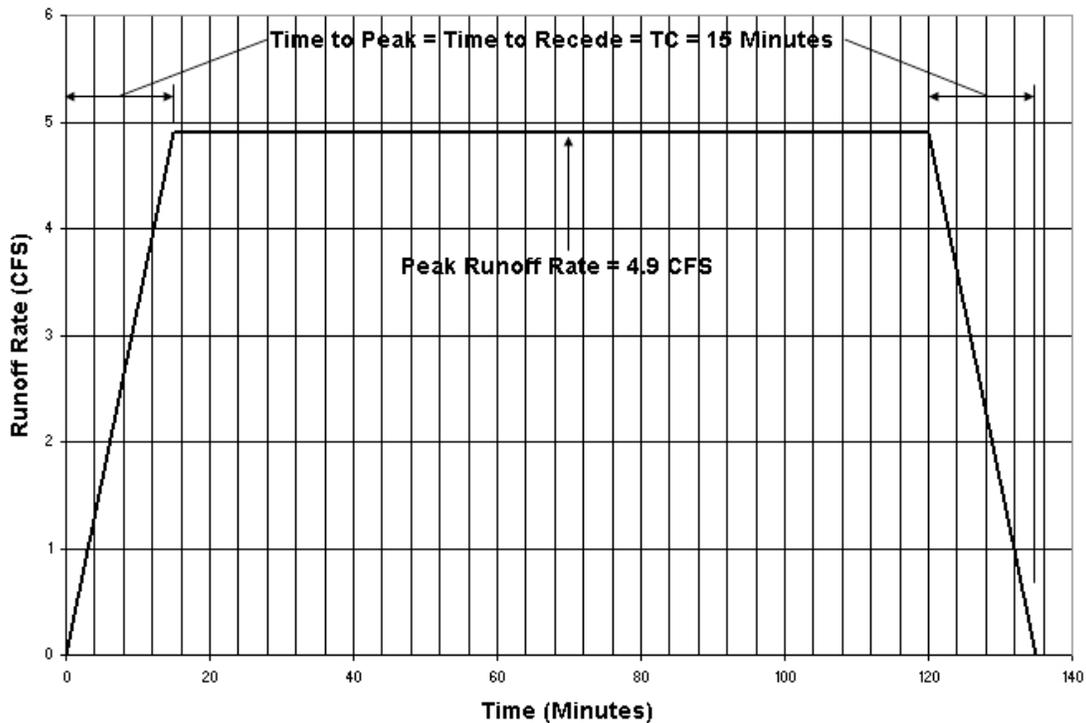
$$I = \text{rainfall intensity (inches per hour)}$$

$$A = \text{drainage area (acres)}$$

$$D = \text{storm duration (hours)}$$

$$Q = (0.78) (0.625 \text{ inches per hour})(10 \text{ acres}) = 4.9 \text{ CFS}$$

In the Modified Rational Method, the runoff hydrograph is then constructed as shown here:



Finally, the total runoff volume is equal to the area under the hydrograph, which is equal to the peak runoff rate times the duration of the storm.

$$V = \text{peak runoff rate} \times \text{storm duration} = Q \times D$$

$$V = 4.9 \text{ cubic feet/second} \times 2 \text{ hours} \times 3600 \text{ seconds/hour}$$

$$V = 35280 \text{ cubic feet} = 0.81 \text{ acre-feet}$$

Stormwater Quantity Storms

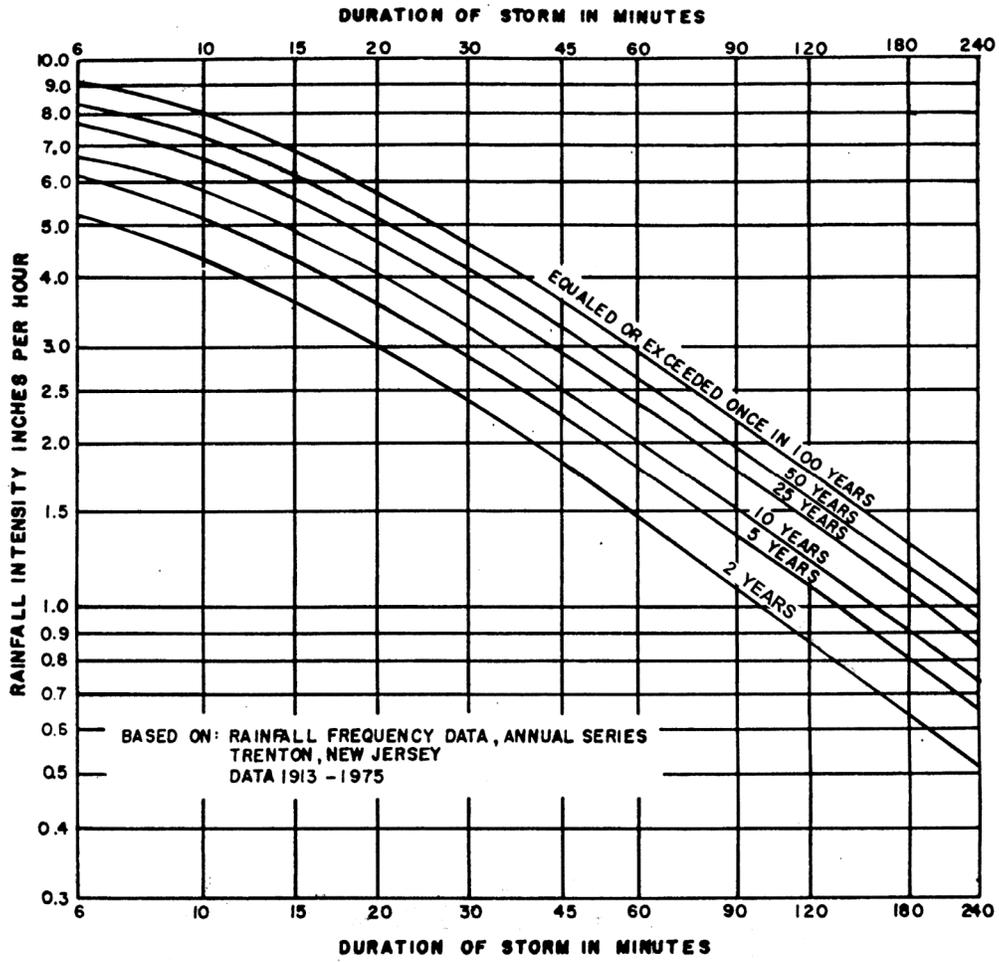
As described in the Stormwater Management Rules, the three storm frequencies of primary concern for stormwater quantity control are the 2, 10, and 100-year events. These storms are of such concern due to their potential to cause or aggravate downstream erosion and/or flooding. In certain instances, however, additional storm frequencies may need to be analyzed to ensure that downstream peak runoff rates and/or velocities are not increased by a land development or redevelopment project.

Selection of the appropriate stormwater quantity storm data will depend on the runoff estimation method being used. When using the NRCS methodology, the NRCS Type III Storm distribution should be selected. Details and data regarding this distribution can be found in the NRCS *Technical Release 55 – Urban Hydrology for Small Watersheds*. When using the Rational Method, the rainfall intensity-duration-frequency (IDF) curves shown in Figure 5-4 may be used. These curves were developed from Trenton area rainfall data between 1913 and 1975 and were adapted from Figure 2.1-2 in the *Technical Manual for Stream Encroachment Permits* prepared by the NJDEP Land Use Regulation Program. IDF curves based on rainfall data collected closer to an actual land development or redevelopment site may also be used if such data covers a sufficiently long time period and is analyzed by appropriate statistical methods.

Use of Long Term or Single Event Rainfall Data

As discussed in the *Fundamentals* section above, long term rainfall data for a watershed or development site may be used in certain runoff computations methods. Long term data can be used as input to the rainfall-runoff computations in place of a hypothetical, statistically-based design storm and, in certain instances, may be a more accurate or representative form of this input. In other instances, rainfall records from a significant historic storm in the watershed may also be used to test or verify a runoff computation or BMP design initially based on a hypothetical design storm. While the use of long term or single event rainfall data is not specifically required in the NJDEP Stormwater Management Rules, it is also not prohibited, since such uses may improve the effectiveness and/or reliability of a runoff computation or BMP design. Analysts and designers wishing to use such data should confer with the relevant review agencies prior to such use to ensure the suitability and acceptability of both the data and the computation method.

Figure 5-4: Rainfall Intensity-Duration-Frequency Curves



Note: Adapted from Figure 2.1-2 in the NJDEP *Technical Manual for Stream Encroachment Permits*.

Modeling Various Site Conditions

This section provides guidance for modeling various site conditions within a drainage area or watershed that may be encountered in the analysis and/or design of structural and nonstructural BMPs. This guidance is provided, where applicable, for the NRCS, Rational, and Modified Rational Methods and is intended to facilitate computation of required runoff volumes, peak rates, and hydrographs. A summary of the guidance for each computation method is presented at the end of this section in Table 5-2.

Pre-Developed Site Land Cover and Hydrologic Condition

As specified in the NJDEP Stormwater Management Rules, the predeveloped land cover at a development site must be assumed to be woods unless it can be verified that a different land cover has existed for at least five years prior to the analysis. Similarly, the predeveloped land cover must be assumed to be in good hydrologic condition for all land covers.

Sites With Pervious and Directly Connected Impervious Cover

It is virtually inevitable that a land development or redevelopment site will have a mixture of pervious and directly connected impervious surfaces, particularly under post-development conditions. As defined by the NRCS and others, impervious surfaces are directly connected when runoff from them can flow as shallow concentrated, channel, or pipe flow directly to the downstream drainage system. While such conditions pose no significant modeling problems for simple, linear methods such as the Rational and Modified Rational Methods, inaccuracies may occur for small rainfall depths when using more detailed, nonlinear methods such as the NRCS methodology. Analysis of such conditions using each method is presented here.

- **Rational and Modified Rational Methods:** Due to the linear character of the basic Rational Equation, a representative Rational Runoff Coefficient (C) can be computed for the entire site by standard area weighting techniques.
- **NRCS Methodology:** Due to the nonlinear character of the NRCS runoff equation and, primarily, the presence of the initial abstraction term I_a , inaccurate runoff estimates can result when the mixture of pervious and directly connected impervious surfaces within a drainage area or watershed are modeled with a weighted average NRCS Curve Number (CN). As discussed in the NRCS' TR-55, "the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place." This problem will be particularly acute for small rainfalls less than an inch or two where the large (but incorrect) initial loss can be 50 percent or more of the total rainfall.

To avoid these errors, it is recommended that runoff volumes be computed separately from the pervious and directly connected impervious portions of the drainage area and then combined into a weighted average runoff volume. This volume averaging technique produces more accurate estimates of total runoff volume than the standard average Curve Number approach. At a minimum, it should generally be used for all rainfalls less than approximately 4 inches in depth. This would include the 1.25-inch/2-hour stormwater quality design storm and the 1-year and 2-year 24-hour storms. The technique can also be used for larger rainfall depths at the designer's discretion.

Example 5-2 below further illustrates this problem and the recommended volume averaging solution for the stormwater quality design storm.

**Example 5-2: Site With Pervious and Directly Connected Impervious Cover
Runoff Volume Computation Using NRCS Methodology**

Description: A 3-acre development site is comprised of 1 acre of impervious surface and 2 acres of lawn and woods with an NRCS Curve Number (CN) of 65. The entire impervious surface is directly connected to the site's drainage system. Compute the site's total runoff volume for the 1.25-inch stormwater quality design storm using the Weighted Average CN technique. Compare the results with the Weighted Average Volume technique.

Stormwater Quality Design Storm = P = 1.25 inches

Total drainage area = 3 acres

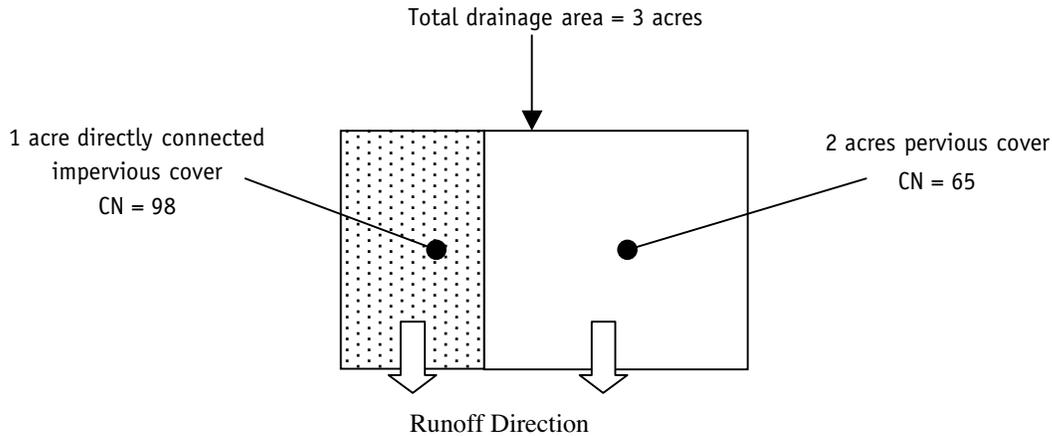
Impervious area = 1 acre (1/3 of total area)

Pervious area = 2 acres (2/3 of total area)

Pervious cover = mixture of lawn and woods Pervious CN = 65

Impervious cover = asphalt Impervious CN = 98

Note: All impervious cover is connected to the drainage system



1. Using Weighted Average Curve Number Technique

$$\text{Weighted CN} = (65)(2/3) + (98)(1/3) = 76$$

$$\text{Average } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{76} - 10 = 3.16 \text{ inches}$$

$$\text{Average initial abstraction} = I_a = 0.2S = (0.2)(3.16) = 0.63 \text{ inches}$$

$$0.8S = (0.8)(3.16) = 2.53 \text{ inches}$$

$$\text{Runoff volume} = Q = \frac{(P - 0.2 S)^2}{P + 0.8 S} = \frac{(1.25 - 0.63)^2}{1.25 + 2.53} = 0.10 \text{ inches}$$

$$\text{Runoff volume} = (0.10 \text{ inches}/12 \text{ inches per foot})(3 \text{ acres})(43,560 \text{ sf per acre})$$

Total site runoff volume = 1089 cubic feet

2. Using Weighted Average Volume Technique

Impervious Area

$$\text{Impervious area } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{98} - 10 = 0.20 \text{ inches}$$

$$\text{Impervious area initial abstraction} = 0.2S = (0.2)(0.20) = 0.04 \text{ inches}$$

$$0.8S = (0.8)(0.20) = 0.16 \text{ inches}$$

$$\text{Impervious area runoff volume} = Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(1.25 - 0.04)^2}{1.25 + 0.16} = 1.04 \text{ inches}$$

$$\text{Runoff volume} = (1.04 \text{ inches}/12 \text{ inches per foot})(1 \text{ acre})(43,560 \text{ sf per acre})$$

$$\text{Impervious area runoff volume} = 3775 \text{ cubic feet}$$

Pervious Area

$$\text{Pervious area } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{65} - 10 = 5.38 \text{ inches}$$

$$\text{Pervious area initial abstraction} = 0.2S = (0.2)(5.38) = 1.08 \text{ inches}$$

$$0.8S = (0.8)(5.38) = 4.30 \text{ inches}$$

$$\text{Pervious area runoff volume} = Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(1.25 - 1.08)^2}{1.25 + 4.30} = 0.005 \text{ inches}$$

$$\text{Runoff volume} = (0.005 \text{ inches}/12 \text{ inches per foot})(2 \text{ acres})(43,560 \text{ sf per acre})$$

$$\text{Pervious area runoff volume} = 36 \text{ cubic feet}$$

$$\text{Total site runoff volume} = 3775 + 36 = 3811 \text{ cubic feet} \\ \text{(vs. 1089 cubic feet using weighted average CN)}$$

As can be seen in Example 5-2 above, the weighted average CN technique produced an estimated stormwater quality design storm runoff volume that was less than 30 percent of the volume produced by the weighted average volume technique. Perhaps more significantly, the example also demonstrates how virtually the entire site runoff for the stormwater quality design storm comes from the impervious portion and that very little comes from the pervious portion (i.e., 3775 cubic feet vs. 36 cubic feet). The significant but erroneous initial loss that the NRCS cautions about in TR-55 can also be seen in the 0.63 inch initial abstraction for the entire site (including 1 acre of impervious surface) produced by the weighted average CN technique.

It is important to note that, in computing a weighted average runoff volume from the development site, Example 5-2 does not address the resultant peak discharge or hydrograph from the site. If both the pervious and directly connected impervious site areas will have the same time of concentration, the weighted runoff volume can then be used directly to compute the peak site discharge or hydrograph. However, if these areas will respond to rainfall with different times of concentration, separate hydrographs should be computed for each and then combined to produce the peak site discharge or hydrograph.

Sites with Unconnected Impervious Cover

As described in detail in *Chapter 2: Low Impact Development Techniques*, an important nonstructural BMP will be new impervious cover that is not directly connected to a site's drainage system. Instead, runoff from these impervious areas will sheet flow onto adjacent pervious areas, where a portion of the impervious area runoff will be given a second opportunity to infiltrate into the soil. Under certain conditions described below, this can help provide both groundwater recharge and stormwater quality treatment for small rainfalls as well as reduce the overall runoff volume that must be treated and/or controlled in a structural BMP downstream. Unconnected impervious areas may either be on-grade (e.g., a parking lot) or above-grade (e.g., a roof), while downstream pervious areas may either be constructed (e.g., lawn) or natural (e.g., woods or meadow).

In most circumstances, impervious areas can be considered unconnected under the following conditions:

1. All runoff from the unconnected impervious area must be sheet flow.
2. Upon entering the downstream pervious area, all runoff must remain as sheet flow.
3. Flow from the impervious surface must enter the downstream pervious area as sheet flow or, in the case of roofs, from downspouts equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.
5. All discharges onto the downstream pervious surfaces must be stable and nonerosive.
6. The shape, slope, and vegetated cover in the downstream pervious area must be sufficient to maintain sheet flow throughout its length. Maximum slope of the downstream pervious area is 8 percent.
7. The maximum roof area that can be drained by a single downspout is 600 square feet.

To determine the hydrologic effects of unconnected impervious cover, the combined effects of the impervious area disconnection and the subsequent infiltration in downstream pervious areas must be quantified. Techniques to do so are presented below.

- **Rational and Modified Rational Methods:** Due to the character of the basic Rational Equation, there is currently no technique for addressing the effects of unconnected impervious cover. As such, neither the Rational nor Modified Rational Methods can be recommended at this time for use at sites with unconnected impervious areas.
- **Methodology Using NRCS Equations:** Computation of the resultant runoff from unconnected impervious areas can be performed using two different methods. The first method is described in the NRCS TR-55. The second method is a two-step technique using the NRCS runoff equation. Both methods are discussed in detail below. Additional discussion and computed examples of unconnected impervious cover are presented in *Chapter 2: Low Impact Development Techniques*.
 - **NRCS TR-55 Methodology:** This method is based on the procedures to compute runoff from unconnected impervious surfaces described in the NRCS TR-55. Complete details of these procedures are described in Chapter 2 of TR-55. It should be noted that the TR-55 procedures are applicable only to sites with less than 30 percent total impervious coverage. In addition, the size of the downstream pervious area must be at least twice as large as the unconnected impervious area.
 - **Two-Step Technique:** This method is a two-step technique using the NRCS runoff equation. First, the resultant runoff from the unconnected impervious area should be computed separately, using the NRCS runoff equation in a manner similar to the technique described above for impervious surfaces. However, once the runoff from the unconnected impervious area is computed, it should then be considered as additional rainfall on the downstream pervious area it sheet flows onto. As a result, these pervious areas will effectively be subject to

their own direct rainfall as well as the “rainfall” flowing from the upstream unconnected impervious areas. The resultant runoff from the downstream pervious areas in response to this combined rainfall can then be computed using the NRCS runoff equation again.

Example 5-3 illustrates this two-step runoff computation technique for unconnected impervious areas. In reviewing the example, it is important to note that the unconnected impervious area runoff depth must be converted to an equivalent uniform rainfall depth over the entire downstream pervious area based on the relative sizes of the unconnected impervious and downstream pervious areas.

Example 5-3: Site With Unconnected Impervious Cover Runoff Volume Computation Using Two-Step Technique

Description: A 3-acre development site is comprised of 1 acre of impervious surface and 2 acres of lawn and woods with an NRCS Curve Number (CN) of 65. Runoff from the entire impervious surface sheet flows onto to the pervious portion of the site before entering the site’s drainage system. Compute the total runoff volume for the 1.25-inch stormwater quality design storm using the NRCS methodology.

Stormwater Quality Design Storm = P = 1.25 inches

Total drainage area = 3 acres

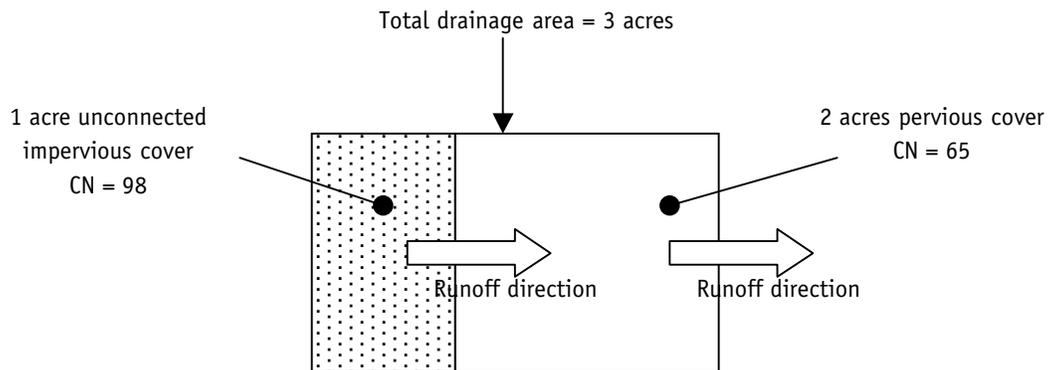
Impervious area = 1 acre (1/3 of total area)

Pervious area = 2 acres (2/3 of total area)

Pervious cover = mixture of lawn and woods pervious CN = 65

Impervious cover = asphalt impervious CN = 98

Note: All impervious area runoff sheet flows onto downstream pervious area



Impervious Area

$$\text{Impervious area } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{98} - 10 = 0.20 \text{ inches}$$

$$\text{Impervious area initial abstraction} = 0.2S = (0.2)(0.20) = 0.04 \text{ inches}$$

$$0.8S = (0.8)(0.20) = 0.16 \text{ inches}$$

$$\text{Impervious area runoff volume} = Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(1.25 - 0.04)^2}{1.25 + 0.16} = 1.04 \text{ inches}$$

$$\text{Runoff volume} = (1.04 \text{ inches}/12 \text{ inches per foot})(1 \text{ acre})(43,560 \text{ sf per acre})$$

$$\text{Impervious area runoff volume} = 3775 \text{ cubic feet}$$

$$\text{Equivalent rainfall depth on downstream pervious area} = \\ (3775 \text{ cubic feet}) / (2 \text{ acres})(43,560 \text{ sf per acre}) = 0.043 \text{ feet} = 0.52 \text{ inches}$$

Pervious Area

$$\text{Total effective rainfall} = \text{direct rainfall} + \text{unconnected impervious area runoff} \\ = 1.25 \text{ inches} + 0.52 \text{ inches} = 1.77 \text{ inches total}$$

$$\text{Pervious area } S = \frac{1000}{CN} - 10 = \frac{1000}{65} - 10 = 5.38 \text{ inches}$$

$$\text{Pervious area initial abstraction} = 0.2S = (0.2)(5.38) = 1.08 \text{ inches}$$

$$0.8S = (0.8)(5.38) = 4.30 \text{ inches}$$

$$\text{Pervious area runoff volume} = Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(1.77 - 1.08)^2}{1.77 + 4.30} = 0.08 \text{ inches}$$

$$\text{Runoff volume} = (0.08 \text{ inches} / 12 \text{ inches per foot})(2 \text{ acres})(43,560 \text{ sf per acre}) \\ = 581 \text{ cubic feet}$$

Pervious area runoff volume = total runoff volume = 581 cubic feet

From the above example, it can be seen that a key parameter in the two-step runoff computation technique for unconnected impervious cover is the effective size of the downstream pervious area. The following three criteria, in conjunction with the seven requirements for all unconnected impervious areas shown above, should be used to determine the effective size of this downstream area:

1. The minimum sheet flow length across the downstream pervious area is 25 feet.
2. The maximum sheet flow length across the unconnected impervious area is 100 feet.
3. While the total flow length area may be greater, the maximum sheet flow length across the downstream pervious area that can be used to compute the total resultant runoff volume is 150 feet.

These criteria are illustrated below in Figures 5-5 and 5-6 for both on-grade and above-grade unconnected impervious areas, respectively. Additional criteria for determining the lower limits of the downstream pervious area are presented in Figure 5-7. When using Figure 5-6 with overlapping pervious areas downstream of roof downspouts, the overlapping areas should be counted only once in the computation of the total pervious area downstream of the roof.

Finally, when computing the peak runoff rate or hydrograph from an area with unconnected impervious cover, the time of concentration of the combined impervious and downstream pervious area should be based upon the T_c of the downstream pervious area only, with the T_c route beginning as sheet flow at the upper end of the pervious area.

Figure 5-5: Downstream Pervious Area Criteria for On-Grade Unconnected Impervious Area

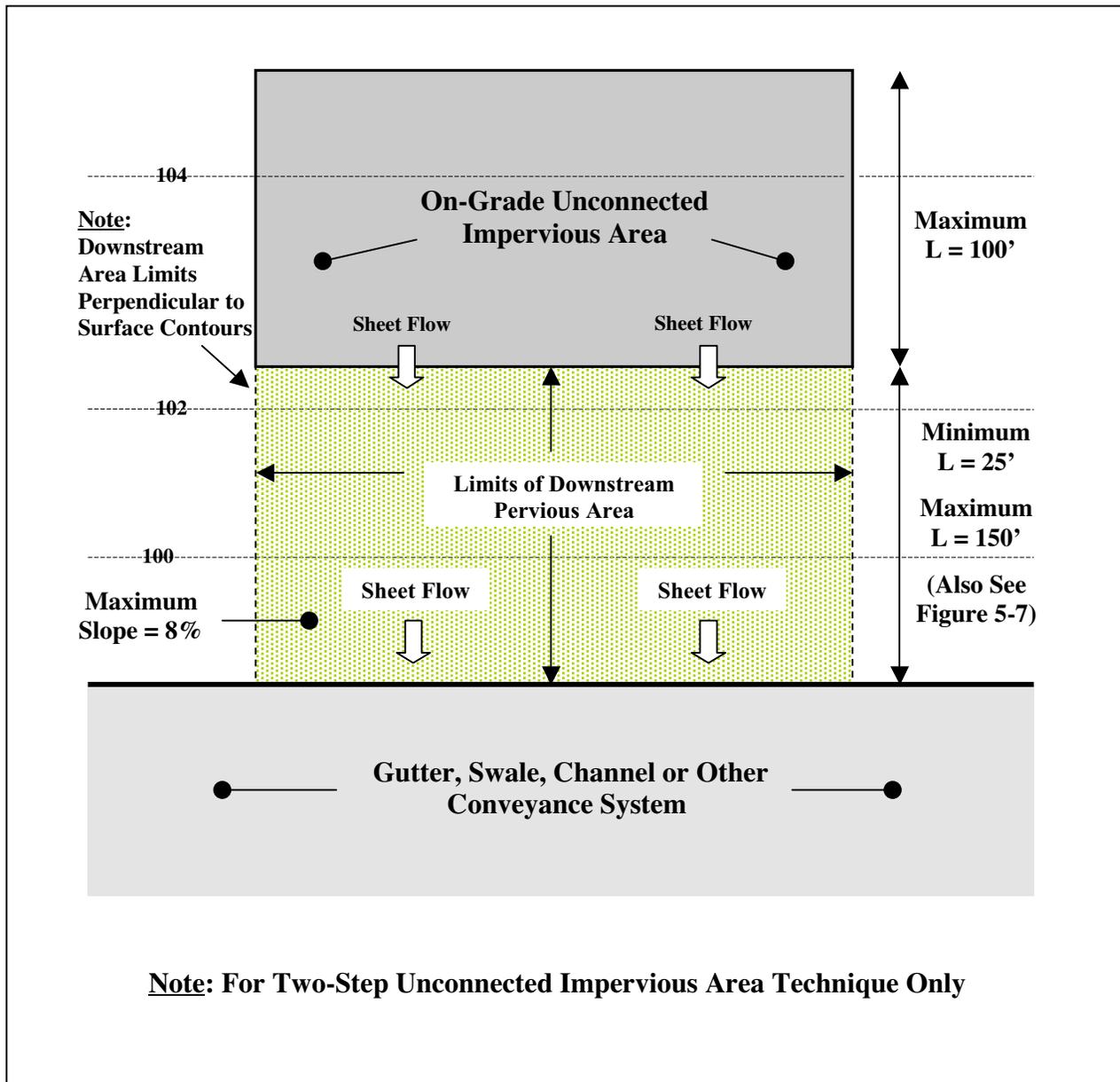


Figure 5-6: Downstream Pervious Area Criteria for Above-Grade Unconnected Impervious Area

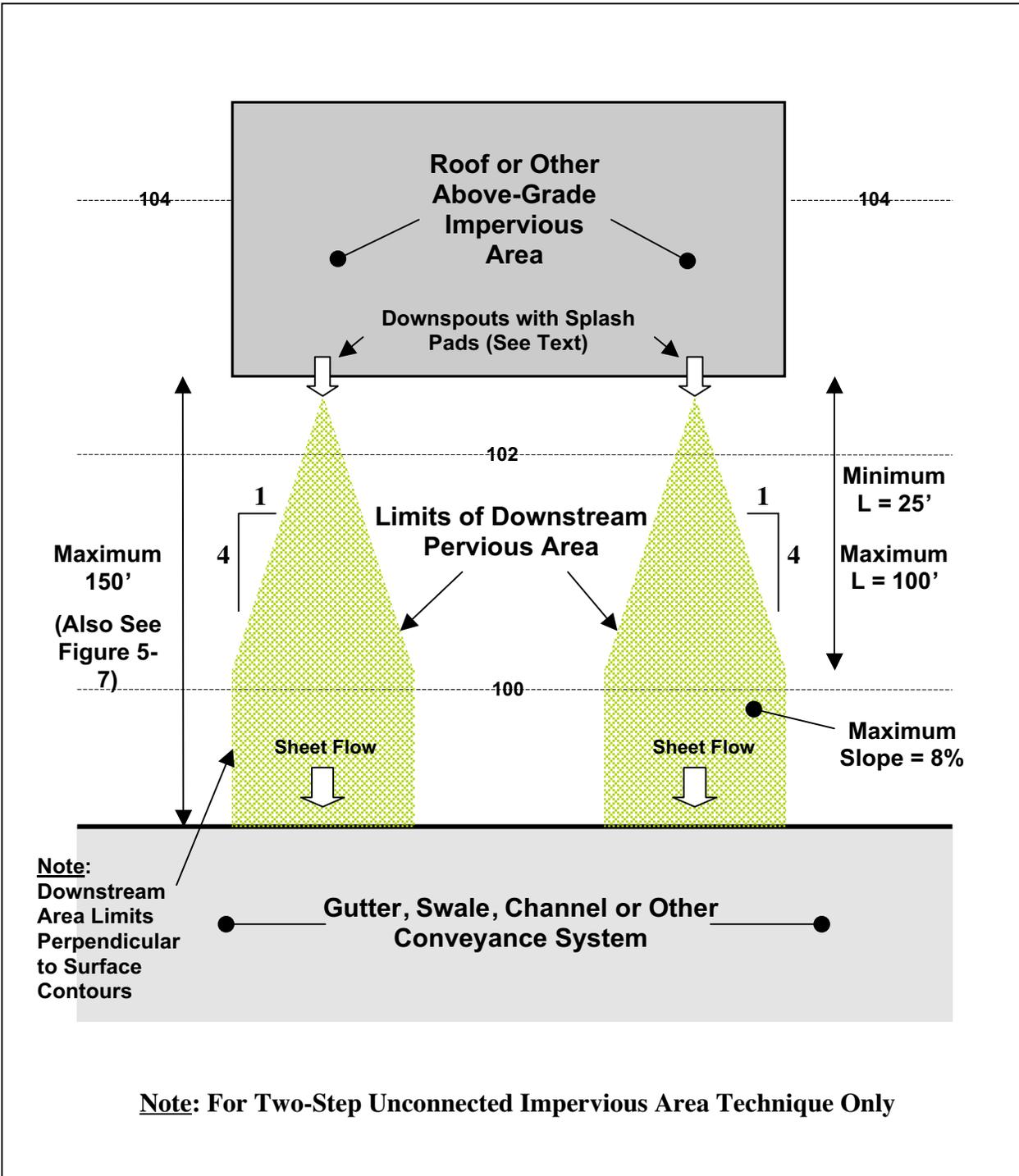
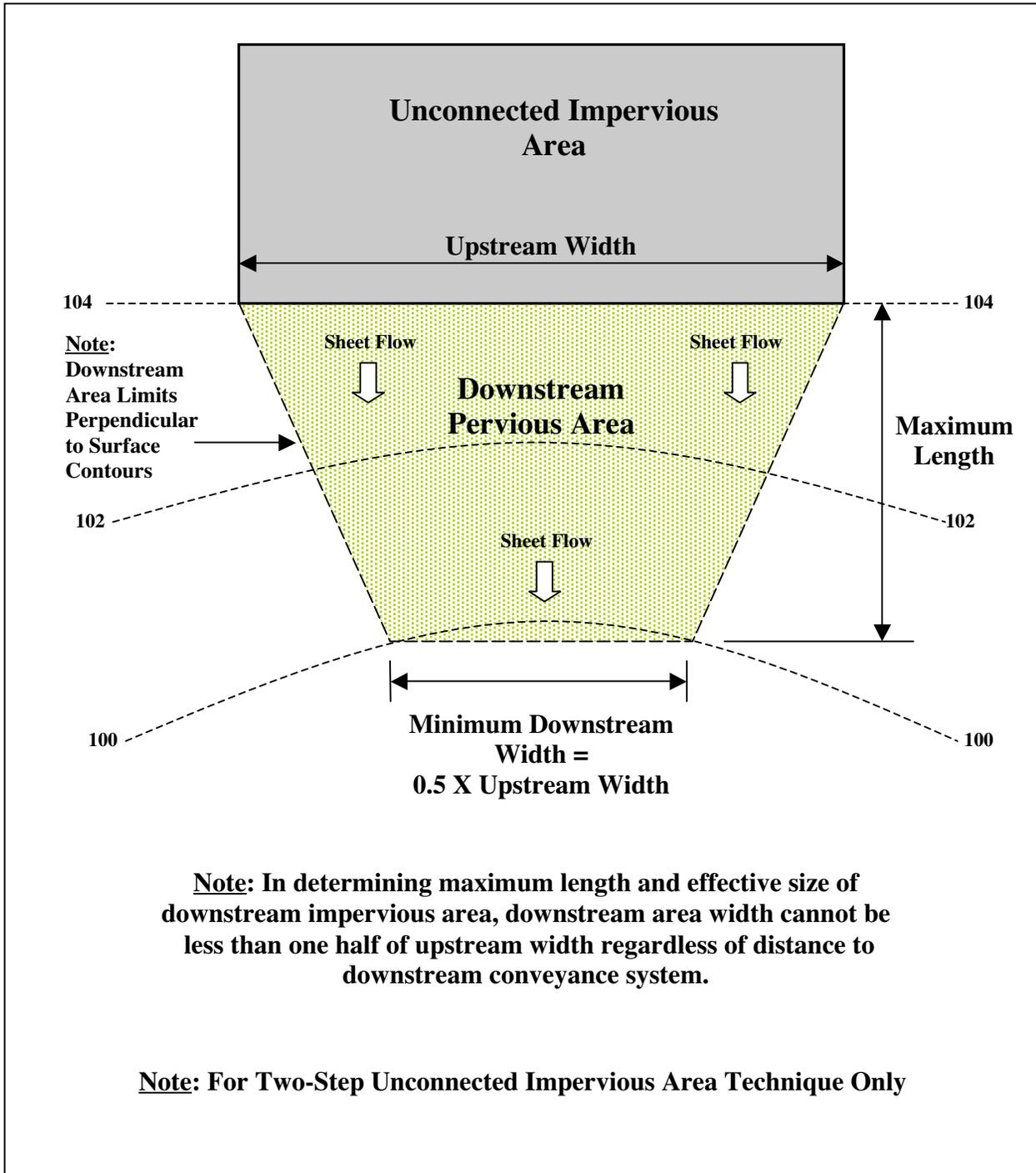


Figure 5-7: Additional Downstream Pervious Area Length and Effective Size Criteria



Sites With Groundwater Recharge

As required by the NJDEP Stormwater Management Rules and described in detail in *Chapter 6: Groundwater Recharge*, land development projects must maintain 100 percent of the site's annual pre-developed groundwater recharge. At most sites, this will require the design and construction of a groundwater recharge BMP that allows the runoff from the groundwater recharge design storm to infiltrate into the site's subsoil. This amount of infiltration can also be used by a designer to help meet the stormwater quality requirements of the Rules. Techniques to do so are presented below. However, to ensure downstream safety and channel stability, the amount of groundwater recharge provided at a development site *cannot* be considered when complying with the Rules' stormwater quantity requirements (i.e., control of the 2, 10, and 100-year storms).

Rational and Modified Rational Methods

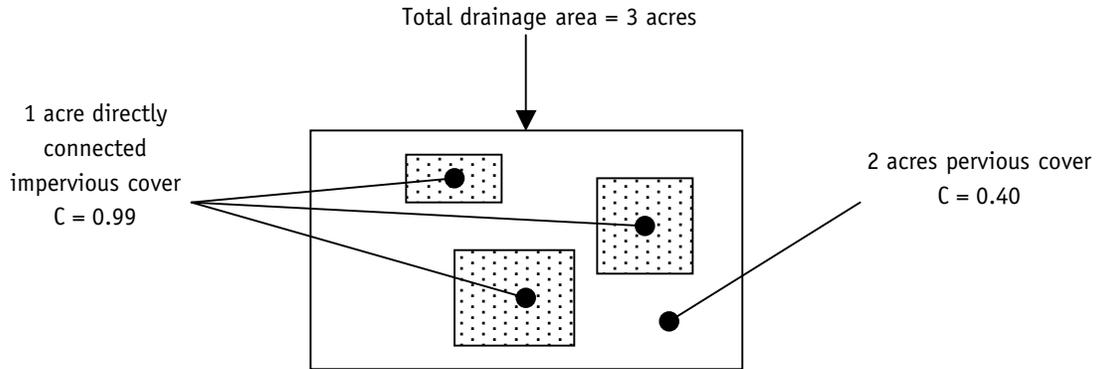
When computing a peak runoff rate for the stormwater quality design storm using the Rational Method, the size of that portion of the site that contributes runoff to the groundwater recharge BMP can be reduced by the ratio of the total groundwater recharge design storm to the 1.25-inch stormwater quality design storm. Similar procedures can be used in most instances to construct a reduced inflow hydrograph for use in the Modified Rational Method. Examples 5-4 and 5-5 below demonstrate these techniques.

Example 5-4: Sites With Groundwater Recharge Stormwater Quality Design Storm Peak Flow Computation Using Rational Method

Description: A 3-acre development site is comprised of 1 acre of impervious surface (Rational $C = 0.99$) and 2 acres of lawn and woods (Rational $C = 0.40$). The post-development time of concentration (T_c) is 20 minutes. All runoff from a 0.5-inch recharge design storm on the impervious surface is recharged. Runoff from larger storms on the impervious surface flows directly to the site's drainage system. Compute the site's total peak runoff rate for the 1.25-inch stormwater quality design storm using the Rational Method.

Recharge Design Storm = 0.5 inches on impervious cover only
Total Stormwater Quality Design Storm = 1.25 inches on entire site
Post-developed $T_c = 20$ minutes
Maximum Stormwater Quality Design Storm $I = 2.2$ inches (see Figure 5-3)

Total drainage area = 3 acres
Impervious area = 1 acre (1/3 of total area)
Pervious area = 2 acres (2/3 of total area)
Pervious cover = mixture of lawn and woods pervious $C = 0.40$
Impervious cover = asphalt impervious $C = 0.99$
Note: All impervious cover is directly connected to the drainage system



Adjusted impervious area due to recharge =

$$\text{Total impervious area} \times \frac{(\text{Stormwater Quality Design Storm} - \text{Groundwater Recharge Design Storm})}{\text{Stormwater Quality Design Storm}}$$

$$= 1 \text{ acre} \times \frac{(1.25 \text{ inches} - 0.5 \text{ inches})}{1.25 \text{ inches}}$$

$$= 1 \text{ acre} \times \frac{0.75 \text{ inches}}{1.25 \text{ inches}} = 1 \text{ acre} \times 0.6 = 0.6 \text{ acres}$$

Adjusted total site area = 0.6 acres impervious + 2.0 acres pervious = 2.6 acres

$$\text{Composite site } C = \frac{(0.6 \text{ acres impervious} \times 0.99) + (2.0 \text{ acres pervious} \times 0.40)}{2.6 \text{ acres total}}$$

$$= \frac{0.59 + 0.8}{2.6} = \frac{1.39}{2.6} = 0.53$$

Peak Stormwater Quality Design Storm runoff rate = C I A

$$= 0.53 \times 2.2 \text{ inches per hour} \times 2.6 \text{ acres} = 3.0 \text{ CFS}$$

Note: Without considering groundwater recharge credit, the peak rate would be:

Total area = 3.0 acres

$$C = \frac{(1.0 \times 0.99) + (2.0 \times 0.40)}{3.0} = \frac{1.79}{3.0} = 0.60$$

Peak stormwater quality runoff rate = 0.60 x 2.2 x 3.0 = 4.0 CFS

Example 5-5: Sites With Groundwater Recharge
Stormwater Quality Design Storm Hydrograph Using Modified Rational Method

Description: For land development site described in Example 5-4 above, compute runoff hydrograph for entire site using Modified Rational Method.

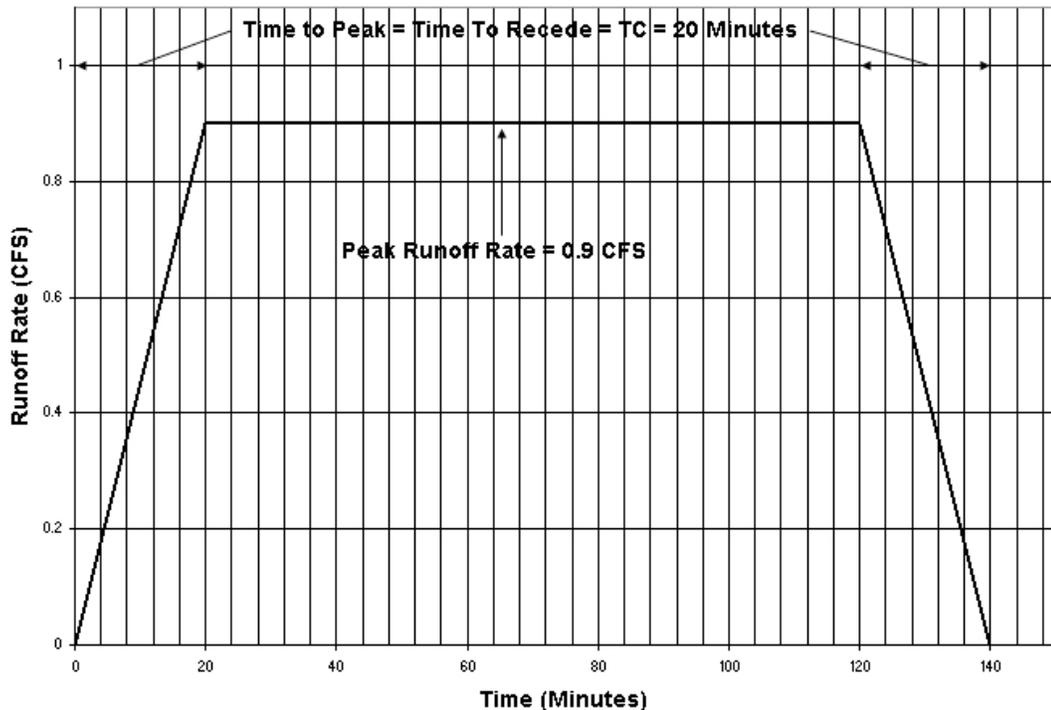
Adjusted total site area = 2.6 acres

Composite site C = 0.54

Average Stormwater Quality Design Storm I = 1.25-inches/2- hours = 0.625 inches per hour

$Q = C I A = 0.54 \times 0.625 \times 2.6 \text{ Acres} = 0.9 \text{ CFS}$

The Modified Rational Method runoff hydrograph is then constructed as shown below:



Note: See Example 5-1 for procedures to construct Modified Rational Method runoff hydrograph. Also see Important Note on page 5-8 regarding use of Modified Rational Method to compute a runoff hydrograph for the stormwater quality design storm.

It is important to note in Examples 5-4 and 5-5 that runoff from only a portion of the site was recharged during the 0.5-inch groundwater recharge design storm and that those areas were distributed throughout the site. This means that the remaining site areas would still be capable of generating runoff and that the overall site would produce runoff throughout the entire stormwater quality design storm. These conditions permitted the assumptions inherent in the Rational and Modified Rational Methods to be reasonably met when computing both the peak runoff rate and hydrograph from the larger, 1.25-inch stormwater quality design storm. Such site conditions are expected to be typical of most land developments.

However, in cases where the groundwater recharge design storm runoff from the entire drainage area is recharged, the assumptions of the Rational and Modified Rational Methods cannot be met. As such, neither method can be recommended for computing the peak site runoff if the recharge volume is to be considered. In such cases, the designer can either continue to use either method without considering the recharge volume or use the NRCS methodology with the actual, nonlinear stormwater quality design storm as shown in Figure 5-2 and Table 5-1.

NRCS Methodology

When using the NRCS methodology to compute the total stormwater quality design storm runoff volume from a development site where all or a portion of the site's groundwater recharge design storm runoff is recharged, the relative amount of recharged runoff volume can be deducted from the total stormwater quality design storm volume. However, due to the nonlinearity of the NRCS runoff equation, such a deduction must be based on the *volume* of groundwater recharge design storm runoff from the recharged area and not simply the size of the recharged areas. Example 5-6 below describes this technique. When computing the peak stormwater quality design storm runoff rate or hydrograph from such a site with the NRCS methodology, it will be necessary to route the stormwater quality design storm hydrograph through the recharge facility. Since the recharge facility will be designed to contain only the normally smaller groundwater recharge design storm, an accurate stage-discharge relationship for the facility's overflow must be included in the routing computations in order to obtain an accurate peak runoff rate or hydrograph.

Example 5-6: Sites With Groundwater Recharge Stormwater Quality Design Storm Volume Using NRCS Methodology

Description: A 3-acre development site is comprised of 1 acre of impervious surface and 2 acres of lawn and woods with an NRCS Curve Number (CN) of 65. Runoff from the entire impervious surface is recharged during a 0.5-inch groundwater recharge design storm. Runoff from larger storms on the impervious surface flows directly to the site's drainage system. Compute the total stormwater quality design storm runoff volume from the site using the NRCS methodology.

Groundwater Recharge Design Storm = 0.5 inches on impervious cover only

Total Stormwater Quality Design Storm = 1.25 inches on entire site

Total drainage area = 3 acres

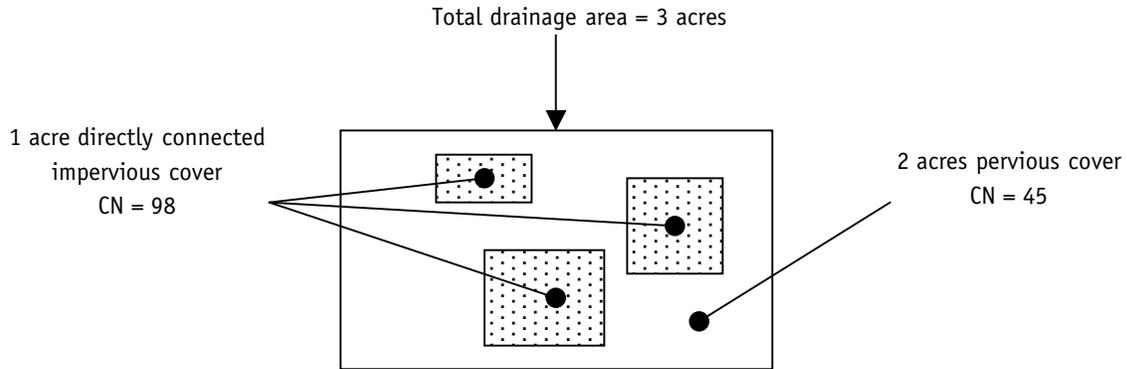
Impervious area = 1 acre (1/3 of total area)

Pervious area = 2 acres (2/3 of total area)

Pervious cover = mixture of lawn and woods pervious CN = 65

Impervious cover = asphalt impervious CN = 98

Note: All impervious cover is directly connected to the drainage system



Impervious Area

$$\text{Impervious area } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{98} \pm 10 = 0.20 \text{ inches}$$

$$\text{Impervious area initial abstraction} = 0.2S = (0.2)(0.20) = 0.04 \text{ inches}$$

$$0.8S = (0.8)(0.20) = 0.16 \text{ inches}$$

Groundwater Recharge Design Storm = 0.5 inches

$$\begin{aligned} \text{Recharged runoff volume for Groundwater Recharge Design Storm} &= Q = \frac{(P - 0.2 S)^2}{P + 0.8 S} \\ &= \frac{(0.50 - 0.04)^2}{0.50 + 0.16} = 0.32 \text{ inches} \end{aligned}$$

Stormwater Quality Design Storm = 1.25 inches

$$\begin{aligned} \text{Runoff volume for Stormwater Quality Design Storm} &= Q = \frac{(P - 0.2 S)^2}{P + 0.8 S} \\ &= \frac{(1.25 - 0.04)^2}{1.25 + 0.16} = 1.04 \text{ inches} \end{aligned}$$

$$\text{Difference in runoff volumes} = 1.04 \text{ inches} - 0.32 \text{ inches} = 0.72 \text{ inches}$$

Net impervious area runoff volume =

$$\begin{aligned} &(0.72 \text{ inches}/12 \text{ inches per foot})(1 \text{ acre})(43,560 \text{ SF per acre}) \\ &= 2614 \text{ cubic feet} \end{aligned}$$

Pervious Area

$$\text{Pervious area } S = \frac{1000}{\text{CN}} - 10 = \frac{1000}{65} \pm 10 = 5.38 \text{ inches}$$

$$\text{Pervious area initial abstraction} = 0.2S = (0.2)(5.38) = 1.08 \text{ inches}$$

$$0.8S = (0.8)(5.38) = 4.30 \text{ inches}$$

$$\text{Pervious area runoff volume} = Q = \frac{(P - 0.2 S)^2}{P + 0.8 S} = \frac{(1.25 - 1.08)^2}{1.25 + 4.30} = 0.005 \text{ inches}$$

$$\text{Runoff volume} = (0.005 \text{ inches}/12 \text{ inches per foot})(2 \text{ acres})(43,560 \text{ SF per acre})$$

$$\text{Total pervious area runoff volume} = 36 \text{ cubic feet}$$

$$\text{Total site runoff volume} = 2614 + 36 = 2650 \text{ cubic feet}$$

Note: in Example 5-2, where none of the impervious surface runoff was recharged, the same site produced 3811 cubic feet of runoff for the stormwater quality design storm.

Time of Concentration Considerations

Computation of a peak runoff rate or hydrograph will require an estimate of a drainage area's time of concentration (Tc). In performing Tc calculations, designers should consider the following factors.

- **Maximum sheet flow length:** When using the segmental Tc procedures contained in Chapter 3 of the NRCS *Technical Release 55 – Urban Hydrology for Small Watersheds* (TR-55), the maximum sheet flow length recommended by the NRCS is 150 feet. According to the NRCS, longer lengths may be used only in special cases, such as smooth, uniformly graded parking lots or athletic fields. In addition, it may be appropriate to use a longer sheet flow length in wooded areas with Hydrologic Soil Group A or B soils and ground slopes of 2 percent or flatter. In such areas, high infiltration rates, low sheet flow velocities, and the presence of surface irregularities that store and infiltrate runoff may limit the generation of runoff to such an extent that a larger than normal area (and therefore a longer than normal sheet flow length) is needed to produce sufficient runoff rates to exceed sheet flow depths and create shallow concentrated flow.
- **Maximum sheet flow roughness coefficient:** According to the NRCS, the maximum Manning's Roughness Coefficient (n) to be used in the Sheet Flow Equation in Chapter 3 of TR-55 is 0.040.
- **Tc routes:** Consideration must be given to the hydraulic conditions that exist along a selected Tc route, particularly in pre-developed drainage areas. Tc routes should not cross through significant flow constrictions and ponding areas without considering the peak flow and time attenuation effects of such areas. As noted in the NJDEP Stormwater Management Rules, such areas can occur at hedgerows, undersized culverts, fill areas, sinkholes, and isolated ponding areas. In general, a separate subarea tributary to such areas should be created and its runoff routed through the area before combining with downstream runoff.
- In certain areas with highly irregular topography, large surface storage volumes, high soil infiltration rates, and/or Karst topography, the segmental Tc method described in Chapter 3 of TR-55 may not be appropriate. In such areas, alternative Tc methods should be used.

**Table 5-2: Summary of Modeling Guidance for Various Site Conditions
Rational, Modified Rational and NRCS Methods¹**

Site Condition or Parameter	Rational Method	Modified Rational Method	NRCS-Based Methods
Mixture of pervious and directly connected impervious surface	Use standard procedures	Use standard procedures	Use weighted average runoff volume
Unconnected impervious surface	Use not recommended	Use not recommended	TR-55 or Two-Step Technique
Groundwater recharge areas	Reduce effective size of recharge area ²	Reduce effective size of recharge area ²	Reduce runoff volume by recharge volume
Time of concentration	Maximum sheet flow length = 150 feet Maximum sheet flow n = 0.40 Include effects of storage and ponding areas		

Notes: Table presents summaries only. See text for complete descriptions for each computation method.

For sites with combination of recharge and non-recharge areas. Methods not recommended where entire area is recharged. See text for details.

References

- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Lucas, W.C. October 2002. DURMM: Delaware Urban Runoff Management Model Users Manual. Delaware Department of Natural Resources and Environmental Conservation.
- McCuen, Richard H. Development and Evaluation of TR-55 Composite Curve Number for Unconnected Imperviousness.
- Northeast National Technical Center. June 1986. Hydrology Technical Note No. N4 – Time of Concentration. USDA Natural Resources Conservation Service.
- Northeast National Technical Center. 1986. Memorandum: Sheet Flow in the Northeast. USDA Natural Resources Conservation Service.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection, Land Use Management Program. September 1995. Technical Manual for Stream Encroachment Permits.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Pitt, R., J. Lantrip and R. Harrison. December 1999. Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity. U.S. Environmental Protection Agency.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C. Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.
- U.S. Army Corps of Engineers Hydrologic Engineering Center. HEC-1 Flood Hydrograph Package Users Manual.
- U.S. Army Corps of Engineers Hydrologic Engineering Center. HEC-HMS Hydrologic Modeling System Users Manual.
- USDA Natural Resources Conservation Service. National Engineering Handbook, Part 630, Hydrology.
- USDA Natural Resources Conservation Service. Technical Release 20 – Project Formulation – Hydrology.
- USDA Natural Resources Conservation Service. June 1986. Technical Release 55 – Urban Hydrology for Small Watersheds.
- USDA Natural Resources Conservation Service. April 2002. Win-TR55 – User Manual.
- Viessman, W. Jr., J.W. Knapp, G.L. Lewis and T.E. Harbaugh. 1977 Introduction to Hydrology – Second Edition. Harper & Row. New York.
- Walesh, S.G. 1989. Urban Surface Water Management. John Wiley & Sons, Inc. New York.
- Wanielista, M.P. and Y.A. Yousef. 1993. Stormwater Management. John Wiley & Sons, Inc. New York.
- Whipple, W., N.S. Grigg, T. Grizzard, C.W. Randall, R.P. Shubinski and L.S. Tucker. 1983. Stormwater Management in Urbanizing Areas. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

New Jersey Stormwater Best Management Practices Manual

April 2004

C H A P T E R 6

Groundwater Recharge

This chapter presents the standards, data, and procedures necessary to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. According to these Rules, a “major development” project, which is one that disturbs at least 1 acre of land or creates at least 0.25 acres of new or additional impervious surface, must include nonstructural and/or structural stormwater management measures that prevent the loss of groundwater recharge at the project site. This requirement is included in the Rules because the loss of groundwater recharge can adversely impact the health of streams and wetlands and the yield of water supply wells. Urban redevelopment and certain linear development projects are exempt from the groundwater recharge requirements, while waivers may be obtained under certain conditions for public roadway, railroad, and pedestrian walkway enlargements. Complete details can be found in Subchapter 5 of the Stormwater Management Rules.

Specifically, the Stormwater Management Rules require that a proposed major land development comply with one of the following two groundwater recharge requirements:

- Requirement 1:** That 100 percent of the site’s average annual pre-developed groundwater recharge volume be maintained after development; or
- Requirement 2:** That 100 percent of the difference between the site’s pre- and post-development 2-Year runoff volumes be infiltrated.

The Stormwater Management Rules allow the site designer to select which requirement to follow. The Rules also state that compliance with either of the above alternative requirements must be demonstrated through hydrologic and hydraulic analysis. Regardless of which alternative requirement is selected, such an analysis will generally begin with a computation of the existing (or pre-developed) hydrologic conditions at the proposed development site. In the case of Requirement 1, these conditions will focus on the annual amount of groundwater recharge that occurs at the site under pre-developed conditions while, for Requirement 2, the focus will instead be on the pre-developed volume of 2-Year site runoff.

These computations will then be followed by similar ones for the proposed (or post-developed) conditions at the site. A comparison of the results of either of these pre- and post-development computations will then yield the annual volume of groundwater that must be recharged (Requirement 1) or 2-Year storm runoff volume that must be infiltrated (Requirement 2) through one or more structural recharge or infiltration BMPs. Ideally, the planning and design of the proposed site will have incorporated nonstructural measures to such an extent that the need for structural facilities is reduced to a practical minimum.

Finally, once the analysis of pre- and post-development conditions has established the need for structural recharge (Requirement 1) or infiltration (Requirement 2) BMPs, the hydrologic and hydraulic analysis would next focus on the actual design of such facilities. This process would include answering such questions such as:

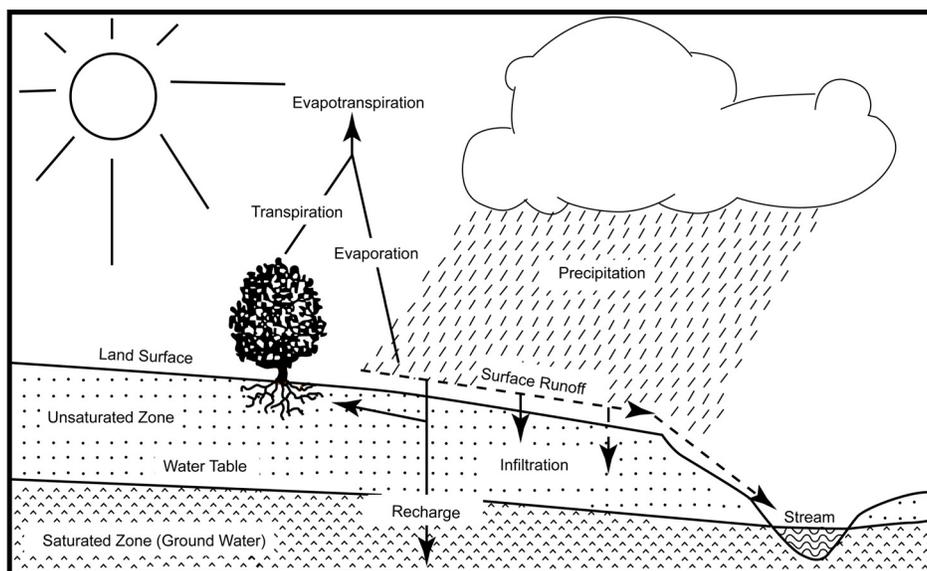
- Should the required recharge or infiltration be achieved at a single facility or several located throughout the development site?
- Should the facilities be located above or below ground?
- Which portions of the development site should be utilized to generate runoff to the facilities?
- What facility dimensions are required?
- Where should the facilities be located on the site relative to buildings, septic systems, property lines, and other sensitive areas?

This chapter presents the groundwater recharge information necessary to perform the hydrologic and hydraulic analysis required for Requirement 1 (maintaining pre-developed annual recharge volumes). Information necessary for the analysis required for Requirement 2 (infiltrating the increased 2-Year runoff volume) is presented in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Design information regarding structural recharge and infiltration BMPs can be found in this chapter and *Chapter 9: Structural Stormwater Management Measures*.

Fundamentals

In both the NJDEP Stormwater Management Rules and this manual, groundwater recharge is defined as precipitation that infiltrates into the soil and is not evapotranspired. Instead, the infiltrated precipitation moves downward to a depth below the root zone of the surface vegetation, where it cannot be removed by that vegetation through uptake and evapotranspiration. At such a depth, it is considered available to enter the soil's saturated zone and become groundwater. The role of groundwater recharge in the overall hydrologic cycle is illustrated in Figure 6-1 below.

Figure 6-1: Groundwater Recharge in the Hydrologic Cycle



Source: New Jersey Geological Survey Report GSR-32.

According to the New Jersey Geological Survey (NJGS):

The potential for natural groundwater recharge begins with precipitation (rain, snow, hail, sleet). Some of the precipitation never seeps into the soil, but instead leaves the system as surface runoff. The water that seeps into the soil is infiltration. Part of the water that does infiltrate is returned to the atmosphere through evapotranspiration. Evapotranspiration refers to water that is returned to the atmosphere from vegetated areas by evaporation from the soil and plant surfaces and soil water that is taken up by plant roots and transpired through plant leaves or needles. Infiltrated water that is not returned to the atmosphere by evapotranspiration moves vertically downward and, upon reaching the saturated zone, becomes ground water. This ground water could be in a geologic material that is either an aquifer or nonaquifer, depending on whether it can yield satisfactory quantities to wells. (NJGS GSR-32)

In addition to supplying water to wells, groundwater can also provide base flow to streams, wetlands, and other water bodies, directly affecting the ecology and geomorphology of these resources.

The potentially adverse impacts of land development on groundwater recharge have long been recognized. From the description presented above, it can be seen that land development activities that either cover permeable soils with impervious surfaces or reduce the soils' permeability through disturbance and compaction will reduce the rate of groundwater recharge that occurs under pre-developed site conditions. As noted above, such reductions in groundwater recharge can adversely impact streams, wetlands, and other water bodies by reducing the volume and rate of base flow to them. Reductions in groundwater recharge to aquifers can also adversely impact the yield of water supply wells. As a result, the New Jersey Stormwater Management Rules require that pre-developed groundwater recharge rates be maintained at land development sites under post-development conditions.

Computing Groundwater Recharge

Overview

As described above, the groundwater recharge requirements of the NJDEP Stormwater Management Rules can be met by demonstrating that the average volume of precipitation that is annually recharged to the groundwater at a major land development site under pre-developed conditions will be maintained following site development. As described in detail below, this can be achieved through a combination of natural recharge over the developed site's pervious surfaces and artificial recharge through groundwater recharge BMPs constructed at the site. The BMP volume is based on an average annual distribution of runoff-producing precipitation events at the site, the impervious drainage area to the BMP, and the losses that may occur to the infiltrated runoff before it can travel below the root zone of surrounding vegetation and become groundwater.

The data and analytic procedures necessary to meet these requirements have been developed by the New Jersey Department of Environmental Protection (NJDEP) with assistance from the New Jersey Geologic Survey (NJGS), the U.S. Geologic Survey (USGS), and professional consultants, and have been compiled into the New Jersey Groundwater Recharge Spreadsheet (NJGRS), a Microsoft Excel-based computer spreadsheet program. The NJGRS is intended for use by site planners, designers, engineers, and reviewers to determine average annual groundwater recharge amounts under both pre- and post-development site conditions and to design the groundwater recharge BMPs necessary to maintain 100 percent of the pre-developed site's annual groundwater recharge rate. Information regarding the NJGRS, including a detailed User's Guide, an example problem, and instructions on how to download the NJGRS from the NJDEP stormwater management website, is presented below. Details of the program's theoretical basis, equations, and supporting databases are also summarized.

In general, the analytic procedures utilized by the NJGRS to achieve compliance with the groundwater recharge requirements of the Stormwater Management Rules (described as Requirement 1 above) can be summarized by the following computational steps:

1. Compute the average amount of annual groundwater recharge occurring over the land development site under pre-developed site conditions.
2. Compute the average amount of annual groundwater recharge occurring over the land development site under post-developed conditions. Such site conditions should reflect the use, to the maximum extent practicable, of nonstructural stormwater management measures at the post-developed site in accordance with the Stormwater Management Rules. Details of such nonstructural measures are presented in *Chapter 2: Low Impact Development Techniques*.
3. Compute any resulting annual groundwater recharge deficit by subtracting the post-developed annual recharge amount in Step 2 from the pre-developed annual amount in Step 1. This deficit represents the average annual amount of groundwater recharge that must be achieved at the development site through structural groundwater recharge BMPs.
4. Determine the storage volume and related dimensions of the structural groundwater recharge BMP that will be required to satisfy the average annual groundwater recharge deficit computed in Step 3 above. In doing so, the BMP volume must be based on the average annual distribution of runoff-producing precipitation events at the development site, the size of the drainage area over which these events will occur (and from which runoff will be collected or captured for recharge), and the infiltration, evapotranspiration, and other losses that may occur to the recharged runoff in the BMP before it can actually enter the groundwater.

Theoretical Basis of Computations

Computation of the average annual groundwater recharge at a land development site under either pre- or post-developed conditions (as described above in Steps 1 and 2) can be performed with the New Jersey Groundwater Recharge Spreadsheet (NJGRS). This Microsoft Excel-based spreadsheet is based on the data and computational procedures contained in the 1993 *Geological Survey Report GSR-32: A Method for Evaluating Ground Water Recharge Areas in New Jersey* developed by the NJGS. As described in the report, GSR-32 utilizes precipitation, soil, land cover, and climate data, and rainfall-runoff and mass balance computations to estimate average annual groundwater recharge amounts at sites within any New Jersey municipality under a variety of surface and development conditions. All pertinent GSR-32 databases and computational algorithms have been incorporated into the NJGRS. As such, use of the NJGRS is governed, in part, by the assumptions and limitations of GSR-32.

Design of the required recharge BMP (as described in Step 4 above) to compensate for the developed site's groundwater recharge deficit (as described in Step 3 above) can also be performed with the NJGRS. The design computations in the NJGRS are based on a number of analytic techniques and databases. Conceptually, a groundwater recharge BMP will recharge the runoff it receives from its drainage area for all storms up to a particular precipitation depth, which can be referred to as the BMP's groundwater recharge design storm. While the recharge BMP will also receive runoff from larger storms, it will only recharge that portion of the runoff that equals the Recharge Design Storm runoff. The remaining runoff from these larger storms will overflow or otherwise bypass the BMP. It is important to note that the range of precipitation depths typically involved in the design of a groundwater recharge BMP are relatively small when compared to depths associated with runoff quality or quantity control. As a result, the NJGRS requires that the entire drainage area to a recharge BMP be impervious, since pervious surfaces would typically not be able to produce a sufficient amount of rechargeable runoff from such small precipitation depths.

Assuming that all of the precipitation falling in a recharge BMP's impervious drainage area can be collected and recharged (i.e., no runoff, infiltration, or recharge losses), computation of the BMP's Recharge Design Storm depth can be conceptually illustrated with the following conversion equation:

$$\begin{array}{r} \text{Total Average} \\ \text{Annual Recharge} \\ \text{Deficit} \end{array} = \begin{array}{r} \text{Annual Sum of} \\ \text{Recharge Design and} \\ \text{Smaller Storm} \\ \text{Depths} \end{array} + \left[\begin{array}{r} \text{Recharge Design} \\ \text{Storm Depth} \end{array} \times \begin{array}{r} \text{Number of} \\ \text{Larger} \\ \text{Storms} \end{array} \right]$$

The above equation shows that, with appropriate precipitation data and ignoring all losses, the total annual recharge deficit at a land development site can be converted to the sum of two precipitation amounts, both of which are based on a single groundwater recharge design storm. The first amount is the sum of all storm depths up to and including the Recharge Design Storm that would occur at the site in an average year. The second amount is the product of the Recharge Design Storm depth times the number of larger storms that would also occur at the site in that same average year.

Unfortunately, most of the ease and simplicity of the conversion equation shown above is gained through its two assumptions: that appropriate precipitation data is available, and that all of the precipitation falling on the BMP's impervious drainage area can be recharged without loss. In reality, compiling such precipitation data for a specific land development site requires considerable effort and resources and must be repeated for each new development site. In addition, precipitation losses will occur and must be taken into consideration in the design of a recharge BMP. As noted above, these losses, which will vary with the total precipitation depth, include those occurring in the conversion of precipitation to runoff, including surface storage, evaporation, and infiltration through cracks, joints, and seams in the drainage area's impervious surface. Further losses will occur once the runoff is delivered to the recharge BMP, primarily in

the form of evapotranspiration by the vegetation above, beneath, and/or adjacent to the BMP. Further complications arise when one attempts to estimate these variable losses. While equations exist to predict such losses for individual storm events, there are none readily available that can do so for an annual precipitation depth.

The NJGRS addresses these problems in several ways. Regarding the need for appropriate precipitation data for all possible development site locations in New Jersey, the NJGRS developers compiled and analyzed 52 years of daily precipitation data collected at 92 precipitation stations throughout New Jersey between 1948 and 1999. To ensure a proper database, only precipitation depths greater than 0.04 inches were considered, since this depth was considered the minimum amount necessary to produce runoff from impervious surfaces. All daily values at each station were sorted for each year and then averaged over the 52 year period of record. Next, all values with the same rank were averaged across all 92 stations to produce an average annual series of 79 precipitation events for the state. Finally, this series was normalized by dividing each event value by 46.32 inches, which was the average annual precipitation for the 92 stations. This produced an average annual series of 79 precipitation events, expressed as a percentage of total annual precipitation, that are analyzed individually by the NJGRS to compute the runoff, infiltration, and recharge losses and the resulting annual groundwater recharge achieved by a recharge BMP at a land development site in any New Jersey municipality.

This average annual series of precipitation events for New Jersey is shown below in Figures 6-2 and 6-3. Figure 6-2 depicts the precipitation depth, expressed as a percentage of total average annual rainfall, of each event in the series in ascending order, while Figure 6-3 depicts, also in ascending order, the events' cumulative percentage of the average annual rainfall. More detailed information about each specific event in the average annual series is contained in the NJGRS' databases. The average annual precipitation series shown in Figure 6-2 is used by NJGRS to produce a site-specific, year-long series of design storms by multiplying each event value in the series by the average annual precipitation in the municipality where the recharge BMP is located. Since the NJGRS also contains average annual precipitation values for each New Jersey municipality, the NJGRS user can generate this site-specific average annual design series simply by specifying the municipality and county in which the development site is located.

Figure 6-2: Average Annual Precipitation Series in NJGRS

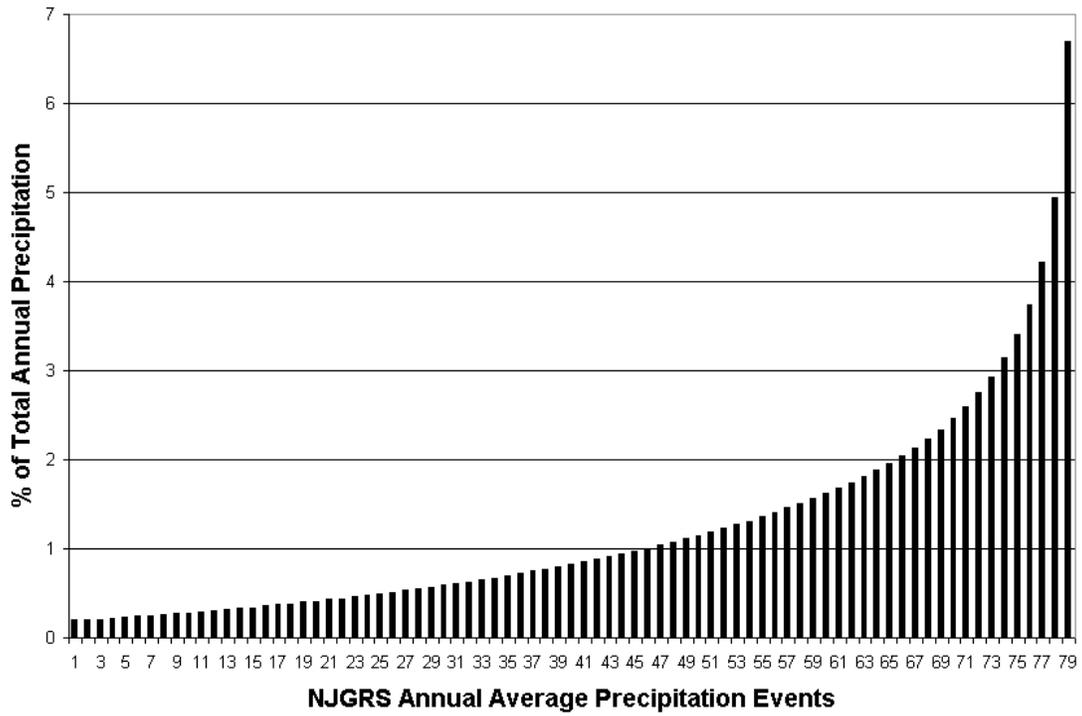
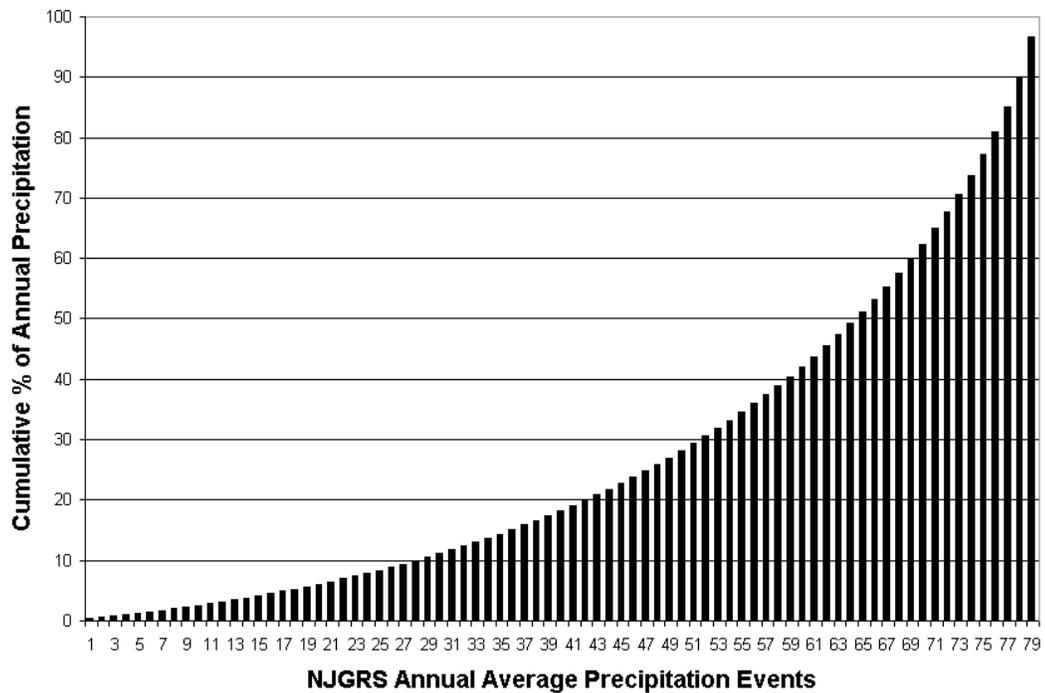


Figure 6-3: Cumulative Total of Average Annual Precipitation Series in NJGRS



Once an average annual design series is computed for the specific recharge BMP site, the NJGRS next addresses the problem of precipitation losses. As noted above, all of the possible losses that will occur, from the time the precipitation falls on the BMP's impervious drainage area to when the recharged water moves below the root zone of the vegetation in or adjacent to the BMP, must be accounted for in order to accurately compute the actual volume that will be recharged. Such losses can include infiltration and surface storage losses on the drainage area surface as the precipitation is converted into runoff, as well as evapotranspiration and infiltration losses as the runoff is converted to recharge within the BMP itself. To compute runoff losses, the NJGRS uses one of three equations depending upon the total depth of the event. These equations are applied to each event in the average annual design series to compute the resultant runoff for each one. This resultant runoff is then used in additional equations that estimate the losses that will occur for each design event once the runoff enters the recharge BMP.

When computing runoff losses for design event depths less than 0.0408 inches, the NJGRS assumes that the entire precipitation depth is consumed by surface storage, infiltration, and other losses and no runoff is produced.

For design event depths between 0.04 and 1.25 inches, the NJGRS uses the following equation to compute runoff:

$$Q = 0.95 (P - 0.0408) 0.90$$

where:

$$Q = \text{Runoff Depth in Inches}$$

$$P = \text{Precipitation Depth in Inches}$$

For design event depths greater than 1.25 inches, the NJGRS uses the NRCS Runoff Equation with a Runoff Curve Number (CN) of 98:

$$Q = \frac{(P - 0.04)^2}{(P + 0.16)}$$

where:

$$Q = \text{Runoff Depth in Inches}$$

$$P = \text{Precipitation Depth in Inches}$$

As noted above, the resultant runoff depth for each design event is then applied to specialized equations developed specifically for the NJGRS to estimate the losses that will occur to the runoff after it is stored in the recharge BMP. These losses will depend upon a number of factors, including the climate at the development site, the specific vegetation and soil conditions at the recharge BMP location, and the depth of the BMP relative to the vegetation's root zone. A complete description of the loss equations used in the NJGRS is presented in the program's User's Guide. By subtracting these losses from the stored runoff, the amount of runoff that is actually recharged for each design event is computed. The NJGRS then adds up the recharge amounts from each design event to obtain a total annual recharge amount, which is then compared with the average annual recharge deficit created by the development to determine whether the recharge BMP's performance is adequate. Similar to the computation of the average annual design series described above, the NJGRS' loss computations are performed automatically each time the user provides new development site or recharge BMP data and then requests a BMP design update. The NJGRS will then either evaluate the performance of the proposed recharge BMP or, if requested, compute the effective BMP storage depth or surface area necessary to offset the development's annual recharge deficit.

New Jersey Groundwater Recharge Spreadsheet (NJGRS)

General Instructions

As described above, the New Jersey Groundwater Recharge Spreadsheet (NJGRS) is a Microsoft Excel-based computer spreadsheet program. It is typically used in a two step procedure, utilizing first the Annual Recharge worksheet and then the BMP Calculations worksheet in the program. During the first step, the average annual groundwater recharge amounts at the site under pre- and post-developed conditions are estimated based upon site data provided by the user. From these estimates, the program computes the average annual groundwater recharge deficit caused by the site development that must be offset by a groundwater recharge BMP. During the second step, this recharge BMP is sized based upon user-specified information regarding both the BMP and its location at the development site. General information regarding each step is provided below. Specific information about the program's use and computation methods are provided in the NJGRS User's Guide, which is presented at the end of this chapter.

It should be noted that, as a spreadsheet, certain cells of the program are reserved for user input while others provide intermediate and final results. All user input cells are shaded with a tan color while spreadsheet output cells are shaded with gray. Only the tan, user-input cells should be changed. In addition, the spreadsheet contains several combinations of commands known as macros. While these macros are essential to the spreadsheet's operations, they are unsigned and, as such, their presence may conflict with the Excel program's security settings in the user's computer. These conflicts would be identified to the user through an error or warning message immediately after opening the NJGRS. If such conflicts are encountered, they can usually be addressed by setting the Excel macro security level to Medium. *The user should determine whether this level of security is acceptable for their own system.* The user would then be prompted to enable the NJGRS macros each time the spreadsheet is opened.

Finally, upon completing use of the NJGRS for a specific project, the user will be asked whether the changes made during use should be saved. While such decisions are at the discretion of each user, it may be helpful for training purposes to retain the spreadsheet original settings, which match those in the NJGRS User's Guide. In this case, a copy of the revised NJGRS with project specific data entered can be saved with a project-specific name using the *Save As* command under *File* on the Excel command line.

Annual Recharge Worksheet

Annual groundwater recharge at a land development site under both pre- and post-developed (or existing and proposed) site conditions can be estimated using the Annual Recharge worksheet in the NJGRS. As discussed above, these estimates are based on the methodology contained in *Geological Survey Report GSR-32: A Method for Evaluating Ground Water Recharge Areas in New Jersey* (GSR-32) developed by the New Jersey Geological Survey. In general, use of this worksheet requires the following user input:

1. Name of municipality and county in which the project site is located (Cell C3). Upon input of this data through use of a drop-down list, the NJGRS will immediately display the average annual precipitation and climate factor for the site's municipality from the GSR-32 databases in the NJGRS. The user can also specify a project name, description, and date in the lines provided (Cells K1, K2, and K3).
2. Land use and land cover (LULC) data for the site under both pre- and post-developed conditions. This data will consist of the area (in acres), LULC characteristics, and soil series name for up to 15 land segments of the pre- and post-developed site. The NJGRS will issue a warning message if the total area specified under pre-developed conditions is different than post-developed. The LULC data and soil series names are listed in a drop-down list next to the respective input cells. It is

important to note that the LULC categories in the drop-down list are based on those contained in Table 2-2 of the NRCS *Technical Release 55 – Urban Hydrology for Small Watersheds*. For a correlation between these LULC categories and those in GSR-32, upon which the NJGRS is based, see Table 6-1 below.

Table 6-1: NJGRS/TR-55 and GSR-32 LULC Descriptions

NJGRS/TR-55 LULC Descriptions	GSR-32 LULC Descriptions
Brush	Brush
Gravel, Dirt	Unvegetated
Impervious Areas	Unlandscaped Developed
Meadow, Pasture, Grassland or Range	Agricultural – Pasture
Open Space	Landscape Open Space
Residential 1 to 2 Acre	1 - 2 Acre Lots
Residential 1/2 to 1 Acre	1/2 - 1 Acre Lots
Residential 1/3 to 1/4 Acre	1/8 - 1/2 Acre Lots
Residential 1/8 Acre or Less	1/8 Acre Lots
Row Crop	Agricultural – General
Small Grain or Legumes	Agricultural – Cropland, Legume
Urban Districts	Landscaped Developed
Woods	Woods
Woods – Grass Combination	Wooded – General

As noted in the NJGRS User’s Guide, it is important to specify a site’s LULC characteristics as accurately as possible. Therefore, while a 1/4 acre residential site could be specified in the NJGRS by the “Residential 1/3 to 1/4 Acre” LULC description in Table 6-1, it is generally more accurate to divide the site into impervious and pervious areas and specify each as a separate land segment in the NJGRS. For example, at a 1/4 acre residential site with a total area of 10 acres consisting of 40 percent connected impervious and 60 percent grassed surfaces and a single soil series, it would be more appropriate to specify the site’s LULC characteristics in the program as a separate 4 acre impervious area land segment and a 6 acre open space land segment. This separation of connected impervious and pervious areas is similar to the technique for computing runoff volume using the NRCS methodology in Chapter 5. It should be noted that the total impervious area for post-developed conditions displayed in Cell M23 of the Annual Recharge worksheet will be based only on those post-developed land segments specified as impervious.

When using the above technique, it should be noted that if any impervious areas at a development site are unconnected (see Chapters 2 and 5 for complete details and requirements), the area used in the impervious surface designations described above for these unconnected areas should be one half of the actual area. For example, if a site has 3 acres of directly connected impervious surface, but 2 acres of unconnected impervious area, the total impervious area specified in the NJGRS can be $3 + (0.5)(2)$ or 4

acres. This 50 percent reduction in the size of unconnected impervious areas accounts for the runoff re-infiltration that can occur downstream of such areas and is consistent with the runoff computations for such areas contained in TR-55. To keep the total site area correct, the user should remember to specify the “remainder” of the unconnected impervious area as a pervious one with the appropriate soil series and LULC based upon the actual pervious area downstream of the unconnected impervious area.

It should also be noted that if a proposed recharge BMP will have a specific location within a land development site with similarly specific LULC and soil characteristics, that portion of the site should be specified as a separate land segment on the Annual Recharge worksheet. This is true even if that segment will be covered with an impervious surface. Doing this will allow the NJGRS to more accurately compute the losses and resultant recharge at the BMP. More details are presented below in the NJGRS User’s Guide, including the need to specify this segment on the BMP Calculation worksheet.

From the above, it can be seen that the more generalized Residential and Urban District LULC descriptions in Table 6-1 above should be used only for general planning studies of groundwater recharge requirements, particularly at sites with multiple lots of similar size and impervious coverage where each lot will have a separate groundwater recharge BMP. Since the soil series in which each BMP will be located may vary from lot to lot, the general LULC descriptions can be used to compute typical or general groundwater recharge requirements and BMP dimensions for the entire site. These general values can then be refined on a lot by lot basis during later, more detailed project phases with specific lot and BMP information.

Finally, in accordance with NJGS Report GSR-32, which is the basis of the NJGRS, zero recharge volume will be computed for any land segment specified for either pre- or post-development conditions that contain soils that are hydric. See Report GSR-32 for more details.

BMP Calculations Worksheet

The dimensions of a groundwater recharge BMP can be either determined or tested using the BMP Calculations worksheet in the NJGRS. This worksheet can be used to calculate the effective depth required at a recharge BMP if the impervious drainage area and BMP area are specified. Conversely, the worksheet can also be used to calculate the required area of the BMP if the drainage area and effective BMP depth are specified. Finally, the BMP Calculations worksheet can be used to analyze a specific recharge BMP with a certain area and effective depth to see what amount of annual groundwater recharge it can provide.

As explained in the NJGRS User’s Guide, it is critical that the surface area of a recharge BMP (variable ABMP) be specified in the program as accurately as possible. This is because the program uses the ratio of the BMP’s drainage area and surface area to determine the resultant depth of runoff in the BMP for each storm event analyzed. In addition, a recharge BMP’s effective depth (variable dBMP) represents the maximum equivalent water depth that can be achieved in the BMP before overflow begins. Therefore, if the proposed recharge BMP will consist, for example, of a subsurface, vertical-walled chamber, dBMP will simply be the maximum achievable depth before the chamber is full and overflow occurs. However, if the proposed BMP will be filled with broken stone or other suitable material, dBMP will be the product of the BMP’s actual or physical depth and the void ratio of the fill material.

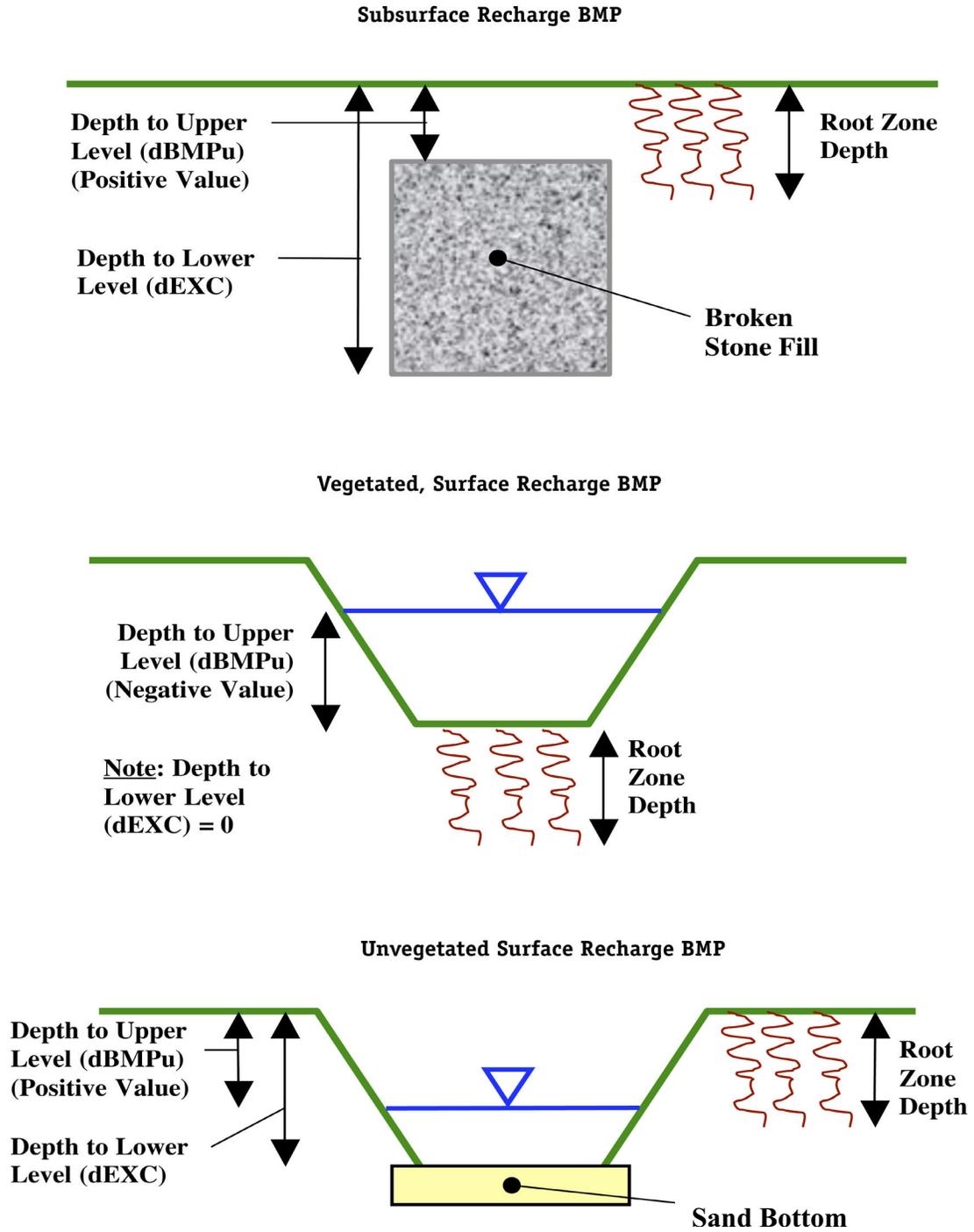
For recharge BMPs that consist of a combination of filled and open areas (e.g., a perforated pipe within a stone filled trench) or for irregular-shaped BMPs with nonvertical sides, dBMP can be computed by dividing the BMP’s total storage volume by its surface area (ABMP). For BMPs with varying surface areas (e.g., a trapezoidal infiltration basin with sloping sides or a perforated elliptical pipe), the user should exercise discretion in selecting the correct surface area to use. In most cases, the average surface area would be appropriate. In all cases, the user should always verify that the product of the specified surface area (ABMP) and effective depth (dBMP) equals the BMP’s total storage volume (variable VBMP in Cell G12). More information and recommendations can be found in the NJGRS User’s Guide.

In addition to the above, it is important to note that the BMP Calculations Worksheet assumes that all runoff stored in the recharge BMP at depths at or below dBMP (i.e., the maximum storage depth in the BMP) will be infiltrated into the soils below the BMP and that any greater runoff amounts will overflow the BMP. As such, the BMP Calculations Worksheet cannot directly model a recharge BMP that will infiltrate some of its runoff while it is simultaneously discharging some through an overflow or other outlet. Examples of such a recharge BMP would include an extended detention basin where stored runoff is simultaneously infiltrated through the basin bottom and out its outlet structure. For such BMPs, alternative BMP calculation techniques will be required.

With regards to BMP location, if a recharge BMP will be located within a particular post-developed land segment specified on the Annual Recharge worksheet, it should be specified in Cell C9 (variable C9) of the BMP Calculations worksheet. As described earlier, doing so will allow the NJGRS to more accurately compute the losses and resultant recharge at the BMP. If this land segment is not specified on the BMP Calculations worksheet, the NJGRS will, by default, use average soil and loss factors based on all of the post-developed land segments specified on the Annual Groundwater Recharge worksheet.

The BMP Calculations worksheet can analyze a recharge BMP located either on grade or constructed below grade through excavation. An excavated BMP can be either a surface or subsurface BMP. The specific type of BMP is described in the BMP Calculations worksheet through its effective depth (dBMP) and two additional vertical distances. The first is the vertical distance from the vegetated ground surface to the maximum water surface level in the BMP (variable dBMPu in Cell C7). This value is positive if the maximum level is below the vegetated ground surface and negative if above the vegetated ground surface. The second is the vertical distance from the vegetated ground surface to the bottom of the BMP (variable dEXC in Cell C8). For example, if the top of a 36-inch deep stone-filled infiltration trench is located 24 inches below ground level, dBMPu would be 24 inches and dEXC would be 60 inches (i.e., dBMPu plus the 36-inch actual depth of the trench). It should be noted, however, that since the trench is filled with gravel with a certain void ratio, the BMP's effective depth (dBMP) would be 36 inches times that void ratio. Using the dBMPu and dEXC variables, virtually all types of recharge BMPs can be specified, including "above the surface," "semi-buried," and "completely buried" BMPs. See Figure 6-4 below and the NJGRS User's Guide for more information.

Figure 6-4: Examples of Depths to Upper (dBMPu) and Lower (dEXC) Levels of Recharge BMP



In using the BMP Calculations worksheet, it is important to note that, by default, the NJGRS takes the values from the Annual Recharge worksheet for the Post-Development Recharge Deficit Volume (Cell K24) and the Total Impervious Area (Cell M23) and specifies them as initial values on the BMP Calculations worksheet for the Post-Development Deficit Recharge (variable Vdef in Cell C14) and Post-Development Impervious Area (variable Aimp in Cell C15). This allows solution of the site's total recharge deficit by a single groundwater recharge BMP that will receive runoff from a developed site's entire impervious area (if specified as impervious land segments). However, in many instances, the single groundwater recharge BMP will receive runoff from only a portion of the site's impervious area (e.g., only roof runoff). In such cases, the user must specify the exact size of Aimp (impervious area to the BMP) in Cell C15. Failure to do this for such BMPs will result in an overestimation of the amount of runoff captured by the BMP and erroneous BMP dimensions and/or recharge amounts.

At other sites, it may be necessary or desirable to utilize more than one groundwater recharge BMP to meet the site's recharge requirements. In such cases, each BMP will not only receive runoff from a portion of the site's impervious surface, but each will also seek to provide only a portion of the site's total recharge deficit. In such cases, the user must specify both the exact Aimp and Vdef (Post-Development Deficit) for each BMP in Cells C14 and 15 of the BMP Calculations worksheet. *In such cases, the user must also use a separate NJGRS spreadsheet for each BMP. Using multiple copies of the BMP Calculations worksheet within a single spreadsheet can yield erroneous results.*

In addition, computational problems can occur if, in designing a recharge BMP, the user selects either an initial BMP surface area (ABMP) or effective depth (dBMP) that is drastically different than the actual value needed to meet the required recharge deficit. If this occurs, the NJGRS may not be able to compute the correct value and will, instead, display excessive large answers or divide by zero messages. If this occurs, the user should adjust the initial value to one that more closely approximates the final answer and rerun the worksheet.

The BMP Calculations worksheet will also present various characteristics of the recharge BMP, including its effectiveness in converting runoff to infiltrated water and then recharged groundwater. See the NJGRS User's Guide presented at the end of this chapter for more information.

BMP Calculation Messages

The BMP Calculations worksheet provides three important messages to check the validity of the computed results. The Volume Balance message (Cell J11) is a check of the Annual BMP Recharge Volume in Cell G14 against the Post-Development Deficit Recharge (variable Vdef in Cell C14). If these values are equal, the problem is solved successfully and the message in this section will read "OK." However, if the BMP's annual recharge volume does not equal Vdef, the message instructs the user to continue to solve the problem. This may also occur if the user changes any of the BMP design parameters and forgets to solve the problem by clicking on any of the two solve buttons.

The dBMP Check message (Cell J12) checks the validity of the value inputted for the dBMP, the BMP's effective depth in Cell C6. If this value is greater than the difference between the depths to the BMP's upper and lower surfaces (variables dBMPu and dEXC in Cells C7 and C8, a warning message is issued telling the user to adjust dBMP. dEXC Check (Cell J13) is the third message. It checks the validity of dEXC to ensure it is larger than dBMPu. If it is not, a message will appear instructing the user to make dEXC larger than dBMPu.

Below these messages is a report on the location of the BMP as specified by the user in Cell C9 (variable segBMP). If the user has entered a valid segment number for segBMP, the message will read "OK." If the user enters a zero for segBMP, the message will read "Location is selected as distributed or undetermined." However, if the user enters a land segment number that was not previously defined in the Annual Recharge

worksheet under Post-Developed Conditions, the message will say: “Land Segment Number Selected for BMP is not Defined.” The user should then make appropriate corrections to segBMP.

See the NJGRS User’s Guide for more information regarding calculation check messages and warnings.

Additional Information

In addition to the above, the following important features and characteristics of the NJGRS should be noted:

1. The NJGRS gives the user the opportunity to specify what percentage of a development site’s annual groundwater recharge deficit must be retained (Cell K23 of the Annual Recharge worksheet). However, it should be noted that the program’s default value is 100 percent which, as noted above, is the amount required by the NJDEP Stormwater Management Rules.
2. The pre- and post-development average annual recharge at a development site is a function, in part, of the municipality in which the site is located. Therefore, changing the name of the municipality in Cell C3 of the Annual Recharge worksheet will change both the pre- and post-development recharge volumes. Similarly, if the user wishes to analyze a site in a different municipality, the new municipality’s name must be entered through the drop-down list in Cell C3 in order to accurately compute pre-and post-development recharge amounts.
3. In Cell K6 of the BMP Calculations worksheet, the NJGRS will display the “Inches of Rainfall to Capture.” This value is also displayed graphically in Chart 1 of the NJGRS along with other pertinent BMP performance information. This value specifies the minimum depth of rainfall over the BMP’s impervious drainage area that must be collected to meet the development site’s average annual recharge deficit. It is also the maximum event rainfall that the BMP can store without overflowing and, as such, it is equal to the BMP’s Recharge Design Storm depth described previously in “Theoretical Basis of Calculations.” This design storm depth is important, as it can be used to estimate the resultant groundwater recharge design storm runoff from a development site with groundwater recharge BMPs. See Examples 4, 5 and 6 in Chapter 5 for more details on this procedure.
4. At the time of the NJGRS’ development, all soil series mapped in New Jersey were included in its databases. Nevertheless, instances may arise where a soil series identified at a land development site has not been included. In such instances, the user should select a similar soil series from the program’s database. In doing so, the following criteria should be utilized, generally in the order presented:
 - Select a NJGRS soil series within the same Hydrologic Soil Group (HSG) as the site soil.
 - Within the same HSG, select an NJGRS soil series with similar textural characteristics and classification as the soil.
 - If the site soil includes a fragipan, bedrock, or other restrictive layer below its surface, select an NJGRS soil series with a similar restrictive depth.
 - If more than one choice of NJGRS soil series appears reasonable, the user may then analyze and compare the annual groundwater recharge amounts for each using the NJGRS program to help make a final selection.

Recharge BMP Design Guidelines

In general, the design of a groundwater recharge BMP to offset a development site's groundwater recharge deficit should follow the standards and guidelines for dry wells, infiltration basins, and pervious paving systems with storage beds presented in Chapter 9. This includes utilizing soil permeability data obtained from tests such as those contained in Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A at the site of the proposed recharge BMP. In addition, the recharge BMP design must be based on the following guidelines:

1. Computation of the pre- and post-development annual groundwater recharge rate and the annual recharge deficit should be based upon the New Jersey Geological Survey Report GSR-32 A Method For Evaluating Ground-Water-Recharge Areas in New Jersey, which is incorporated into the NJGRS.
2. Only the directly connected impervious portions of a recharge BMP's drainage area can be used to compute runoff to the BMP. In the NJGRS, the input parameter Aimp, which is the size of the recharge BMP's drainage area, must represent only directly connected impervious surfaces. This is particularly relevant for infiltration basins and pervious paving systems used for groundwater recharge that may also have pervious and unconnected impervious areas draining to them.
3. Runoff collected from roofs and other above-grade surfaces can be directly conveyed to a recharge BMP. However, roof gutter guards and/or sumps or traps equipped with clean-outs should be included upstream of the recharge BMP wherever possible to minimize the amount of sediment or other solids that can enter the BMP.
4. Runoff collected from parking lots, driveway, roads, and other on-grade impervious surfaces and conveyed to a subsurface recharge BMP must be pretreated to remove 80 percent of TSS in order to prevent the loss of storage volume and/or recharge capacity due to sedimentation and clogging. Exceptions may be possible for patios, tennis courts, and similar on-grade impervious surfaces with minimal TSS loadings on case-by-case basis. Such treatment can also be used to meet the site's overall TSS removal requirements. In addition, all on-grade drainage areas to a subsurface recharge BMP should consist only of impervious surfaces. Exceptions to this requirement may include roadway right-of-ways, vegetated parking lot medians, planting and landscape beds, and other pervious surfaces provided that they comprise only a small percentage of the total drainage area and will not generate an excessive amount of TSS or other material that might adversely impact the subsurface recharge BMP. As noted above, if such areas are part of the actual drainage area, they must not be included in the drainage area size (variable Aimp) used in the NJGRS' BMP Calculations worksheet to design the recharge BMP.

In addition, it should be noted that, since the BMP Calculations Worksheet assumes that all runoff from a recharge BMP's impervious drainage area will be delivered to the BMP, it cannot directly account for runoff losses incurred at a pretreatment measure located between the drainage area and the recharge BMP. If such losses will occur due to the selected pretreatment measure, appropriate compensating adjustments may be attempted in the BMP Calculations Worksheet input data or alternative BMP calculation techniques utilized.

5. In general, County Soil Surveys prepared by the U.S. Department of Agriculture and the State Soil Conservation Committee can be used to obtain the soil series data required for the determination of annual land development site recharge rates and deficits and the dimensions of recharge BMPs using the NJGRS program. However, site soil tests will be required at the actual location of a proposed recharge BMP in order to confirm the BMP's ability to function properly without failure. Such tests should include a determination of the textural classification and permeability of the soil

at the bottom of the proposed recharge BMP. As noted above, permeability testing can be conducted in accordance with Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A.

Depending upon the type, location, use, and maximum design storm of the selected recharge BMP, minimum design soil permeability rates will vary from 0.2 to 0.5 inches per hour and that a factor of safety of 2 must be applied when converting a tested permeability rate to a design rate. In addition, the soil permeability rate must allow the recharge BMP to fully drain its maximum design storm runoff volume within 72 hours. Recharge BMP locations that fail to meet these two requirements should be rejected and alternative onsite locations selected. A groundwater recharge waiver may be sought from the applicable reviewing agencies if suitable permeability rates cannot be found at any recharge BMP locations on the development site.

See Chapter 9 for details on structural best management practices that can be used as recharge BMPs, including minimum design permeability rates. Such BMPs include dry wells (Chapter 9.3), infiltration basins (Chapter 9.5), and certain types of pervious paving systems (Chapter 9.7).

6. The results of the BMP site soil testing should be compared with the County Soil Survey data used in the NJGRS' annual recharge and BMP design computations to ensure reasonable data consistency. If significant differences exist between the BMP site soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised annual recharge and BMP design computations based upon the site soil test results. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the site soil data is accurate. It should also be noted that significant inconsistencies between development site soil tests and the County Soil Survey may warrant revisions to the site's stormwater quality and quantity storm computations.
7. The development site areas that extensive site soil testing determine to have permeability rates less than 0.2 inches per hour may be considered to belong to Hydrologic Soil Group D in the NJGRS program. For such areas, the user may use any HSG D soil in the NJGRS soil series database to define such site areas in the NJGRS' Annual Recharge worksheet. In accordance with the assumptions of both the NJGRS program and N.J. Geological Survey's Geological Survey Report GSR-32: A Method for Evaluating Ground Water Recharge Areas in New Jersey, such areas will not produce any groundwater recharge. Once again, the assignment of HSG D to any development site areas should be discussed with the local Soil Conservation District prior to proceeding to help ensure that the site soil data is accurate.

The New Jersey Groundwater Recharge Spreadsheet (NJGRS)

User's Guide

Version 2.0 – November 2003

There are two computational worksheets in the NJGRS spreadsheet:

- Annual Recharge:** This worksheet, which resides on the first page of the spreadsheet, is used to estimate the annual groundwater recharge volumes that occur naturally under the Pre-Developed and Post-Developed Conditions. Based on the value of “percent of Pre-Developed Annual Recharge to Preserve” that the user provides (NJDEP currently requires 100 percent for this parameter), the worksheet calculates the “Post-Development Annual Recharge Deficit” in cubic feet. This is the annual recharge volume that must be provided by one or more groundwater recharge BMPs.
- BMP Calculations:** This worksheet, which resides on the second page of the spreadsheet, is used to design the required size and configuration of one or more groundwater recharge BMPs to satisfy the “Post-Development Annual Recharge Deficit” calculated in the Annual Recharge worksheet.

NOTE: Only the above worksheets in the NJ Groundwater Recharge Spreadsheet are for user input. Charts 1 through 3 can be viewed for visual inspection of the results. Other worksheets in the spreadsheet are either for internal calculations or contain the databases used by calculations. The user should refrain from changing anything in these worksheets.

Part 1: Using the Annual Recharge Worksheet

Figure 1: Screen Capture Showing the Annual Recharge Worksheet

A		B		C		D		E		F		G		H		I		J		K		L		M	
1		New Jersey Groundwater Recharge Spreadsheet Version 2.0 November 2003		Annual Groundwater Recharge Analysis (based on GSR-32)										Project Name: Sample Project											
2		Select Township ↓		Average Annual P (in)		Climatic Factor												Description: This is a test application							
3		MIDDLESEX CO., PERTH AMBOY CITY		47.8		1.53												Analysis Date: 09/01/03							
Pre-Developed Conditions												Post-Developed Conditions													
Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)	Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)	Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)	Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)		
1	1.4	Open space	Woodstown	12.9	65,498	1	1.5	Impervious areas	Keyport	0.0	-	1	1.5	Impervious areas	Keyport	0.0	-	1	1.5	Impervious areas	Keyport	0.0	-		
2	0.3	Gravel, dirt	Woodstown	6.9	7,536	2	1.6	Gravel, dirt	Woodstown	6.9	40,191	2	1.6	Gravel, dirt	Woodstown	6.9	40,191	2	1.6	Gravel, dirt	Woodstown	6.9	40,191		
3	3.5	Woods-grass combination	Woodstown	13.5	171,255	3	3.65	Open space	Keyport	13.4	177,667	3	3.65	Open space	Keyport	13.4	177,667	3	3.65	Open space	Keyport	13.4	177,667		
4	1.4	Open space	Keyport	13.4	68,146	4	3.65	Open space	Woodstown	12.9	170,762	4	3.65	Open space	Woodstown	12.9	170,762	4	3.65	Open space	Woodstown	12.9	170,762		
5	0.5	Gravel, dirt	Keyport	7.5	13,657	5	0					5	0					5	0						
6	3.3	Woods-grass combination	Keyport	13.9	165,963	6	0					6	0					6	0						
7	0					7	0					7	0					7	0						
8	0					8	0					8	0					8	0						
9	0					9	0					9	0					9	0						
10	0					10	0					10	0					10	0						
11	0					11	0					11	0					11	0						
12	0					12	0					12	0					12	0						
13	0					13	0					13	0					13	0						
14	0					14	0					14	0					14	0						
15	0					15	0					15	0					15	0						
Total = 10.4				Total Annual Recharge (in)		Total Annual Recharge (cu-ft)		Total = 10.4				Total Annual Recharge (in)		Total Annual Recharge (cu-ft)		Total = 10.4				Total Annual Recharge (in)		Total Annual Recharge (cu-ft)			
				13.0		492,054		Annual Recharge Requirements Calculation ↓				10.3		388,620						10.3		388,620			
Procedure to fill the Pre-Development and Post-Development Conditions Tables:												% of Pre-Developed Annual Recharge to Preserve = 100%		Total Impervious Area (sq ft)		65,340									
For each land segment, first enter the area, then select TR-55 Land Cover, then select Soil. Start from the top of the table and proceed downward. Don't leave blank rows (with A=0) in between your segment entries. Rows with A=0 will not be displayed or used in calculations. For impervious areas outside of standard lots select "Impervious Areas" as the Land Cover.												Post-Development Annual Recharge Deficit= 103,435		(cubic feet)											
Soil type for impervious areas are only required if an infiltration facility will be built within these areas.												Recharge Efficiency Parameters Calculations (area averages):													
				RWC= 3.94 (in)		DRWC= 3.94 (in)																			
				ERWC = 0.93 (in)		EDRWC= 0.93 (in)																			

- Figure 1 is a screen capture from an example application of the Annual Recharge Worksheet. All user-input cells are tan colored. All gray colored cells are used to show calculation results or internal validity checks and must *not* be changed by the user. The three cells at the upper right corner of the sheet are where the user can input project information. These inputs are optional, but they can help in identifying the project and the alternative being analyzed.
- As the first step, the user must select the project's municipality. Click once on the municipality cell (Cell C3) and select the project's county and municipality from the drop-down list of all New Jersey municipalities, which is arranged by county in alphabetical order. Once the user has selected a municipality, the values of average annual precipitation and the climate factor are set for that municipality in the two cells to the immediate right of the municipality's name (Cells D3 and E3).
- The next step is to provide information about pre-developed site conditions. The first column is the land segment number (Cells A6 to A20). Up to 15 different land segments can be inputted in this table.

NOTE: If you have more than 15 different land segments, try to combine similar segments together or subdivide your area into smaller areas not consisting of more than 15 land segments.

- For each land segment, first enter the area in acres. Then select an appropriate TR-55 land cover description from the drop-down list of standard NRCS land cover descriptions. Finally, select the segments soil series from the drop-down list. Note that, as soon as the area for a segment is entered, the entries for other columns become visible and selectable. Start from the top of table and proceed downward. Do not leave blank rows (with zero area) between land segment entries; rows with zero areas will not be displayed or used in calculations.

NOTE: Once you click on any of these cells a pop-up help message will appear to briefly tell you about the required input for that cell.

- As can be seen from the list of available TR-55 land cover descriptions in the drop-down list, there may be more than one way to describe the pre-developed land cover at a project site, particularly when that cover is a mixture of pervious and impervious surfaces such as a single family residential development. For assistance, see the guidelines in the New Jersey Groundwater Recharge Spreadsheet (NJGRS) section of Chapter 6 for selecting segment limits and land cover descriptions. Finally, it should be noted that, under the Pre-Developed Conditions section, it is not necessary to specify the soil series for site segments with impervious land cover, since the natural recharge in these segments is set at zero.

NOTE: If the soil you select for a land segment is hydric, recharge will be set to zero for that segment.

- Once the user has completed inputting all land covers in the table for the Pre-Developed Conditions, check the total area in acres (Cell B21) to ensure that the total project area is correct. The last two columns of this table show the naturally occurring average annual recharge amount as a depth (in inches over the segment area) and a volume (in cubic feet) for each land segment. At the bottom of these columns (Cells E22 and F22), the average recharge depth (in inches) and the total annual recharge volume (in cubic feet) over the total area under Pre-Developed Conditions is given. This number is later used in the calculation of any post-development recharge deficit.
- The above procedure can also be used to enter the required data for the post-developed site conditions. In doing so, please note the following additional requirements:
 1. To correctly compute the performance and/or required size of a proposed groundwater recharge BMP, the area in which the BMP will be located must be entered as a separate site

segment with its associated soil series. The number of this segment must also be specified on the BMP Calculations spreadsheet (see below).

2. As noted above, it is normally not necessary to specify the soil series within an impervious site segment. However, the soil series of the impervious segment must be specified if a proposed groundwater recharge BMP will be located within or below it (e.g., a stone-filled infiltration trench below a parking lot). As noted in 1 above, the soil series is necessary in order to accurately compute the performance and/or required size of the proposed BMP.
- Finally, as noted above, see the guidelines in the New Jersey Groundwater Recharge Spreadsheet (NJGRS) section of Chapter 6 for further assistance in selecting appropriate segment limits and TR-55 land cover descriptions for post-developed site conditions.

NOTE: Soil series selected for the impervious areas in the Post-Developed Conditions table are automatically displayed in orange, signifying that they have no effect on the site's natural annual recharge calculation (i.e., recharge set to zero for all land segments classified as "Impervious areas" regardless of the soil type), but that they can affect the artificial annual recharge volume of any groundwater recharge BMP set below them.

- Once the user has completed inputting all land segment information in the table for the Post-Developed Conditions, once again check the total project area (Cell I21) to ensure that the total post-development project area is correct.

NOTE: If the total area in the Post-Developed Conditions is different from the total area in the Pre-Developed Conditions, a warning message will appear to the right of the total Post-Developed project area (Cell J21).

- As an additional check, the total impervious area (in square feet) under Post-Developed conditions will be shown at the bottom right of this table (Cell M23). Please note that this value reflects only those impervious areas specified as separate project segments and does not include any impervious areas within those segments specified by the standard TR-55 residential or urban land descriptions. The last two columns of this table show the naturally occurring average annual recharge depth (in inches) and volume (in cubic feet) for each land segment. At the bottom of these columns (Cells L22 and M22), the average recharge depth (in inches) and the total annual recharge volume (in cubic feet) over the total area under Post-Developed Conditions is given. This number is also used later in the calculation of any Post-Development recharge deficit.
- Immediately below the Post-Developed Conditions table is the Annual Recharge Requirements Calculation section. The user needs to input the "percent of Pre-Developed Annual Recharge to Preserve" (Cell K23) to set the percentage of the recharge under Pre-Developed Conditions that must be maintained under the Post-Developed Conditions. The NJDEP Stormwater Management Rules at N.J.A.C. 7:8 currently requires this value to be 100 percent, which is the spreadsheet's default value. The spreadsheet then computes the difference between the total annual recharge volumes for Pre- and Post-Developed Conditions and multiplies it by the "percent of Pre-Developed Annual Recharge to Preserve." The resulting value is shown as the "Post-Development Annual Recharge Deficit" in the worksheet (Cell K24). This amount is 103,435 cubic feet in the case of the example in Figure 1. This is the volume of groundwater recharge that must be artificially recharged under Post-Developed Conditions annually through groundwater recharge BMPs.
- The "Recharge Efficiency Parameter Calculations" table shown below the "Post-Development Annual Recharge Deficit" show the parameters calculated by this worksheet that are later used in the BMP Calculations worksheet.

NOTE: The Appendix to this guide provides the basic equations and defines the variables used in Recharge Efficiency Parameter Calculations.

Part 2: Using the BMP Calculations Worksheet

This worksheet allows the proper sizing of groundwater recharge BMPs to provide the desired or required volume of annual groundwater recharge. Alternatively, it can be used to evaluate the performance of a user-specified recharge BMP. As described in Chapter 2, groundwater recharge BMPs can also be referred to as Low Impact Development BMPs (or LID-BMPs), depending on their size and location in the project site.

Figure 2: Screen Capture from the BMP Calculations Worksheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Project Name		Description			Analysis Date		BMP or LID Type						
2	Sample Project		This is a test application			09/01/03								
3	Infiltration BMP Input Parameters				Root Zone Water capacity Calculated Parameters				Recharge Design Parameters					
4	Parameter	Symbol	Value	Unit	Parameter	Symbol	Value	Unit	Parameter	Symbol	Value	Unit		
5	BMP Area	ABMP	6656.0	sq.ft	Empty Portion of RWC under Post-D Natural Recharge	ERWC	0.93	in	Inches of Runoff to capture	Qdesign	0.54	in		
6	BMP Effective Depth, this is the design variable	dBMP	5.2	in	ERWC Modified to consider dEXC	EDRWC	0.93	in	Inches of Rainfall to capture	Pdesign	0.67	in		
7	Upper level of the BMP surface (negative if above ground)	dBMPu	-5.2	in	Empty Portion of RWC under Infiltr. BMP	RERWC	0.74	in	Recharge Provided Avg. over Imp. Area			19.0	in	
8	Depth of lower surface of BMP, must be >= dBMPu	dEXC	0.0	in					Runoff Captured Avg. over imp. Area			24.8	in	
9	Post-development Land Segment Location of BMP Input Zero if Location is distributed or undetermined	SegBMP	0	unitless										
10	Solve for ABMP to provide Vdef	Solve for dBMP to provide Vdef	Default Vdef & Aimp		BMP Calculated Size Parameters				CALCULATION CHECK MESSAGES					
11					ABMP/Aimp	Aratio	0.10	unitless	Volume Balance-->	OK				
12					BMP Volume	VBMP	2.873	cu.ft	dBMP Check-->	OK				
13	Parameters from Annual Recharge Worksheet				System Performance Calculated Parameters				dEXC Check--> OK					
14	Post-D Deficit Recharge (or desired recharge volume)	Vdef	103.435	cu.ft	Annual BMP Recharge Volume		103.435	cu.ft	BMP Location-->	Location is selected as distributed or undetermined				
15	Post-D Impervious Area (or target Impervious Area)	Aimp	65,340	sq.ft	Avg BMP Recharge Efficiency		76.7%	Represents % Infiltration Recharged	OTHER NOTES					
16	Root Zone Water Capacity	RWC	3.94	in	%Rainfall became Runoff		78.3%	%	Pdesign is accurate only after BMP dimensions are updated to make rech volumes deficit volume. The portion					
17	RWC Modified to consider dEXC	DRWC	3.94	in	%Runoff Infiltrated		66.2%	%	of BMP infiltration prior to filling and the area occupied by BMP are ignored in these calculations. Results are					
18	Climatic Factor	C-factor	1.53	no units	%Runoff Recharged		50.8%	%	sensitive to dBMP, make sure dBMP selected is small enough for BMP to empty in less than 3 days. For land					
19	Average Annual P	Pavg	47.8	in	%Rainfall Recharged		39.7%	%	Segment Location of BMP if you select "impervious areas" RWC will be minimal but not zero as determined by					
20	Recharge Requirement over Imp. Area	dr	19.0	in					the soil type and a shallow root zone for this Land Cover allowing consideration of lateral flow and other losses.					
21	How to solve for different recharge volumes: By default the spreadsheet assigns the values of total deficit recharge volume "Vdef" and total proposed impervious area "Aimp" from the "Annual Recharge" sheet to "Vdef" and "Aimp" on this page. This allows solution for a single BMP to handle the entire recharge requirement assuming the runoff from entire impervious area is available to the BMP. To solve for a smaller BMP or a LID-IMP to recharge only part of the recharge requirement, set Vdef to your target value and Aimp to impervious area directly connected to your infiltration facility and then solve for ABMP or dBMP. To go back to the default configuration click the "Default Vdef & Aimp" button.													

- Figure 2 is a screen capture from a portion of the BMP Calculations worksheet. While most of the calculations in this worksheet are performed in a separate worksheet, the portion shown in Figure 2 can be studied to understand the worksheet usage. There are several sections and solve buttons in this part of the worksheet, as explained below.

NOTE: The three entries for Project Name, Description and Analysis Date are automatically copied from the Annual Recharge Sheet to the top of this sheet. The user can optionally input information regarding Groundwater Recharge BMP type.

Recharge BMP Input Parameters

- The user may start by inputting an initial value for the BMP surface area in square feet (variable ABMP) in Cell C5. In the NJGRS program, the variable ABMP is used in conjunction with the size of the recharge BMP's drainage area to determine the depth of stored runoff in the BMP resulting from a specific rain event. If a specific recharge BMP is being analyzed, ABMP will be based on the

actual area of the BMP. If the spreadsheet is being used to determine the required recharge BMP dimensions, this value should be an initial estimate of the required surface area to satisfy the Post-Developed Recharge Deficit volume. This deficit volume (variable Vdef) is shown in Cell C14 and is either user-specified or, by default, taken from the Post-Development Annual Recharge Deficit computed on the Annual Recharge worksheet (Cell K24).

- Next, a value for the recharge BMP's effective storage depth (variable dBMP) must be specified in inches in Cell C6. In the NJGRS program, dBMP represents the maximum equivalent water depth that can be achieved in the BMP before overflow begins. Therefore, if the proposed recharge BMP will, for example, be a subsurface, vertical-walled chamber, dBMP will simply be the maximum achievable depth before the chamber is full and overflow occurs. However, if the proposed BMP will be filled with broken stone or other suitable material, dBMP will be the product of the BMP's actual or physical depth and the void ratio of the fill. For recharge BMPs that consist of a combination of filled and open areas (e.g., a perforated pipe within a stone filled trench) or for irregular, nonrectangular BMP shapes (e.g., a perforated elliptical pipe or an infiltration basin with sloping sides), dBMP can be computed by dividing the BMP's total storage volume by its surface area.
- Just like the BMP surface area variable ABMP, the dBMP value entered for effective storage depth can be either a given value for a specific recharge BMP or an initial guess for a BMP to be sized by the spreadsheet. If this second option is selected, the user should remember that the resultant dBMP computed by the program may or may not be its actual or physical depth, depending on whether the BMP uses broken stone or other media in which to store runoff.
- In addition to dBMP, the user must also provide two additional recharge BMP depths. In Cell C7, the variable dBMPu is the vertical distance from the vegetated ground surface to the maximum water level of the BMP. This value should be positive if the maximum level is below the ground surface and negative if above the vegetated ground surface. In Cell C8, the variable dEXC is the vertical distance from the vegetated ground surface to the bottom of the BMP. For example, if the top of a 36-inch deep stone-filled infiltration trench (void ratio = 0.33) is located 24 inches below ground level, dBMPu would be 24 inches and dEXC would be 60 inches (i.e., dBMPu plus the 36-inch actual or physical depth of the trench). Remember, however, that since the trench is filled with gravel, the effective BMP depth (dBMP) would be 12 inches (i.e., 36 inches times 0.33). Using the dBMPu and dEXC variables, virtually all types of recharge BMPs can be specified, including "above the surface," "semi-buried," and "completely buried" BMPs. See Figure 6-4 for additional examples of dBMPu and dEXC.
- The next input cell on the BMP Calculations worksheet is the variable segBMP (Cell C9). This variable represents the post-developed site segment (as specified on the Annual Recharge worksheet) in which the proposed recharge BMP will be located. For example, if the recharge BMP is proposed to be built in Land Segment 3 in the Post-Developed Conditions table shown in Figure 1, then enter 3 for segBMP on the BMP Calculations worksheet.
NOTE: Input zero for segBMP if the location of the BMP is still undetermined or a series of identical BMPs will be distributed over multiple site segments.
- The last input cell on the BMP Calculations worksheet is the variable Aimp (Cell C15). Similar to the variable Vdef in Cell C14, Aimp is either user-specified or, by default, taken from the Total Impervious Area computed on the Annual Recharge worksheet (Cell M23).

- Once values and/or initial guesses are entered in the input cells, either of two solve buttons can be used to solve the design problem. These buttons are described below.

**Solve for ABMP to
provide Vdef**

NOTE: Click this button to automatically evaluate the value of ABMP that provides Vdef given all other input values.

**Solve for dBMP to
provide Vdef**

NOTE: Click this button to automatically evaluate the value of dBMP that provides Vdef given all other input values.

If the initial guess values you enter for ABMP or dBMP are drastically off from what is needed to satisfy Vdef (i.e., too small or too big, too shallow or too deep), the program may not be able to find the right answer. You can tell the answers are not acceptable because negative values or division by zero signs will show up. If this happens just change your ABMP and/or dBMP values to more realistic numbers and solve the problem again.

- It is important to remember that, by default, the spreadsheet takes the values computed on the Annual Recharge worksheet for the Post-Development Recharge Deficit Volume (Cell K24) and the Total Impervious Area (Cell M23) and specifies them as initial values on the BMP Calculations worksheet for the Post-Development Deficit Recharge (variable Vdef in Cell C14) and Post-Development Impervious Area (variable Aimp in Cell C15). This allows solution of the site's total recharge deficit by a single groundwater recharge BMP that will receive runoff from the site's entire impervious area. However, in many instances, the single groundwater recharge BMP will receive runoff from only a portion of the site's impervious area (e.g., only roof runoff). In such cases, the user must specify the exact size of Aimp (impervious area to the BMP) in Cell C15. Failure to do this for such BMPs will result in an overestimation of the amount of runoff captured by the BMP and erroneous BMP dimensions and/or recharge amounts.
- At other sites, it may be necessary or desirable to utilize more than one groundwater recharge BMP to meet the site's recharge requirements. In such cases, each BMP will not only receive runoff from a portion of the site's impervious surface, but each will also seek to provide only a portion of the site's total recharge deficit. In such cases, the user must specify both the exact Aimp and Vdef (Post-Development Deficit) for each BMP in Cells C14 and 15 of the BMP Calculations worksheet. *IMPORTANT: In such cases, the user must also use a separate NJGRS spreadsheet for each BMP. Using multiple copies of the BMP Calculations worksheet within a single spreadsheet can yield erroneous results.*

NOTE: These procedures are also summarized in a note at the bottom of the BMP Calculations worksheet.

**Default
Vdef & Aimp**

NOTE: Click this button to retrieve the initial, default values of Vdef and Aimp from the Annual Recharge worksheet.

- Similar to the Annual Recharge worksheet, the user-input cells in the BMP Calculations worksheet are tan colored. This includes the cells for Vdef and Aimp so that they can be altered from their default values by the user. As described above, these cells are initially assigned default values from the Annual Recharge worksheet so the user does not have to input values for certain sites and BMPs. All gray colored cells are used to show calculation results or internal validity checks and must *not* be changed by the user.

NOTE: Remember that the default configuration assumes that the runoff from the site's entire impervious area (set by specifying one or more land segments to "Impervious Areas" on the Annual Recharge worksheet) will drain to the BMP. If only a portion of this impervious area will do so, the correct impervious area must be specified for Aimp (Cell C15) on the BMP Recharge worksheet.

- The values shown in Figure 2 above are the final results obtained by solving for ABMP (with a constant dBMP of 5.2 inches) to satisfy the entire annual recharge deficit of 103,435 cubic feet (which is the default Vdef value from the Annual Recharge worksheet). The user can tell the results are correct by comparing the calculated Annual BMP Recharge Volume amount in Cell G14 (under the "System Performance Calculated Parameters" heading) with the Vdef amount in Cell C14. In addition, the user can see that the volume balance is shown to be "OK" (Cell J11) in the "Calculation Check Messages" section.

Parameters from Annual Recharge Worksheet

- This section of the BMP Calculations worksheet contains various parameters initially computed in and then transferred from the Annual Recharge worksheet. As noted above, the initial values for Vdef (Cell C14) and Aimp (Cell C15) are taken from the Post-Development Recharge Deficit Volume (Cell K24) and the Total Impervious Area (Cell M23) on the Annual Recharge worksheet. A complete description of when the user must specify other values for these parameters is presented above. The values for Root Zone Water Capacity (variable RWM in Cell C16) and RWC Modified to Consider dEXC (variable DRWC in Cell C17) are automatically adjusted to reflect the user's choice for the excavation depth (variable dEXC) of the BMP. The values for Climatic Factor (variable C-Factor in Cell C18) and Average Annual P (variable Pavg in Cell C19) are constant values for the municipality selected in Cell C3 of the Annual Recharge worksheet. It is important to note that if the user wishes to analyze a site in a different municipality, the user must go back to the Annual Recharge worksheet and change the municipality's name in order to obtain the correct C-Factor and Pavg values on the BMP Calculations worksheet.

WARNING: By changing the municipality, you also change the site's annual recharge deficit.

- The final value shown in this section of the BMP Calculations worksheet is the Recharge Requirement over Impervious Area (variable dr in Cell C20). This value is the average depth of annual recharge in inches over the impervious area (Aimp) specified (either by default or the user) in Cell C15. The value of dr is calculated by dividing Vdef by Aimp.

Root Zone Water Capacity Calculated Parameters

- This section of the BMP Calculations worksheet contains the calculated results for three root zone water capacity parameters. These values are needed for estimating the recharge efficiency of the groundwater recharge BMP under consideration. These parameters enable the NJGRS spreadsheet to estimate what portion of the infiltrated water from the BMP will travel downward below the root zone of the surrounding vegetation. As described above, this degree of water movement is the technical definition of groundwater recharge. The values of these three root zone water capacity parameters are automatically adjusted for the municipality and LULC segment in which the BMP is to be located. If the variable segBMP (Cell C9) is set to zero, weighted averages of these three parameters are utilized based on all the land segments specified on the Annual Recharge worksheet.

NOTE: See the Appendix to this guide for more information about these three root zone water capacity parameters.

BMP Calculated Size Parameters

- This section of the BMP Calculations worksheet contains values for two recharge BMP design parameters. The parameter Aratio (Cell G11) is computed by dividing the area (ABMP) of the BMP by the impervious area (Aimp) draining to it. The parameter VBMP (Cell G12) is the maximum storage volume in the BMP. It is computed by multiplying the BMP area (ABMP) by its effective depth (dBMP). These values can be checked by the user to help ensure that the ABMP, Aimp, and dBMP values have been inputted and used correctly by the NJGRS spreadsheet.

System Performance Calculated Parameters

- This section of the BMP Calculations worksheet contains various calculated BMP performance values. Of these, the Annual BMP Recharge Volume value (Cell G14) is the most important, since it must match the Post-Development Deficit Recharge value (variable Vdef in Cell C14) for the BMP to completely satisfy the site's annual recharge deficit or target recharge volume (as described above).
- The next parameter, Average BMP Recharge Efficiency (Cell G15), specifies the percentage of infiltrated water that is recharged (i.e., travels below the root zone) over an average year. This efficiency depends on many factors, including the project location, land cover, soil types, BMP dimensions, and depth of BMP. For the example shown in Figure 2 above, the recharge efficiency of the selected BMP is 76.7 percent.
- The remaining performance values in this section (Cells G16 to G19) are self-explanatory.

Recharge Design Parameters

- Inches of Runoff to Capture (variable Qdesign in Cell K5) is the first value in this section of the BMP Calculations worksheet. This value is the minimum depth of runoff over the BMP's tributary impervious area that must be captured and directed to the BMP to allow it to meet the site's groundwater recharge deficit. Similarly, Inches of Rainfall to Capture (variable Pdesign in Cell K6) specifies the minimum depth of rainfall over the BMP's impervious area that must be similarly controlled by the BMP to meet the site's recharge deficit. This value is also the maximum event rainfall the BMP can store without overflowing and, therefore, is the design rainfall for the BMP as described above.
- The next parameter in this section, Recharge Provided Average over Impervious Area (Cell K7) is the total annual depth of groundwater recharge provided by the BMP. For a site's recharge deficit to be met, this value must equal the Recharge Requirement over Impervious Area (variable dr in Cell C20). Runoff Captured Average over Impervious Area (Cell K8) is the last parameter in this section. It is the total annual depth of runoff over the impervious area tributary to the BMP that infiltrates into the ground. As such, it does not contain that part of the impervious area runoff to the BMP that overflows from the BMP during rainfall events greater than the BMP's design rainfall (Pdesign).

Calculation Check Messages

- This section the BMP Calculations worksheet provides three important messages to check the validity of the computed results. The Volume Balance message (Cell J11) is a check of the Annual BMP Recharge Volume in Cell G14 against the Post-Development Deficit Recharge (variable Vdef in Cell C14). If these values are equal, the problem is solved successfully and the message in this section should read “OK.” However, if the BMP’s annual recharge volume does not equal Vdef, the message instructs the user to continue to solve the problem. This may also occur if the user changes any of the BMP design parameters and forgets to solve the problem by clicking on any of the two solve buttons described above.
- The dBMP Check message (Cell J12) checks the validity of the value inputted for the dBMP, the BMP’s effective depth in Cell C6. If this value is greater than the difference between the depths to the BMP’s upper and lower surfaces (variables dBMPu and dEXC in Cells C7 and C8, a warning message is issued telling the user to adjust dBMP. dEXC Check (Cell J13) is the third message. It checks the validity of dEXC to make sure it is larger than dBMPu. If it is not, a message will appear instructing the user to make dEXC larger than dBMPu.
- Below these messages is a report on the location of the BMP as specified by the user in Cell C9 (variable segBMP). If the user has entered a valid segment number for segBMP, the message will read “OK.” If the user enters a zero for segBMP, the message will read “Location is selected as distributed or undetermined.” However, if the user enters a land segment number that was not previously defined in the Annual Recharge worksheet under Post-Developed Conditions, the message will say “Land Segment Number Selected for BMP is not Defined.” The user should then make appropriate corrections to segBMP.

Other Notes

- This section of the BMP Calculations worksheet contains notes regarding the assumptions and limitations of the calculations in this worksheet. In the current version of the spreadsheet, these notes refer to the following aspects of spreadsheet use:
 1. The variable Pdesign (Cell K6) is accurate only after the BMP’s annual recharge volume (Cell G14) is equal to the site’s recharge deficit (variable Vdef in Cell C14). In addition, Pdesign is computed from the results of the BMP’s performance. It is not used to compute that performance.
 2. A recharge BMP results are sensitive to its effective depth (dBMP in Cell C6). The user must ensure that the selected dBMP is small enough for the BMP to empty in less than 72 hours.
 3. If a BMP is located within an impervious Post-Development land segment, the Root Zone Water Capacity (variable RWC in Cell C16) at the BMP will be minimal, but not zero. This allows consideration for lateral flow and other losses at the BMP.

A P P E N D I X

Basic Equations and Variables Used in Recharge Efficiency Parameters Calculations

Basic Equations for Soil Water Capacity

- A. Equation from GSR-32:

$$RWC = \text{Root Depth} \times AWC \quad (1)$$

RWC: Root Zone Water Capacity, (inch)

AWC: Available Water Capacity, (inch/ft)

- B. New Equation:

$$ERWC = (1 - 0.5 \times C\text{-Factor}) \times RWC \quad (2)$$

ERWC: Empty Root Zone Water Capacity under natural recharge, (inch)

C-Factor: Climate Factor = Ratio of precipitation to potential ET, (unitless)

Range of Values in NJ: RWC: (0.3, 14.35), C-Factor: (1.18-1.83)

ERWC: (0.02, 5.88)

Infiltration and Artificial Recharge under BMP or LID-IMP

$$\text{Average Annual Total Infiltration Depth} = \sum_{i=1}^n \text{Minimum } (Q_i / A_{\text{ratio}}, d_{\text{BMP}}) \quad (3)$$

n = total number of runoff producing precipitation events in an average year

A_{ratio} = Ratio of surface area of BMP (A_{BMP}) to the impervious surface area served by the BMP (A_{imp}), unitless.

Find Average Empty RWC under Infiltration Facility

- A. Modification to account for the buried depth of the facility

We know that $d_{\text{BMPb}} = d_{\text{EXC}} - \text{Max}(0, d_{\text{BMPu}})$;

We can define the following relationship:

$$DRWC = \text{Max} \{0, \text{Root Depth} - 0.5 d_{\text{BMPb}} - (d_{\text{EXC}} - d_{\text{BMPb}})\} AWC$$

which can be simplified to:

$$DRWC = \text{Max} (0, \text{Root Depth} - d_{\text{EXC}} + 0.5 d_{\text{BMPb}}) AWC \quad (4)$$

DRWC = Root zone water capacity under BMP modified for the buried portion of the BMP and calculated over all land segments, (inch)

- B. Define the empty portion of EDRWC

$$EDRWC = (1 - 0.5 \times C\text{-Factor}) \times DRWC \quad (5)$$

EDRWC = Empty Portion of DRWC, (inch)

- C. Account for the effect of moisture supplied by infiltration facility in reduction of empty portion of root zone

$$RE_{avg} = (1/n) \sum_{i=1}^n \text{Maximum (EDRWC - infi)} \quad (6)$$

RE_{avg} = DRWC modified to account for infiltration under BMP, (inch)

infi = Infiltration depth in BMP during “i”th event (inch)

$$RERWC = (n/365) \times RE_{avg} + [(365-n)/n] \times EDRWC \quad (7)$$

RERWC = Average empty root zone water capacity under BMP operation calculated for the average RWC of all land segments (inch)

$$RBMP = \sum_{i=1}^n \text{Maximum (infi - RERWC, 0)} \quad (8)$$

RBMP = Total infiltration depth under BMP during an average year, (inch)

$$\text{BMP Recharge Efficiency} = \frac{RBMP}{\sum_{i=1}^n \text{infi}} \quad (9)$$

In equations (8) and (9), results are very sensitive to C-Factor. As C-Factor increases, natural recharge increases and recharge deficit due to development increases. The NJGRS equations imply that if a development is constructed in an area of high natural recharge, the recharge efficiency of a BMP at the site would also be high. Therefore, the size of required recharge BMP should not be unduly large in areas with a large C-Factor.

The above parameters are calculated in the spreadsheet for each land segment as well as for the entire area (area weighted average) under Post-Developed Conditions. If the user specifies the location of the recharge BMP, the relevant parameters of the same land segment will be used. If the user does not specify the location, the average soil and loss factors based on all of the post-developed land segments specified on the Annual Groundwater recharge worksheet will be used.

References

- American Society of Civil Engineers. 2001. Standard Guidelines for Artificial Recharge of Ground Water – EWRI/ASCE 34-01. Reston, Virginia.
- Bouwer, H. 2002. Artificial Recharge of Groundwater: Hydrogeology and Engineering. *Hydrogeology Journal* (2002) 10:121-142.
- deVries, J.J. and Simmers, I. 2002. Groundwater Recharge: An Overview of Processes and Challenges. *Hydrogeology Journal* (2002) 10:5-17.
- Lerner, D.N. 2002. Identifying and Quantifying Urban Recharge: A Review. *Hydrogeology Journal* (2002) 10:143-152.
- Linsley, R.K. Jr., Kohler, M.A., and Paulhus, J.L.H. 1975. *Hydrology for Engineers*. McGraw-Hill. New York.
- Maryland Department of the Environment. 2000. 2000 Maryland Stormwater Design Manual – Volume I – Stormwater Management Criteria. Water Management Administration. Baltimore, MD.
- Scanlon, B.R., Healy, R.W., and Cook, P.G. 2002. Choosing Appropriate Techniques for Quantifying Groundwater Recharge. *Hydrogeology Journal* (2002) 10:18-39.
- Sophocleous, M. 2002. Interactions Between Groundwater and Surface Water: The State of the Science. *Hydrogeology Journal* (2002) 10:52-67.
- USDA Natural Resources Conservation Service. National Engineering Handbook, Part 630, Hydrology.
- USDA Natural Resources Conservation Service. June 1986. Technical Release 55 – Urban Hydrology for Small Watersheds.
- Viessman, W. Jr., Knapp, J.W., Lewis, G. L., and Harbaugh, T.E. 1977. *Introduction to Hydrology – Second Edition*. Harper & Row. New York.
- Zomorodi, K. 2002. Development of Groundwater Recharge and LID Computational Techniques for New Jersey. Dewberry & Davis, LLC. Fairfax, Virginia.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 7

Landscaping

Landscaping is critical to improving both the function and appearance of stormwater best management practices (BMPs). This chapter provides landscaping criteria and plant selection guidance for effective stormwater BMPs. Part 1 describes the natural plant communities of New Jersey based on plant hardiness zones and physiographic regions. Plant selection for stormwater BMPs should match as closely as possible the natural plant communities of that region. Part 2 outlines general guidance that should be considered when landscaping any stormwater BMP. Part 3 presents more specific guidance on landscaping criteria and plant selection for individual BMP designs described in Chapter 9. These include:

- constructed stormwater wetlands;
- infiltration basins and sand filter practices;
- bioretention systems;
- open channels;
- vegetative filters and forested buffers;
- wet ponds; and
- extended detention basins.

Part 4 considers plant acquisition and planting guidelines. Part 5 deals with other plant considerations, such as vegetation maintenance, invasive species, plant availability, and costs.¹

Native Species

This manual encourages the use of native plants in stormwater management facilities. Native plants are defined as species that evolved naturally to live in this region. Practically speaking, this specifically refers to species that lived in New Jersey before Europeans explored and settled in America. Many introduced species were weeds brought in by accident; others were intentionally introduced and cultivated for use as medicinal herbs, spices, dyes, fiber plants, and ornamentals.

¹ Parts of this chapter were adopted directly from the 2000 Maryland Stormwater Design Manual (Schueler and Claytor 2000). The chapter also contains material added and adapted to the physiography, plant life, and growing conditions of New Jersey.

Introduced species often escape cultivation and begin reproducing in the wild. This is significant ecologically because many introduced species out-compete or even replace indigenous species in the wild. Some introduced or aggressive species are invasive, have few predators, and can take over naturally occurring species at an alarming rate. These include reed canary grass (*Phalaris arundinacea*), phragmites (*Phragmites communis*), kudzu (*Pueraria* spp.), purple loosestrife (*Lythrum salicaria*), Norway maple (*Acer platanoides*), autumn olive (*Elaeagnus umbellata*), Japanese honeysuckle (*Lonicera japonica*), Japanese rose (*Rosa multiflora*), garlic mustard (*Alliaria officinalis*), birdsfoot trefoil (*Lotus corniculatus*), lesser celandine (*Ranunculus ficaria*), and cattail (*Typha latifolia*). By planting non-aggressive, native species in stormwater management facilities, we can protect New Jersey's natural heritage, encourage biodiversity, and provide a legacy for future generations.

Note: Although both phragmites and cattails can be invasive, they also provide water quality and some wildlife benefits. These species should not necessarily be recommended and, if they do appear on site, it is questionable whether a considerable amount of effort or money should be spent controlling or eradicating these species.

Native species have distinct genetic advantages over non-native species for planting in New Jersey. Because they have evolved to live here naturally, indigenous plants are best suited for our local climate. This translates into greater survivorship and less replacement maintenance during the life of a stormwater management facility. Both of these attributes provide cost savings for facility owners.

Finally, people often plant exotic species for their ornamental value. While it is important to plant aesthetic stormwater management facilities for public acceptance and maintenance of property value, it is not necessary to introduce foreign species for this purpose. Many native species can be used as ornamentals. The following species are part of New Jersey's natural heritage and provide high aesthetic value throughout the year: rhododendron (*Rhododendron maximum*), pink azalea (*Rhododendron nudiflorum*), red maple (*Acer rubrum*), pin oak (*Quercus palustris*), sycamore (*Platanus occidentalis*), flowering and shrub dogwoods (*Cornus* spp.), mountain laurel (*Kalmia latifolia*), willow (*Salix* spp.), white pine (*Pinus strobus*), Atlantic white cedar (*Chamaecyparis thyoides*), American holly (*Ilex americana*), swamp rose (*Rosa palustris*), sunflowers (*Helianthus* spp.), lobelias (*Lobelia* spp), pickerel weed (*Pontederia cordata*), swamp rose mallow (*Hibiscus moscheutos*), and yellow pond lily (*Nuphar advena*).

When selecting ornamentals for stormwater management facilities, planting preference should be given to native ornamentals. Refer to the plant lists in Part 5 for a list of native species available for stormwater management facility planting.

Part 1: Natural Plant Communities of New Jersey

Plant Hardiness Zones

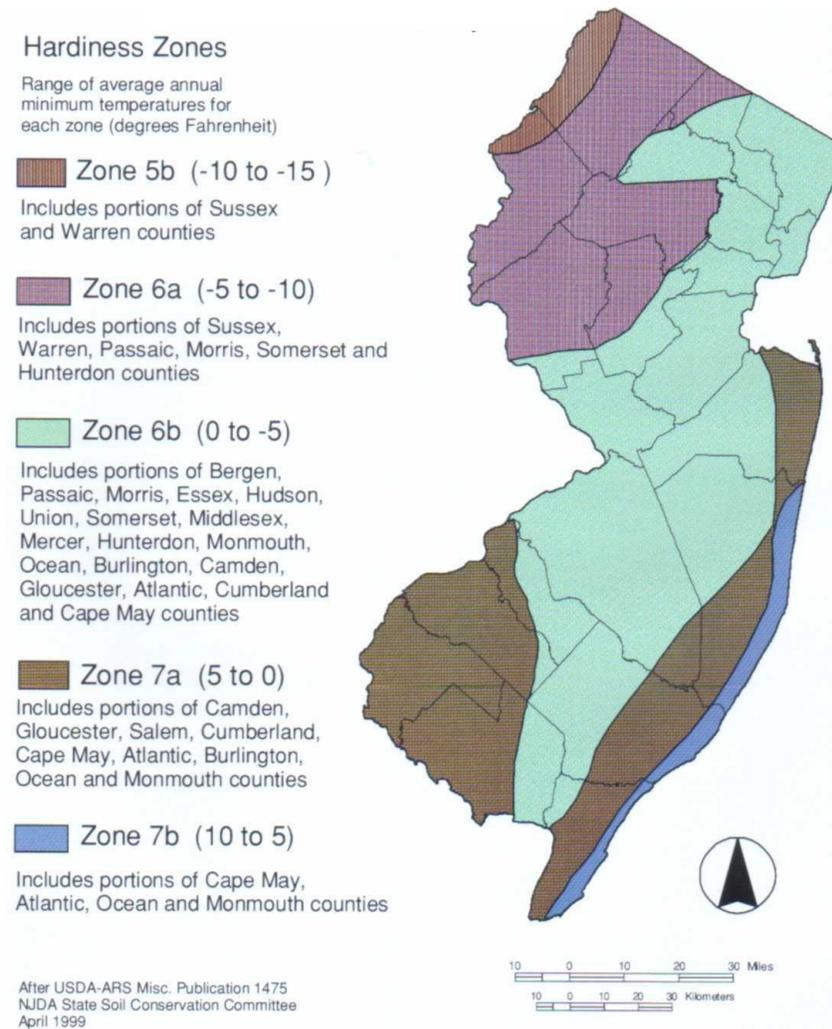
Hardiness zones are based on historical annual minimum temperatures recorded in an area. A BMP's location in relation to plant hardiness zones is important because plants differ in their ability to withstand very cold winters. This does not imply that plants are not affected by summer temperatures; New Jersey summers can be very hot, and heat tolerance should be considered in plant selection as well.

It is best to recommend plants known to thrive in specific hardiness zones. The plant list included at the end of this chapter identifies the hardiness zones for each species listed as a general planting guide. It should be noted, however, that certain site factors can create microclimates or environmental conditions that permit the growth of plants not listed as hardy for that zone. By investigating numerous references and using personal experience, a designer should be able to confidently recommend plants that will survive in microclimates.

Table 7-1: USDA Hardiness Zones for New Jersey

Zone		USDA Minimum Temperature
Temperate Zone 5	a	-20 to -15
	b	-15 to -10
Temperate Zone 6	a	-10 to -5
	b	-5 to 0
Temperate Zone 7	a	0 to 5
	b	5 to 10

Figure 7-1: USDA Plant Hardiness Zones' Average Annual Minimum Temperature (New Jersey)



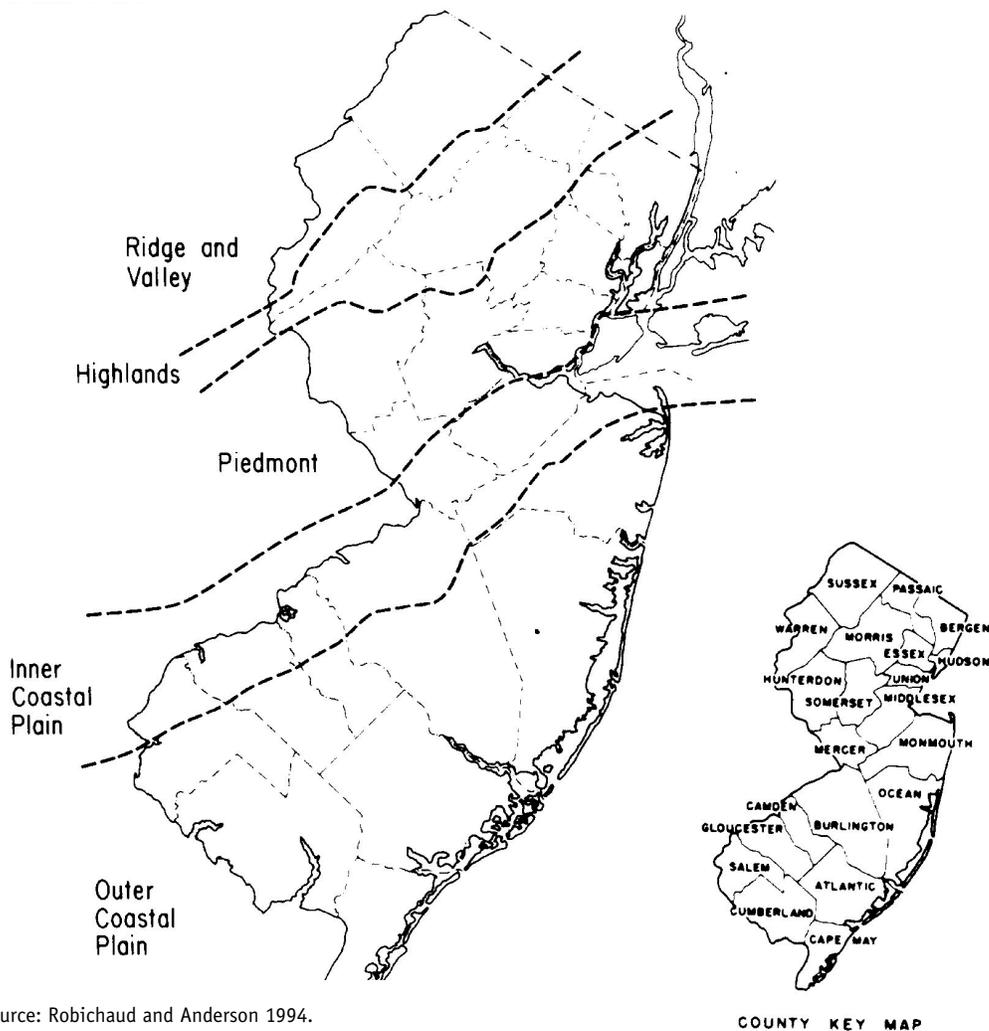
This figure can be viewed in color in the PDF version of this chapter available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Physiographic Provinces

New Jersey's five physiographic sections describe distinct geographic regions in the state with similar physical and environmental conditions (Figure 7-2). These physiographic provinces include, from west to east, the Ridge and Valley, Highlands, Piedmont, Inner Coastal Plain, and Outer Coastal Plain. Each physiographic region is defined by unique geological strata, soil type, drainage patterns, moisture content, temperature, and degree of slope, which often dictate the predominant vegetation. Because the predominant vegetation has evolved to live in these specific conditions, a successful stormwater management facility planting design can be achieved through mimicking these natural associations.

The five physiographic regions are described below with associated vegetation listed for general planting guidance.² For more detailed information and plant listings, please refer to Plant Communities of New Jersey (Robichaud and Anderson 1994).

Figure 7-2: The Five Physiographic Sections of New Jersey



Source: Robichaud and Anderson 1994.

² These descriptions were adapted, in part, from Robichaud and Anderson 1994, and Robichaud and Buell 1973.

Ridge and Valley Section

The Ridge and Valley physiographic province in the northwestern corner of New Jersey covers 635 square miles or about 7 per cent of the total land in New Jersey. It occupies a large part of Warren and Sussex counties. Ridges and valleys occur in this section because parent rock formations underlying the ridges and the valleys differ. Softer rocks such as limestone and shale erode faster than the more resistant sandstone and conglomerates. The lowest valley levels occur wherever limestone underlies the surface; the areas of shale, a slightly more resistant rock, are about 200 to 400 feet higher than the limestone, and ridges occur wherever the bedrock material is more resistant to erosion, such as sandstone or conglomerate rock.

Differences in parent rock material not only account for the variation in relief, but also create contrasts in the kind and amount of soil coverage. In general, the soil covering the Kittatinny and other ridges in this section is poor in quality from the standpoint of vegetation. The soil layer is thin on the ridges, with bedrock exposed in many places. Also, the ridge soil tends to be very acidic and of low fertility and, often, very stony.

In contrast, the soils in the valleys, derived from limestone and shale that were covered by glacial till, are for the most part deeper, more fertile, and well drained. Peat or large muck deposits (thick layers of organic material) may occur where shallow glacial lakes once existed. These were later invaded by vegetation, the dead remains of which accumulated as peat or muck.

Highlands Section

The Highlands physiographic province is located southeast of the Ridge and Valley section and covers about 900 square miles or approximately 12 per cent of New Jersey's land area. As shown in Figure 7-2, this section is broader at the north, where it is about 20 miles wide; at its southern end bordering the Delaware River Valley, it is only 10 miles wide. The Highlands region also has parallel ridges and valleys, but these differ from the Ridge and Valley section in the type of parent rock underlying the surface. Also, the ridges are more massive and generally much broader, while the valleys are narrower and have steeper slopes. Frequent rock outcroppings occur. Glacially formed lakes, such as Lake Hopatcong and Green Pond, contrast with adjacent ridges to make the Highlands a very scenic area of New Jersey.

The geologic formations of the Highlands region are estimated to be approximately 1 billion years old. Elevations in the northern part of the basin in the Highlands average approximately 1,000 feet above mean sea level, while the southern part of the Highlands show valley contours reaching a low of 350 feet. Ridges of the Highlands have resisted erosion due to the very hard rock, sandstone, gneiss, granite, marble, quartzite, igneous, and metamorphic material of which they are made. Highland valleys consist of much softer materials of limestone or shale, making them less resistant to erosion. The soils of the Highlands have been weathered from glacial till deposits and eroding bedrock and are generally shallow and stony, with frequent rock outcrops.

Piedmont Section

The Piedmont physiographic province, which occupies about 21 per cent of New Jersey's land area, is composed mostly of shale, sandstone, and argillite formations that are typically red or brownish-red in color. These formations are less resistant to erosion than the adjacent Highland gneissic rock and so, in comparison to the Highlands, the Piedmont is actually a lowland. The Piedmont section slopes gently southeastward from about 400 feet above sea level at its northwestern margin, to an elevation less than 100 feet at its southern margin bordering the Delaware, and to sea level at Newark Bay. Flat in some areas, the Piedmont contour is slightly rolling with mostly gentle slopes; however, in some areas, rivers have cut rather steep-sided valleys.

Interestingly, in the Piedmont, several ridge formations tower over the adjacent lowlands – the three Watchung Mountains (850, 650, and 350 feet high), Cushtunk Mountain, the Sourlands, and the Palisades. These ridges are made of intrusive or extrusive lava material known as diabase and basaltic rocks, both of which are much harder than the shale and sandstone of the Piedmont. While the diabase and basalt have resisted erosion, the less resistant shale and sandstone have been worn down, resulting in the lower elevations.

Differences in rock formations, combined with the fact that glacial deposits of varying age covered only part of the Piedmont, have resulted in a variety of soil types within the area. These variations appear to be less important to vegetation than the variation of soil water drainage.

Exposed rock and soil at the surface of the Piedmont is the product of intense weathering of local bedrock and the influence that glacial ice sheets had on the landscape. Continuous cycles of freezing and thawing in the rocks and soils produced landform characteristics consisting of subsurface depressions and uneven ground. Boulder fields, like those found on the Rocky Hill Ridge, were heaved to the surface by the expanding and contracting of the permafrost during glacial periods. During the interglacial periods when the ice sheets retreated, massive loads of sediment were deposited in meltwater streams. Remnants of these outwash sediments formed thin, patchy deposits known as till on the surface of the Piedmont uplands. Riverbeds, stream valleys, and other lowlands were filled with glacial sediments, forming river terraces and wide outwash plains. Silt, clay, and fine sand deposits filled the bottoms of glacially formed lakes and ponds, which have since become swamps and meadows layered with peat and muck. Subsequent weathering and erosion have continued to shape and reshape the surface and produce the modern soil profile of the Piedmont.

Common Species of Ridge and Valley, Highlands, and Piedmont Sections

Tree Species	Understory
<ul style="list-style-type: none"> • Hickory • Chestnut oak • Scarlet oak • Scrub oak • White oak • Red oak • Black oak • Scrub pine • Pitch pine • Short leaf pine • White pine • Hemlocks • Beech • Black jack oak • Sugar maple 	<ul style="list-style-type: none"> • Sweet fern • Flowering dogwood • Black haw • Chinquapin • Sassafras • Redbud • Mountain laurel • Blueberry • Fringe tree • Pink azalea • Spicebush • Maple-leaved arrowwood

Inner and Outer Coastal Plain Sections

The Inner and Outer Coastal Plain provinces are recognized by flat or gently rolling topography and elevations rising from sea level to a height of 373 feet. Coastal Plain marshes and swampy tidal flats occur throughout the New Jersey Coastal Zone. Sands, sandy loams, and silt loams resulting from sea deposits make up the soils of the Coastal Plain. The climate is mild and sometimes rainy, similar to that found further south. Because of low topographic relief and proximity to sea level, extensive swamp areas are common to the Coastal Plain province. Most notable are the Atlantic White Cedar swamps found in the Pinelands.

Common Species of the Inner and Outer Coastal Plain Sections

Tree Species	Understory
<ul style="list-style-type: none">• Loblolly pine• Virginia pine• Pitch pine• Pond pine• Sweet gum• Willow oak• Water oak• Basket oak• Pin oak• Post oak• Spanish oak• Black cottonwood• Pale hickory• Bitternut hickory• Sweet bay• American holly• Beech• Tulip tree• River birch	<ul style="list-style-type: none">• Blueberry• Huckleberry• Greenbrier• Sand blackberry• Beach plum• Beach heather• Bay berry• Sweet pepper bush• Azalea• Maleberry• Stagger bush• Fetter bush• Inkberry• Alder buckhorn

Floodplain Regions

Floodplains occur across New Jersey's physiographic provinces as low-lying areas adjacent to streams and rivers. Floodplain plant communities are similar across most of the state because of common soil characteristics governed by occasional flooding and high groundwater. Stormwater management facilities are often located in floodplains, and plant associations in these areas can provide valuable information for successful BMP plantings.

Common Species of Floodplain Regions

Tree Species	Understory
<ul style="list-style-type: none">• River birch• Willows• Silver maple• Sweet gum• Sycamore• Box elder• Green ash• American elm• Swamp white oak• Basswood• Hackberry	<ul style="list-style-type: none">• Shrub willows• Ninebark• Silky and redosier dogwoods• Sweet pepperbush• Buttonbush• Spicebush• Winterberry and inkberry holly• Elderberry• Alders

Three Hydrologic Zones

Before planting within a stormwater management facility, it is necessary to determine which hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation; as an aid to landscape designers, these tolerance levels have been divided into six zones for which corresponding plant species have been identified.

Part 4 includes a native plant list with appropriate hydrologic zones designated for each species. The hydrologic zones that are bracketed “[]” are where the plants tend to occur. There may be other zones listed outside of these brackets. These plants may occur in these zones, but are not typically found in them. On occasion, plants may be found outside of their hardiness and hydrologic zone. Plants tend to grow anywhere they can compete and survive. Additionally, hydrologic conditions in a stormwater management facility may fluctuate in unpredictable ways; thus, the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, expose the soil, and increase the chance for erosion.

Part 2: General Landscaping Guidance for all Stormwater BMPs

- Plant trees and shrubs at least 15 feet from a dam's toe of slope.
- Do not plant trees or shrubs known to have long taproots within the vicinity of earth dams or subsurface drainage facilities.
- Plant trees and shrubs at least 15 feet from perforated pipes.
- Plant trees and shrubs at least 25 feet from a riser structure.
- Provide 15-foot clearance from a non-clogging, low flow orifice.
- Herbaceous embankment plantings should be limited to 10 inches in height to ensure visibility for inspectors looking for burrowing rodents that may compromise the integrity of the embankment.
- Provide additional stabilization methods for slopes steeper than 2:1, such as turf reinforcement mats or erosion control blankets. Use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container crowns or root mats of more permanent plant material.
- Use erosion control blankets and fabrics in channels that are subject to frequent wash-outs.
- Stabilize all emergency spillways with plant material that can withstand strong flows.
- Root material should be fibrous and substantial, but lack a taproot.
- Place sod in channels that are not stabilized by erosion control blankets.
- Divert flows temporarily from seeded areas until plants are stabilized.
- Check water tolerances of existing plant materials prior to inundating the area.
- Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- Do not block maintenance access to structures with trees or shrubs.
- To reduce thermal warming, shade inflow and outflow channels as well as the southern exposure of ponds, when possible.
- Avoid plantings that will require routine or intensive chemical applications, i.e., turf areas.
- Have soil tested to determine whether amendments are needed.
- Indigenous plant species should be specified over exotic or foreign species because they are well adapted to local on-site soil conditions and require few or no additional amendments.
- Decrease the areas where turf is used. Use low-maintenance ground cover to absorb run-off.
- Plant riparian buffers with trees, shrubs, and native grasses, where possible, to stabilize banks and provide shade.
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen unattractive views into the site. Aesthetics and visual characteristics should be a prime consideration.
- Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- Carefully consider the long-term vegetation management strategy for the BMP, keeping in mind the maintenance legacy for future owners. Keep maintenance areas and access free of vegetation to allow vehicle clearance. Provide a planting surface that can withstand compaction from vehicles using maintenance access roads. Make sure the facility maintenance agreement includes requirements that ensure vegetation cover in perpetuity.
- If a BMP is likely to receive excessive amounts of de-icing salt, salt tolerant plants should be used.
- Provide signage for stormwater management areas to help educate the public, and for wildflower areas, when possible, to designate limits of mowing.
- Avoid the overuse of any plant materials, e.g., maples.
- Preserve existing natural vegetation when possible.

Soil Preparation

It is necessary to test the soil in which you are about to plant in order to determine pH, whether acid, neutral, or alkaline; major soil nutrients, nitrogen, phosphorus, and potassium; and minerals such as chelated iron and lime.

Have soil samples analyzed by experienced and qualified individuals such as those at the Rutgers Cooperative Extension, who will explain the results in writing and recommend which soil amendments would be required. Certain soil conditions, such as marine clays (glaucanite), can present serious constraints to the growth of plant materials and may require the guidance of qualified professionals. When poor soils cannot be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas recently involved in construction can become compacted so that plant roots cannot penetrate the soil. Seeds will lie on the surface of compacted soils and are often washed away or eaten by birds. For planting success, soils should be loosened to a 4-inch depth. Hard soils may require discing to a deeper depth. The soil should be loosened regardless of the ground cover to improve seed contact with the soil, increase germination rates, and allow the roots to penetrate the soil. For areas to be sodded, discing is necessary so that roots can penetrate the soil. Good growing conditions can prevent poor vegetative cover, which saves money because vegetation will not need to be replanted.

Whenever possible, topsoil should be spread to a depth of 4 to 6 inches over the entire area to be planted. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

If topsoil has been stockpiled in deep mounds for a long period of time, it is necessary to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, inoculate the soil after application.

Because newly installed plant material requires water to recover from the shock of being transplanted, be sure that a source of water is provided, especially during dry periods. This will reduce plant loss and provide the new plant materials a chance to establish root growth.

Part 3: Specific Landscaping Criteria for BMPs

It is important to recognize that plants typically found in wetlands may be cultivated in non-wetland conditions; hence the importance of obtaining plants cultivated in similar hydrologic and soil conditions as those present in the stormwater management facility. A plant typically found in wetlands, but cultivated in non-wetland conditions, may not survive if installed in wetland conditions.

Ponds and Constructed Wetlands

Before planting within a stormwater management facility, determine which hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation; the six zones described in this section will dictate which plants will survive where. Every facility does not necessarily exhibit all of these zones.

Table 7-2: Hydrologic Zones

Zone	Zone Description	Hydrologic Conditions
Zone 1	Deep water pool	1-6 feet deep permanent pool
Zone 2	Shallow water bench	6 inches to 1 foot deep
Zone 3	Shoreline fringe	Regularly inundated
Zone 4	Riparian fringe	Periodically inundated
Zone 5	Floodplain terrace	Infrequently inundated
Zone 6	Upland slopes	Seldom or never inundated

Zone 1: Deep Water Pool (1 to 6 feet)

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from 1 to 6 feet in depth and are best colonized by submergent plants, if at all. This pondscaping zone has not been routinely planted for several reasons: first, the availability of plant materials that can survive and grow in this zone is limited; and second, it is feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization, i.e., transport of plant fragments from other ponds via the feet and legs of waterfowl. If submerged plant material becomes more commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce resedimentation and improve oxidation while creating a greater aquatic habitat.

Select plants that can:

- withstand constant inundation of water of 1 foot or greater in depth;
- withstand being submerged partially or entirely;
- enhance pollutant uptake; and
- provide food and cover for waterfowl, desirable insects, and other aquatic life.

Suggested emergent or submergent species include, but are not limited to: spatterdock (*Nuphar luteum*), water lily (*Nymphaea odorata*), duckweed (*Lemna* spp.), duck potato (*Sagittaria latifolia*), wild celery (*Vallisneria americana*), sago pondweed (*Potamogeton pectinatus*), and redhead grass (*Potamogeton perfoliatus*).

Zone 2: Shallow Water Bench (6 inches to 1 foot)

Zone 2 includes all areas that are inundated below the normal pool to a depth of 1 foot; it is the primary area where emergent plants will grow in stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and non-aquatic animals, creating a diverse food chain that includes predators that provide natural regulation of mosquito populations, thereby reducing the need for insecticide applications.

Select plants that can:

- withstand constant inundation of water to depths between six inches and 1 foot deep;
- be partially submerged;
- enhance pollutant uptake; and
- provide food and cover for waterfowl, desirable insects, and other aquatic life.

Plants will stabilize the bottom and edge of the pond, absorbing wave impacts and reducing erosion when the water level fluctuates. In addition to slowing water velocities and increasing sediment deposition rates, plants can reduce re-suspension of sediments caused by the wind. Plants can also soften the engineered contours of the pond and conceal drawdowns during dry weather.

Appropriate herbaceous species include: water plantain (*Alisma plantago-aquatica*), three-sided sedge (*Dulichium arundinaceum*), managrasses (*Glyceria* spp.), soft rush (*Juncus effusus*), arrow arum (*Peltandra virginica*), smartweeds (*Polygonum* spp.), pickerelweed (*Pontederia cordata*), lizard tail (*Saururus cernuus*), many bulrushes (*Scirpus* spp.), and giant bur-reed (*Sparganium eurycarpum*).

Zone 3: Shoreline Fringe (regularly inundated)

Zone 3 encompasses the shoreline of a pond or wetland and extends vertically about 1 foot from the normal pool. This zone may be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. To stabilize the soil in this zone, Zone 3 must have a vigorous cover.

Select plants that can:

- stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation;
- withstand occasional inundation of water, as plants will be partially submerged at times;
- shade the shoreline, whenever possible, especially the southern exposure, to help reduce water temperature;
- enhance pollutant uptake;
- provide food and cover for waterfowl, songbirds, and wildlife (large plants can be selected and located to control overpopulation of waterfowl);
- be located to reduce human access to potential hazards without blocking maintenance access;
- have very low maintenance requirements because they may be difficult or impossible to reach;

- be resistant to disease and other problems that require chemical applications, since chemical application is not advised in stormwater ponds; and
- be native plants, when possible, because they are low-maintenance and disease-resistant.

Many of the emergent wetlands plants outlined in Table 7-3 also thrive in Zone 3. Some other herbaceous species that do well include: cardinal flower (*Lobelia cardinalis*), blue flag iris (*Iris versicolor*), sweet flag (*Acorus calamus*), Marsh marigold (*Caltha palustris*), swamp milkweed (*Asclepias incarnata*), bentgrass/redtop (*Agrostis* spp.), switchgrass (*Panicum virgatum*), Canada bluejoint (*Calamagrostis canadensis*), many bulrushes (*Scirpus* spp.), and spike rushes (*Eleocharis* spp.).

If shading is needed along the shoreline, the following woody species are suggested: river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), white ash (*Fraxinus americana*), pussy willow (*Salix discolor*), swamp rose (*Rosa palustris*), buttonbush (*Cephalanthus occidentalis*), highbush blueberry (*Vaccinium* spp.), red osier/silky dogwood (*Cornus stolonifera/amomum*), grey dogwood (*Cornus racemosa*), arrowwood (*Viburnum dentatum*), spicebush (*Lindera Benzoin*), sweetbells (*Leucothoe racemosa*), sweet pepperbush (*Clethra alnifolia*), winterberry (*Ilex verticillata*), inkberry holly (*Ilex glabra*), serviceberry (*Amelanchier* spp.), black willow (*Salix nigra*), red maple (*Acer rubrum*), willow oak (*Quercus phellos*), swamp white oak (*Quercus bicolor*), pin oak (*Quercus palustris*), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), sweet bay magnolia (*Magnolia virginiana*), and American sycamore (*Platanus occidentalis*).

Zone 4: Riparian Fringe (periodically inundated)

Zone 4 extends from 1 to 4 feet above the normal pool. Plants in this zone are subject to periodic inundation after storms and may experience saturated or partly saturated soil. Nearly all of the temporary extended detention area is included within this zone.

Select plants that can:

- withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months;
- stabilize the ground from erosion caused by run-off;
- shade the low-flow channel to reduce pool warming whenever possible;
- enhance pollutant uptake;
- be very low maintenance, as they may be difficult or impossible to access;
- provide food and cover for waterfowl, songbirds, and wildlife (plants may also be selected and located to control overpopulation of waterfowl); and
- be located to reduce pedestrian access to the deeper pools.

Native plants are preferred because they are low-maintenance and disease-resistant. Frequently used plant species in Zone 4 include: many asters (*Aster* spp.) and goldenrods (*Solidago* spp.), beebalm (*Monarda didyma*), bergamont (*Monarda fistulosa*), lobelias (*lobelia* spp.), coneflower (*Rudbeckia* spp.), violets (*Viola* spp.), lilies (*Lilium* spp.), primrose (*Oenothera* spp.), milkwort (*Polygala* spp.), flatsedge (*Cyperus* spp.), hollies (*Ilex* spp.), steplebush (*Spirea tomentosa*), serviceberry (*Amelanchier arborea*), nannyberry (*Viburnum lentago*), sweet pepperbush (*Clethra alnifolia*), bayberry (*Morella pensylvanica*), elderberry (*Sambucus canadensis*), sweetbay magnolia (*Magnolia virginiana*), hawthorn (*Crataegus*), shrub dogwoods (*Cornus* spp.), green ash (*Fraxinus pennsylvanica*), river birch (*Betula nigra*), sweetgum (*Liquidambar styraciflua*), American hornbeam (*Carpinus caroliniana*), persimmon (*Diospyros virginiana*), and red maple (*Acer rubrum*).

Zone 5: Floodplain Terrace (infrequently inundated)

Zone 5 is periodically inundated by floodwaters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two-year or C_{pv} water surface elevation up to the 10 or 100-year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone and establish low maintenance natural vegetation.

Select plants that can:

- withstand occasional but brief inundation during storms and, between storms, typical moisture conditions that may be moist, slightly wet, or even swinging entirely to drought conditions during the dry weather period;
- stabilize the basin slopes from erosion;
- be very low maintenance as ground cover since they may be difficult to access on steep slopes or mowing frequency may be limited (a dense tree cover may help reduce maintenance and discourage resident geese); and
- provide food and cover for waterfowl, songbirds, and wildlife.

Placement of plant material in Zone 5 is often critical. Some commonly planted species in Zone 5 include: phlox (*Phlox* spp.), solomon's seal (*Polygonatum biflorum*), many fescues (*Festuca* spp.), many viburnums (*Viburnum* spp.), Virginia rose (*Rosa virginiana*), American hornbeam (*Carpinus caroliniana*), cherries (*Prunus* spp.), willow oak (*Quercus phellos*), hickories (*Carya* spp.), and witch-hazel (*Hamamelis virginiana*).

Zone 6: Upland Slopes (seldom or never inundated)

This zone extends above the maximum 100-year water surface elevation and often includes the outer buffer of a pond or wetland. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe. Plant selections should be made based on soil condition, light, and function within the landscape because little or no water inundation will occur. Ground covers should require infrequent mowing to reduce the cost of maintaining this landscape.

Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

Some frequently used plant species in Zone 6 include: fine fescues (*Festuca* spp.), basswood (*Tilia americana*), Flowering dogwood (*Cornus florida*), Sassafras (*Sassafras albidum*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), scarlet oak (*Quercus coccinea*), white oak (*Quercus alba*), Black oak (*Quercus velutina*), and pine species (*Pinus* spp.).

Infiltration and Filter Systems

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for groundwater recharge and stormwater quality control. In some instances where permeability is great, these facilities are used for quantity control as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters.

When properly planted, vegetation will thrive and enhance the functioning of these systems. For example, pre-treatment buffers will trap sediments that often are binded with phosphorous and metals. Vegetation planted in the facility will aid in nutrient uptake and water storage. Additionally, plant roots will provide arteries for stormwater to permeate soil for groundwater recharge. Successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Figure 7-3: Plan View of Hydrologic Zones Around Stormwater Basin



PONDSCAPING ZONE 3

New England Aster, Marsh Aster, Marsh Marigold, Tussock Sedge, Spotted Joe Pye Weed, Forget Me Nots, Inkberry, Willow species, Shrub Dogwood, Pin Oak, River Birch, Sycamore, Swamp White Oak.



PONDSCAPING ZONE 4

Purple Cone Flower, Birds Foot Trefoil, Slender Rush, Deer Tongue Grass, Switch Grass, Serviceberry, Gray Birch, Hackberry, Sweet Pepper Bush (Coastal Plain), Gray Stem Dogwood, Redosier Dogwood, Green Ash, Black Gum.



PONDSCAPING ZONE 5

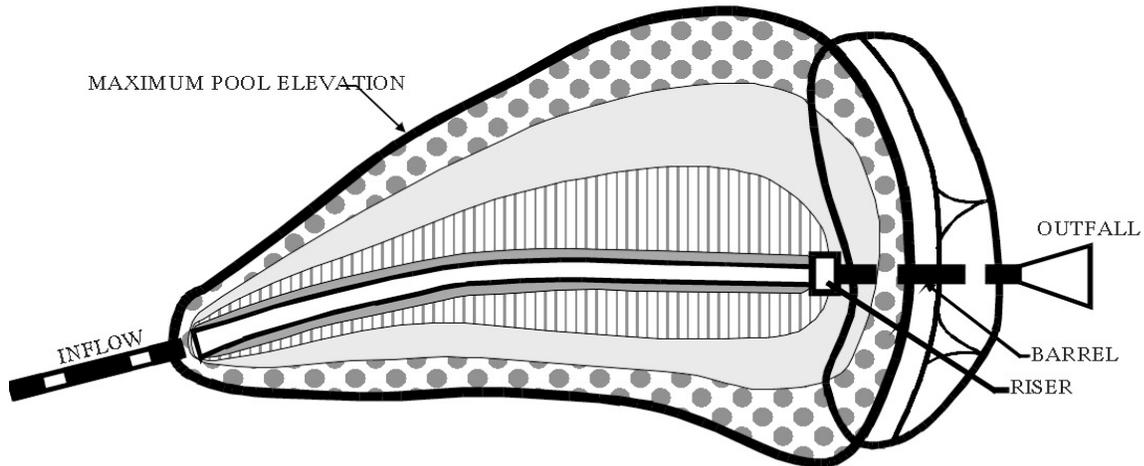
Many wildflowers and native grasses. American Holly, Witch Hazel, Ninebark, Red Oak, American Elderberry, Lowbush Blueberry, Maple Leaf Viburnum, Nannyberry, Blackhaw Viburnum.



PONDSCAPING ZONE 6

(Floodplain) Mostly native ornamentals as long as soils drain well. Many natives. All species must be able to tolerate flood plain conditions. Hackberry, Pitch Pine, Sheep Fescue, Wildflowers, many native grasses.

Note: Tree and shrub setback requirements from the dam embankment, riser, and pipes should be strictly followed.



PLAN VIEW

Source: Adapted from Schueler and Claytor 2000.

Figure 7-4: Plan View of a Shallow Marsh Planting

- 
PONDSCAPING ZONE 1
 12"-36" depth: Water Lily, Deep Water Duck Potato, Sago Pond Plant

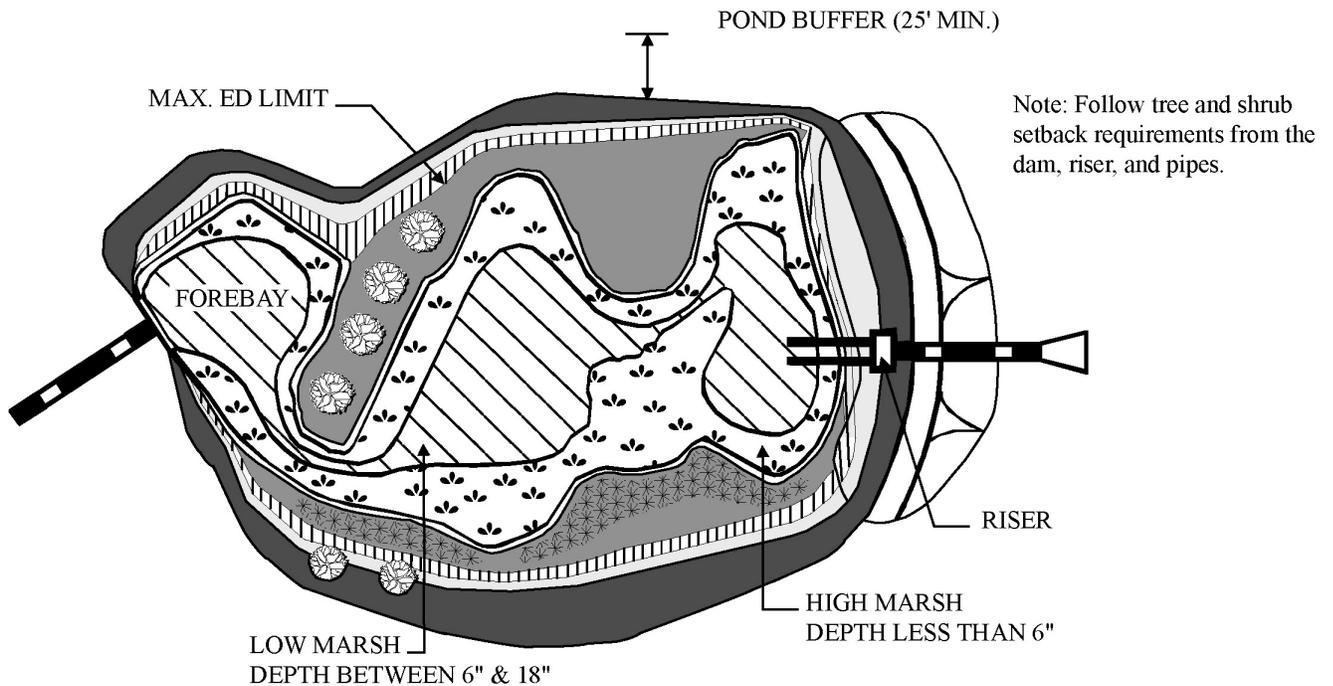
- 
PONDSCAPING ZONE 2
 0"-12" depth: Blue Flag Iris, Duck Potato, Flowering Bulrush, Soft rush, Sedges

- 
PONDSCAPING ZONE 3
 New England Aster, Marsh Aster, Tussock Sedge, Spotted Joe Pye Weed, Inkberry, Shrub willow and Dogwood species, Pin Oak, River Birch, Sycamore, Swamp White Oak

- 
PONDSCAPING ZONE 4
 Slender Rush, Deer Tongue Grass, Switch Grass, Service Berry, Gray Birch, Hackberry, Sweet Pepper Bush, Gray Stem Dogwood, Red Osier Dogwood, Green Ash, Black Gum

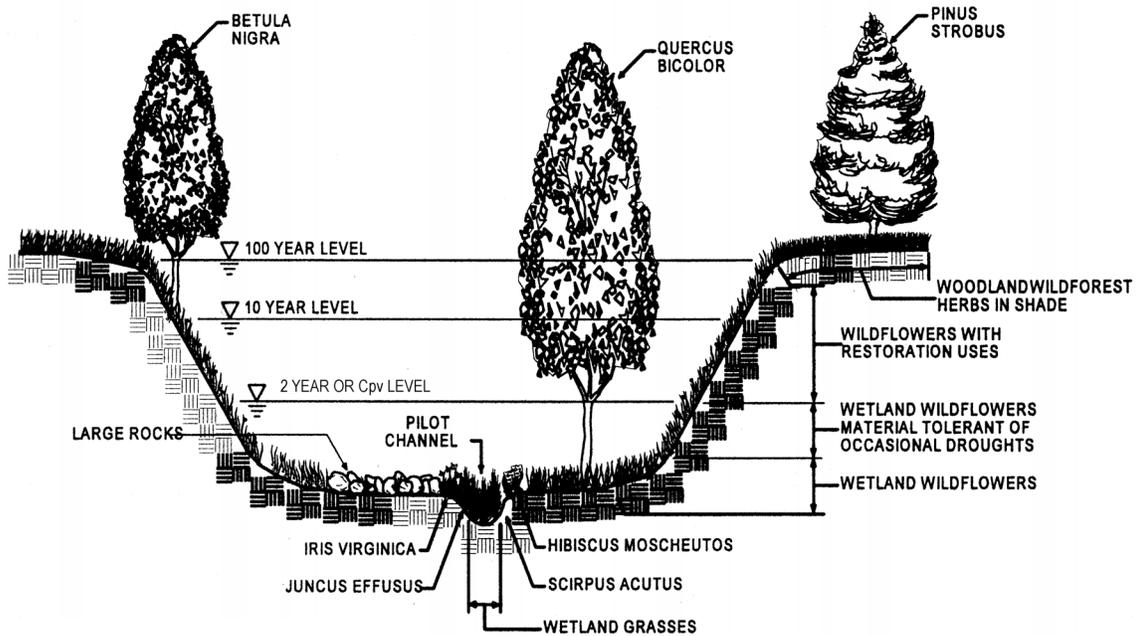
- 
PONDSCAPING ZONE 5
 (Many Wildflowers & Native Grasses), American Holly, Witch Hazel, Ninebark, Red Oak, American Elderberry, American Hemlock, Lowbush Blueberry, Nannyberry, Blackhaw Viburnum

- 
PONDSCAPING ZONE 6
 (Floodplain) Mostly ornamentals as long as soil drains well, many natives. All species must be able to tolerate floodplain conditions. Hackberry, Pitch Pine, Sheep Fescue, Wildflowers, Grasses



Source: Adapted from Schueler and Claytor 2000.

Figure 7-5: Section of a Typical Stormwater Management Detention Pond



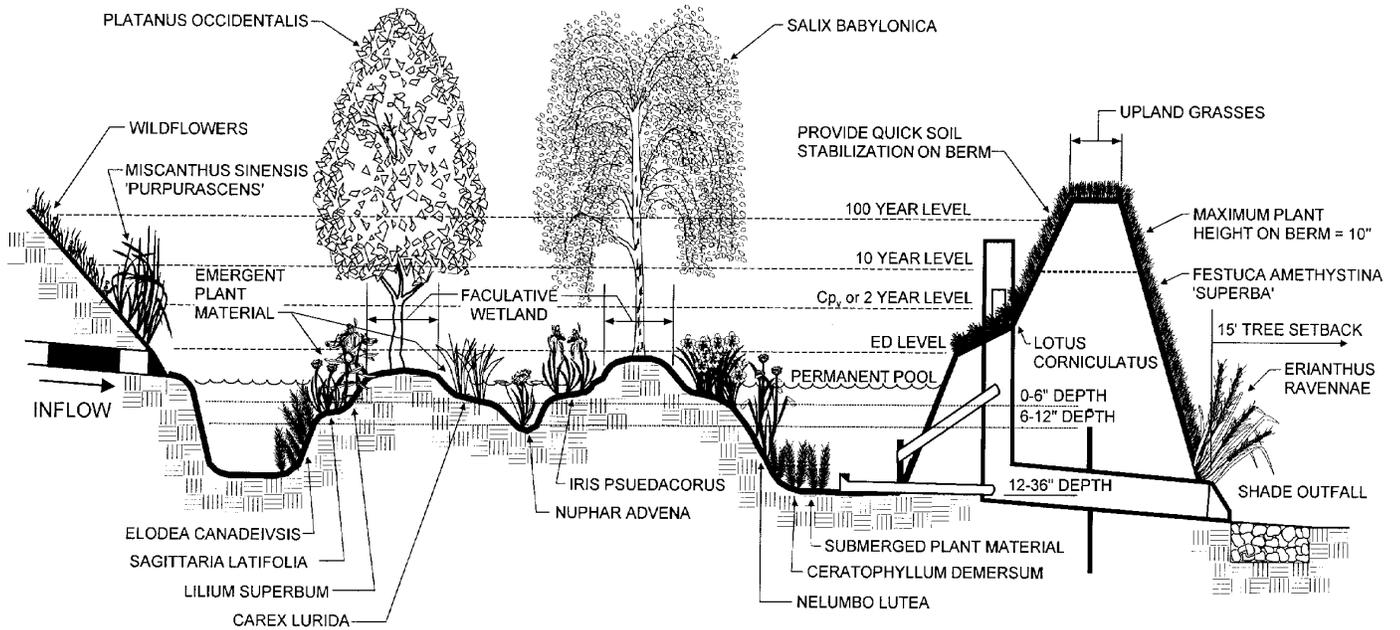
Source: Claytor and Schueler 1997.

Design Constraints

- Planting buffer strips of at least 20 feet will cause sediments to settle out before reaching the facility, thereby reducing the possibility of clogging.
- Determine areas that will be saturated with water as well as water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 7-7 and Table 7-4 for planting material guidance).
- Plants known to send down deep taproots should be avoided in systems where filter fabric is used as part of the facility design.
- Test soil conditions to determine whether soil amendments are necessary.
- Plants should be located to allow access for structure maintenance.
- Stabilize heavy flow areas with erosion control mats or sod.
- Temporarily divert flows from seeded areas until vegetation is established.

See Figure 7-6 for additional design considerations.

Figure 7-6: Section of Typical Shallow Extended Detention Marsh System



Source: Claytor and Schueler 1997.

Part 4: Bioretention

Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through absorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

Table 7-3: Common Emergent Wetland Plant Species Used for Stormwater Wetlands and on Aquatic Benches of Stormwater Ponds

Common Name	Scientific Name	Inundation Tolerance
Arrow arum	<i>Peltandra virginica</i>	up to 12"
Arrowhead/Duck potato	<i>Sagittaria latifolia</i>	up to 12"
Pickernelweed	<i>Pontederia cordata</i>	up to 12"
Blunt spike rush	<i>Eleocharis obtusa</i>	up to 3"
Bushy beardgrass	<i>Andropogon glomeratus</i>	up to 3"
Common three-square	<i>Scirpus pungens</i>	up to 6"
Iris (blue flag)	<i>Iris versicolor</i>	up to 6"
Marsh hibiscus	<i>Hibiscus moscheutos</i>	up to 3"
Spatterdock	<i>Nuphar luteum</i>	up to 36"
Sedges	<i>Carex</i> spp.	up to 6"
Soft rush	<i>Juncus effusus</i>	up to 6"
Switchgrass	<i>Panicum virgatum</i>	up to 3"
<p>Note 1: Inundation tolerance is maximum inches below the normal pool; most plants prefer shallower depths than the maximum indicated.</p> <p>Note 2: For additional plant options, consult the stormwater planting list in Section 5. Other good sources include the NJDA Standards for Soil Erosion and Sediment Control in New Jersey, Design of Stormwater Wetland Systems (Schueler 1992), and Wetland Planting Guide for the Northeastern United States (Thunhorst 1993).</p>		

Details of the planting soil are discussed in *Chapter 9.1 Standard for Bioretention Systems*. The soil should be free of stones, stumps, roots, or other woody material over 1 inch in diameter. Brush or seeds from noxious weeds, such as Johnson grass, Mugwort, Nutsedge, Purple loosestrife, and Canadian thistle should not be present in the soils. Placement of the planting soil should be in lifts of 12 to 18 inches, loosely compacted (tamped lightly with a dozer or backhoe bucket). Specific soil characteristics are presented in Table 7-4.

Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system by helping to maintain soil moisture and avoiding surface sealing that reduces permeability. Mulch helps prevent erosion and provides a microenvironment suitable for soil biota at the mulch/soil interface. It also serves as a pre-treatment layer, trapping the finer sediments that remain suspended after the primary pretreatment.

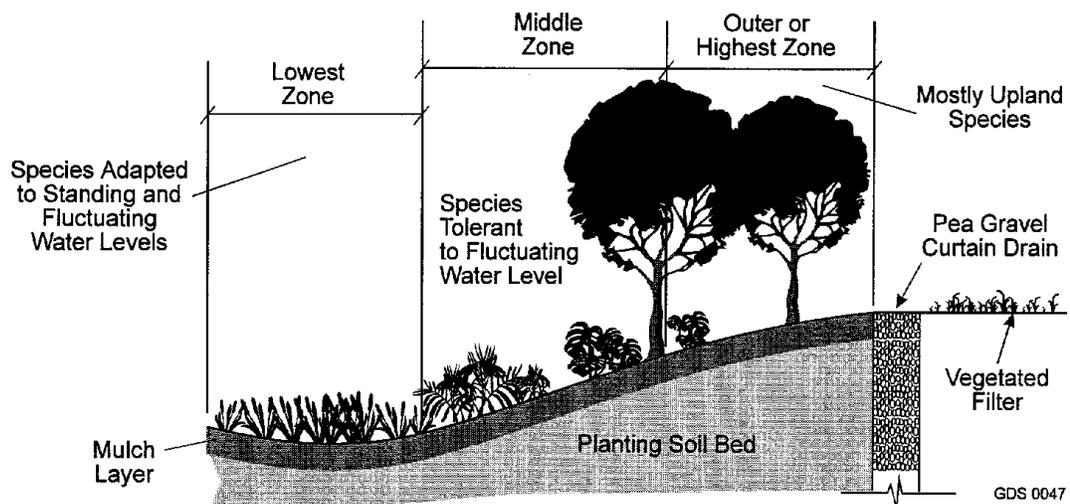
The mulch layer should be standard landscape style, single or double, shredded hardwood mulch or chips. The mulch layer should be well aged (stockpiled or stored for at least 12 months), uniform in color, and free of other materials such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of 3 inches. Grass clippings should not be used as a mulch material.

Table 7-4: Planting Soil Characteristics

Parameter	Value
pH range	5.2 to 7.00
Organic matter	1.5 to 4.0%
Magnesium	35 lbs. per acre, minimum
Phosphorus (P205)	75 lbs. per acre, minimum
Potassium (K20)	85 lbs. per acre, minimum
Soluble salts	< = 500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%

Source: Adapted from Schueler and Claytor 2000.

Figure 7-7: Planting Zones for a Bioretention Facility



Source: Claytor and Schueler 1997.

Plant Material Guidance

Plant materials should conform to the American Nursery and Landscape Association publication American Standard Nursery Stock and be selected from certified, reputable nurseries. A landscape architect or other qualified designer should specify a sequence of construction, a description of the contractor's responsibilities, planting schedule and installation specifications, initial maintenance, and a warranty period stipulating expectations of plant survival. *Planting Guidance* below presents some typical issues for planting specifications.

Open Channels

Consult Table 7-7 for grass species that perform well in the stressful environment of an open channel. For more detailed information, consult the Standards for Soil Erosion and Sediment Control in New Jersey. If a BMP is likely to receive excessive amounts of de-icing salt, salt tolerant plants should be used.

Planting Guidance

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an upland-species ecosystem. The community should be dominated by trees, but have a distinct community of understory trees, shrubs, and herbaceous materials. By creating a diverse, dense plant cover, a bioretention facility will be able to treat stormwater runoff and withstand urban stresses from insects, disease, drought, temperature, wind, and exposure.

Planting Plan Design Considerations

- Native plant species should be specified, not exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance (see Table 7-2).
- Species layout should generally be random and natural.
- A canopy should be established with an understory of shrubs and herbaceous materials.
- Woody vegetation should not be specified in the vicinity of inflow locations.
- Trees should be planted primarily along the perimeter of the bioretention area.
- Exotic (non-native) vegetation should not be specified.
- Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, and drought) should be considered when laying out the planting plan.
- Aesthetics and visual characteristics should be a prime consideration.
- Traffic and safety issues must be considered.
- Existing and proposed utilities must be identified and considered.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure 7-7). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports plants that prefer drier soil conditions but can tolerate occasional inundation by water. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. A sample of appropriate plant materials for bioretention facilities is included in Table 7-5. The layout of plant material should be flexible, but should follow the general principals described in Table 7-6. The objective is to have a system that resembles a random and natural plant layout while maintaining optimal conditions for plant establishment and growth. For a more extensive bioretention plan, consult the Design Manual for Use of Bioretention in Stormwater Management (ETA&B 1993) or Design of Stormwater Filtering Systems (Claytor and Schueler 1997).

Table 7-5: Commonly Used Species for Bioretention Areas

Trees	Shrubs	Herbaceous Species
<i>Acer rubrum</i> Red maple	<i>Clethra alnifolia</i> Sweet pepperbush	<i>Andropogon glomeratus</i> Lowland broomsedge
<i>Betula nigra</i> River birch	<i>Ilex verticillata</i> Winterberry	<i>Eupatorium purpureum</i> Sweet-scented Joe Pye weed
<i>Juniperus virginiana</i> Eastern red cedar	<i>Cephalanthus occidentalis</i> Buttonbush	<i>Scirpus pungens</i> Three square bulrush
<i>Chionanthus virginicus</i> Fringe-tree	<i>Hamamelis virginiana</i> Witch hazel	<i>Iris versicolor</i> Blue flag
<i>Nyssa sylvatica</i> Black gum	<i>Vaccinium corymbosum</i> Highbush blueberry	<i>Lobelia cardinalis</i> Cardinal flower
<i>Diospyros virginiana</i> Persimmon	<i>Ilex glabra</i> Inkberry	<i>Panicum virgatum</i> Switchgrass
<i>Platanus occidentalis</i> Sycamore	<i>Ilex verticillata</i> Winterberry	<i>Dichanthelium clandestinum</i> Deertongue
<i>Quercus palustris</i> Pin oak	<i>Viburnum dentatum</i> Arrowwood	<i>Rudbeckia laciniata</i> Cutleaf coneflower
<i>Quercus phellos</i> Willow oak	<i>Lindera benzoin</i> Spicebush	<i>Scirpus cyperinus</i> Woolgrass
<i>Salix nigra</i> Black willow	<i>Morella pennsylvanica</i> Bayberry	<i>Vernonia noveboracensis</i> New York ironweed
<p>Note: For more plant section options for bioretention, consult Design Manual for Use of Bioretention in Stormwater Management (ETA&B 1993) or Design of Stormwater Filtering Systems (Claytor and Schueler 1997).</p>		

Table 7-6: Planting Specification Issues for Bioretention Areas

Specification Element	Elements
Sequence of construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean up.
Contractor's responsibilities	Specify the contractor's responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting schedule and specifications	Specify the plants to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify the warranty period, the required survival rate, and the expected condition of plant species at the end of the warranty period.

Table 7-7: Common Grass Species for Open Channels

Common Name	Scientific Name	Notes
Alkali saltgrass	<i>Puccinellia distans</i>	Cool, good for wet, saline swales
Fowl bluegrass	<i>Poa palustris</i>	Cool, good for wet swales
Canada bluejoint	<i>Calamagrostis canadensis</i>	Cool, good for wet swales
Creeping bentgrass	<i>Agrostis palustris</i>	Cool, good for wet swales, salt tolerant
Red fescue	<i>Festuca rubra</i>	Cool, not for wet swales
Redtop	<i>Agrostis gigantea</i>	Cool, good for wet swales
Rough bluegrass	<i>Poa trivialis</i>	Cool, good for wet, shady swales
Switchgrass	<i>Panicum virgatum</i>	Warm, good for wet swales, some salt tolerance
Wildrye	<i>Elymus virginicus/riparius</i>	Cool, good for shady, wet swales
<p>Notes: These grasses are sod forming and can withstand frequent inundation, and are ideal for the swale or grass channel environment. A few are also salt-tolerant. Cool refers to cool season grasses that grow during the cooler temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot, mid-summer months.</p> <p>Where possible, one or more of these grasses should be in the seed mixes. For a more thorough listing of seed mixes see Table 7-8 in Part 5 or consult the Standards for Soil Erosion and Sediment Control in New Jersey.</p>		

Vegetative Filters and Stream Buffers

For design and plant selection of vegetative filter strips and stream buffers, consult the USDA Natural Resources Conservation Service, New Jersey Conservation Practice Standards No. 342 “Critical Area Planting,” No. 393 “Filter Strip,” or No. 391 “Riparian Stream Buffers,” available on the web at www.nj.nrcs.usda.gov through the Electronic Field Office Technical Guide (eFOTG).

Part 5: Obtaining and Planting Native Wetland Plant Propagules

There are many ways to obtain plant materials for wetland revegetation, not all of which are appropriate for every project. The process of choosing which plants will be used, in what form, and how they will be obtained should be thought out as far ahead of time as possible. Several criteria will help you make these decisions:

- Have a clear idea of the project goals and objectives (as basic as whether restoration includes woody or herbaceous vegetation or both, and what wetland functions are desired – wildlife food and habitat, water quality improvement, or soil stabilization).
- Know the hydrology on site. Some plants will tolerate only certain water levels, and some plant materials can be established only under particular hydrologic regimes. For example, it makes no sense to select seeds of a shallow water emergent for an area with standing water over 3 feet deep. The seeds will not germinate, and even if they did, the plant would not tolerate those conditions.
- Determine other unique site factors. What are the soils like? Are there micro-topographies that can be exploited? Are geese or deer a problem? Is the site shaded or in full sun?

Once you have decided on the list of potential species for the site, you need to choose the appropriate plant form. Often, this decision is based on project budget, material cost, and the acceptable level of failure. Seeds are usually less expensive than container plants, but generally do not yield great successes and take longer to establish.

Part of the choice of appropriate plant forms depends on what is available. See Tables 7-9 and 7-10 for a complete listing of plant species and available plant forms. Into this mix comes the issue of ecotypes. An ecotype is a population of plants that has become genetically differentiated in response to the conditions of a particular habitat, and it has a distinctive limit of tolerance to environmental factors. For example, wetland plants growing around a pond in Maine are likely to have later flowering times and be more cold hardy than plants of the same species growing around a pond in Florida. When restoring wetland vegetation, consider using local ecotypes as much as possible. Using plants that are already adapted to your conditions can contribute greatly to the success of a revegetation project.

Herbaceous Plants

Herbaceous (non-woody) plants such as grasses, sedges, rushes, and wildflowers are available in many forms, some of which you can readily assemble for a project.

Seed

Using seed to revegetate a wetland is often a low-cost technique, especially if you plan to collect seed yourself. Purchasing seed is more expensive than collecting, but a collection made by a professional ensures that you have good quality seed and allows you to use some species with which you may be unfamiliar. Seeding a wetland can be tricky, since water levels must be carefully controlled. Seed needs to remain close to the soil surface to receive the three elements necessary for germination: moisture (not inundation), heat, and light. Most herbaceous wetland seed requires some pre-germination treatment, either stratification, a period of exposure to cold, moist conditions, and/or scarification (abrasion of the seedcoat) before they will germinate. If seeds are planted in the fall right after cleaning, winter freeze-thaw and bacterial activity may take care of these requirements. For a spring seeding, it is important to know whether the seed has been treated. Generally, there is a greater chance for failure when using seeds rather than plants for revegetation, and little information is available for direct seeding many species. However, seeding can be used in conjunction with other planting methods to enhance restoration.

Dormant Propagules

Dormant propagules are overwintering, underground plant parts such as rhizomes, bulbs, corms, and tubers. These parts are fairly easy to work with; they can be purchased from vendors and transplanted into project sites. Revegetating a wetland with these materials is recommended over seeding because plant material is more likely to survive. Some important points to keep in mind:

- Store collected propagules in a cool, moist (not wet) location until needed. These materials have a much shorter shelf-life than seeds, so collect as close to planting time as possible.
- Dormant propagules are best purchased from local wetland plant vendors. This helps ensure that local ecotypes are used. Locally purchased plants are usually of high quality since long distance shipping is eliminated. When the plant materials shipment arrives, inspect the plants; propagules should be firm, not mushy. If they appear to be decomposing or smell bad, do not accept them.
- In temperate regions, wetland plant materials require a cold treatment to break dormancy. Planting propagules during fall, winter, or early spring will ensure that they receive the cold period necessary to develop normally.

Bare Root Plants and Plugs

Herbaceous plants are commonly grown in greenhouse flats, producing plants with a 2-inch root ball or “plug.” Some, however, may be sold as bare-root clumps. Bare-root plants are best planted in the early spring, whereas plants grown in a potting mix can generally be planted through mid-summer. Some nurseries grow deeper rooting species such as warm-season grasses in cone shaped containers referred to as Cone-tainers™ or Deep '38s™ (referring to the number of plants in a flat).

Container Plants

Using container plants (quart size or larger) to restore vegetation on a site can be costly, but healthy plants with intact root balls have an advantage over other plant materials in that they do not need to expend energy on re-growing fine roots (as is the case with bareroot materials), germinating, and growing roots and shoots (as is the case with seeds and dormant vegetative propagules). Container materials can be planted at any time of the year, as long as the ground is not frozen and there is adequate moisture. Some nurseries only contract-grow container material since this size plant requires more time to grow.

Handling Herbaceous Plants

While you will most likely not be propagating and growing your own container plants, you may find, especially if a project is delayed, that you will have to pot up and store bareroot plants, dormant propagules, donor plugs, or even seeds that have limited longevity. Wetland plants are not particularly fussy, so they do not require special soil. Clean topsoil is fine for most species. Be careful not to use soil with a lot of weed seeds, or you may end up transporting problem plants into the wetland. If clean topsoil is not available, you can use bagged topsoil. A 1:1 mix of sand and peat is also useful, especially for germinating small seeds of herbaceous species. While many wetland plants can grow under normal watering regimes, you can cut down on watering and acclimate them to the intended site by letting containers sit in tubs partially filled with water.

In the normal scheme of things, you will be buying your container plants from a wetland plant vendor. As with the other materials discussed, try to find as local a supplier as possible to minimize any difficulties the plants will have adapting to local climate conditions. Inspect container plants for overall health and appearance – plant leaves should not appear pale or have yellowing or brown tips, and stems should be

firm, not spindly. Look for evidence of pests or diseases – holes, wilting, or actual bug sightings should be cause to question the quality of materials. Pull plants from containers to look for strong root systems, with lots of white roots. If you specify particular sizes for materials, be sure that plants' roots fill the containers. Herbaceous materials can be sold in various sizes, but are most commonly available as plugs, quarts, or gallon sized containers. They are grown from seed, cuttings, vegetative propagules, or division. Containers may be made of plastic or biodegradable material such as peat, paper, or fiber.

Woody Plants

Woody plants for wetland revegetation are available in many of the same forms as herbaceous species; however, working with woody plants can take a bit more planning since they grow more slowly than herbaceous plants and it can take several growing seasons for materials to be ready for transplanting.

Seed

The advantages and disadvantages to working with woody plant seed are similar to those for herbaceous seed, that is, using seed is generally inexpensive, but can be tricky, particularly with species whose seed is preferred animal food (e.g., acorns).

Woody plant seed vendors can provide seeds for your project, but these suppliers are rare and, depending on your area, it may be difficult to obtain seed of local origin unless you collect it yourself. Try to get viability or germination information for any seeds you purchase.

Hardwood Cuttings

Stem cuttings from woody plants made during the dormant season are known as hardwood cuttings. These types of plant materials are particularly useful for revegetation on wetland edges and banks, just above the water line within the saturated soil zone. Cuttings are available to a limited extent from nurseries. Disadvantages to using hardwood cuttings include that they can dry out quickly, and that they may have high mortality rates, depending on site conditions.

The best candidates for hardwood cuttings are species of willow, poplar, and shrub dogwoods; these root readily without special treatment. Generally, cuttings are made from one to three-year-old stems, at least 18 inches long and .5 to 1.25 inches in diameter for best results; older materials do not root as readily.

Hardwood cuttings should be stored cold and moist until spring planting. To prime cuttings to form roots quickly after planting, soak cuttings in water for at least 24 hours prior to planting. This process swells the tissue that will expand from the cuttings to form roots.

Bareroot Plants

Bareroot trees and shrubs are commonly grown by native plant nurseries, and are fairly low-cost materials to work with. They are easy to store, transport, and plant, but survival is not as good as with materials that have intact roots.

When purchasing bareroot plants, look for good quality seedlings with a height of at least 18 inches and a root collar of 3/8 inches. Plants should have a substantial root mass left – about equal to the top. Do not accept materials that appear to have too much top growth to the amount of root. Plants should be firm and the growing layer underneath the bark should be green when a small area of the bark is scratched off.

Store bareroot plants in a cool, damp, dark location. Moist sawdust or soil can be packed loosely around the plants to prevent the roots from drying out. Bareroot plants can be stored successfully for several months prior to planting, as long as their roots do not dry out or freeze, and they do not leaf out.

Container Plants and Balled and Burlapped Material

The most expensive and cumbersome restoration materials, but also the most successful in terms of survival, are container plants. Balled and burlapped (B&B) plants are expensive, but can have lower survival rates because of the loss of roots when dug from nursery beds (similar to bareroot materials). Both types can be planted at any time of the year, so long as hydrologic conditions are favorable and the ground is not frozen.

There are probably few instances when you would actually go through the process of ordering container materials for a project, and it is therefore useful to know what to expect when you purchase trees and shrubs from commercial growers. Order early – as soon as you know what you need for a project, start shopping. It can take two growing seasons or longer to propagate woody plants, especially seedlings. Be sure to specify plant size: if you ask only for specific container sizes, you may end up with tiny plants.

Before you accept delivery of container or B&B stock, look at the quality of the materials, particularly the roots. With container plants, remove several plants from the pots and check roots to be sure they fill the pots and are large enough to support the top growth without being pot-bound. Large, thick roots circling inside the pots or girdling other roots are indicative of plants that have outgrown their containers and were not transplanted to larger pots in time. B&B plants should have solid root balls with enough of the root systems present to support the top growth of the plants.

Overall quality is important. Plants for revegetation sites need not be perfect landscape specimens, but they should be vigorous and healthy, with no leaf damage, wilting, or pest insects. Healthy plant material is most able to tolerate less than ideal conditions and survive on a restoration site.

Direct Seeding of Wetland Plants

Many wetland plants are very difficult to seed in the wild. Wetland plant seeds usually require three things to germinate: heat, water, and light. The need for light means that wetland plant seeds must be seeded on the surface and cannot be covered with soil. Planting the seed with a drill will cover the seed, especially if packer wheels or drag chains are used.

Many species have a very hard seed coat that takes up to a year or longer to break down enough for the embryo to germinate. Many species require special stratification treatments to prepare the seed for planting. These treatments include everything from acid wash to mechanical scarification, from pre-chilling to extremely high temperature soil conditions. Occasionally, dormant seeding (seeding during the late fall or winter after the plants have gone dormant) can be successful, but it depends on the species.

Not having absolute control of the water going into the wetland or riparian area is the most common mistake that occurs when seeding wetland plants. Without good water control, when water enters the system the newly planted seeds will float to the water surface and move to the water's edge, where wave action will deposit the seed in a very narrow zone. The seed will germinate here and the stand will generally be quite successful so long as the hydrologic conditions are maintained for the various species deposited there. With good water control, the seeds, for the most part, will stay in place, and the stand will cover the wetland bottom instead of just around the fringe.

Some species, when seeded in a greenhouse setting, require a cold-hot stratification environment for successful germination. This means that the seeds are placed in cold storage at 32-36° F for 30 to 60 days and are then planted in moist soil containers at about 100° F. Heat is one of the essential requirements for germination and growth.

Based on these difficulties, using direct seeding of herbaceous plants as the primary means of revegetating a site will require more attention to planning and control of site hydrology during the establishment period. It also means you will need to know the specific germination/stratification requirements (if any) the targeted species require. Typically, direct seeding of herbaceous species is not used as the primary means of active revegetation, but as a method to increase the overall species diversity in a wetland, especially around the perimeter, and to establish populations of specific target species. The use of wetland herbaceous plugs is recommended over the use of wetland seed. However, the grass seeding mixtures in Table 7-8 may be used to quickly vegetate newly prepared wetland or fringe areas. Seeding alone may also be used if natural regeneration of indigenous species is desired.

Table 7-8: Grass Mixtures for Quickly Vegetating Wetland Sites

Species	Common Name	Remarks
<i>Agrostis gigantea</i>	Redtop	SP,I,CG
<i>Agrostis palustris</i>	Creeping bentgrass	P,I,CG
<i>Calamagrostis canadensis</i>	Canada bluejoint	P,N,CG
<i>Cinna arundinacea</i>	Wood reedgrass	P,N,CG
<i>Dicanthelium clandestinum</i>	Deertongue	P,N,WG
<i>Elymus virginicus</i> VA./riparius	Riparian wildrye	P,N,CG
<i>Lolium multiflorum</i>	Annual ryegrass	A,I,CG
<i>Panicum virgatum</i>	Switchgrass	P,N,WG
<i>Poa trivialis</i>	Rough bluegrass	P,I,CG
<i>Poa palustris</i>	Fowl bluegrass	P,N,CG
<i>Puccinellia distans</i>	Alkali saltgrass	P,N,CG
<i>Tripsacum dactyloides</i>	Eastern gamagrass	P,N,WG
Legend: P = perennial CG = cool-season grass A = annual WG = warm-season grass I = introduced CL = cool-season legume N = native SP = short-lived perennial		

Note: Warm-season grass seeding rates are based on Pure Live Seed (PLS).

Suitable Seed Mixtures

SEED MIX 1: Warm-season mixture suitable for highly acid soils. Provides excellent wildlife value.

- Blackwell switchgrass 3 lbs./ac. PLS
- Tioga deertongue 5 lbs./ac. PLS
- Annual ryegrass (nurse) 5 lbs./ac. PLS

SEED MIX 2: Cool-season mixture suitable for highly erosive areas. Provides fair wildlife value.

- Canada bluejoint 2 lbs./ac.
- Redtop 1 lbs./ac.

SEED MIX 3: All native mixture suitable for somewhat acid soils. Provides good to excellent wildlife value.

- Blackwell switchgrass 3 lbs./ac. PLS
- Tioga deertongue 5 lbs./ac. PLS
- Wild rye 5 lbs./ac.

SEED MIX 4: Turfgrass mixture suitable for moist, shady areas.

Rough bluegrass	25 lbs./ac.
Creeping bentgrass	10 lbs./ac.

SEED MIX 5: Native grass mixture for shady sites/forested floodplains.

Wood reedgrass	2 lbs./ac.
VA or Riparian wildrye	5 lbs./ac.

SEED MIX 6: Mixture for providing quick, temporary cover in areas where planting may be delayed due to seasonal restrictions, e.g. seed in late fall, plant permanent vegetation the following spring. Excellent wildlife value.

Redtop	1 lbs./ac.
Annual ryegrass	8 lbs./ac.

SEED MIX 7: This mixture is suitable for wet, saline areas, i.e., along roadsides, adjacent to tidal areas.

Creeping bentgrass	10 lbs./ac.
Alkali saltgrass	5 lbs./ac.

SEED MIX 8: Permanent cover mix providing quick perennial cover for saturated areas that will not be planted with other species.

Eastern gamagrass	5 lbs./ac. PLS
Redtop or creeping bentgrass	2 lbs./ac.
Fowl bluegrass	5 lbs./ac.
Wild rye	8 lbs./ac.
Switchgrass	5 lbs./ac. PLS

If aesthetics are desired, the following wildflowers are tolerant of saturated conditions and any or all may be added to the above mixtures at the rates specified:

<i>Asclepias incarnata</i> (Swamp milkweed)	2 lbs./ac.
<i>Aster novae-angliae</i> (New England aster)	0.5 lb./ac.
<i>Aster novi-belgii</i> (New York aster)	0.5 lb./ac.
<i>Bidens frondosa</i> (Beggar's tick sunflower)	1 lb./ac.
<i>Caltha palustris</i> (Marsh marigold)	0.5 lb./ac.
<i>Chelone glabra</i> (Turtlehead)	1 lb./ac.
<i>Eupatorium fistulosum</i> (Joe-pye weed)	1 lb./ac.
<i>Helenium autumnale</i> (Sneezeweed)	1 lb./ac.
<i>Lobelia cardinalis</i> (Cardinal flower)	0.5 lb./ac.
<i>Lobelia siphilitica</i> (Blue lobelia)	0.5 lb./ac.
<i>Mimulus ringens</i> (Monkey flower)	1 lb./ac.
<i>Rudbeckia laciniata</i> (Green-headed coneflower)	1 lb./ac.
<i>Solidago rugosa</i> (Wrinkle-leaf goldenrod)	0.5 lb./ac.
<i>Solidago patula</i> (Rough goldenrod)	0.5 lb./ac.
<i>Verbena hastata</i> (Blue vervain)	1 lb./ac.
<i>Vernonia noveboracensis</i> (New York ironweed)	2 lbs./ac.

Wetland Transplanting with Plugs

Natural wetland systems normally have high species diversity. When selecting plant species for the project wetland, try to copy a nearby natural wetland using these techniques:

- Identify the particular hydrology in areas where the individual plant species are growing.
- Make note of how deep the water is.
- Try to imagine how long the plants will be inundated.
- Determine whether the plants are in flowing or relatively stagnant water.

Rarely will a natural wetland be totally stagnant through time. Generally, there is water flowing into the wetland from somewhere, either above ground or from groundwater. Spring and fall overturn, as well as wind mixing, helps to circulate the water.

Next, prepare the planting area. The easiest way to plant wetland species plugs is by flooding your planting site. Standing water is much easier to plant than dry soil (this also ensures that the watering system, whatever it may be, works before you plant). Make sure the soil is saturated enough so that you can dig a hole with your hand. This is more successful with fine soils than with coarse soils. Take the plug trays and place them in a Styrofoam cooler (you will not need the lid). Try to cover most of the roots with water while in transit. At the planting site, drain off most of the water so the cooler will float. Use the cooler to move the plugs around the wetland as you plant. Select a spot in your wetland to put a plug, reach into the water with your hand and dig out a hole deep enough for the plug to fit all the way in. Push the plug into the hole and pack around it with your hand. Make sure all of the roots are covered with soil. Be careful to not dislodge the plug and expose the roots when moving around. Start at one end of the planting site and work toward the opposite end.

Spacing of the plugs is a common concern. Research has indicated that many wetland plants will typically spread about 9 to 12 inches in a full growing season. Typically, wetland species are planted on 18 inch centers. Even though it takes fewer plants to plant an area at a wider spacing, plantings at wider spacing have less overall success than planting at a closer spacing. The exact reason for this is unknown, but it could be a sympathetic response to plants of the same species. If the project budget does not allow for the purchase of enough plants to cover the wetland bottom, plant the plugs on 18 inch centers, but plant them in copses or patches that are about 10 feet square or in diameter. Space the copses about 10 feet apart. The copses can be planted to different species according to the hydrology. For hydrologic Zone 2, Scheuler (1996) recommends planting at least five to seven species of emergent plants, three of which should be arrowhead (*Sagittaria latifolia*), three square (*Scirpus pungens*), and soft-stem bulrush (*Scirpus tabernaemontanii*). Based on experience, these three species will establish readily and spread quickly without being too aggressive. Over time, the plants will spread out into the unplanted areas. The additional species selected for the wetland system can be chosen to mimic natural wetlands in the area and/or enhance water quality, wildlife value, or aesthetics. Generally, it is best to keep water levels as shallow as possible to promote greater species diversity and assimilate a higher concentration of pollutants. High nutrient inflows and greatly fluctuating water levels tend to promote the more aggressive species such as reed canarygrass, cattails, and phragmites.

The optimum planting window for wetland plants is from March through late July. Planting plugs in the fall and winter has resulted in frost heaving of the plugs so that only about one-third of the plug remained in the ground. The availability of water is critical – wetland plants like it hot and wet. They tend to spread faster with warmer temperatures. If you plant in the spring, it will take the plants a while to get going, but they will have a longer establishment period. Fall planting will generally result in lower establishment success because of the shorter growing season and frost heaving damage.

The plants can be successfully established in a wide variety of soil textures. Successful wetland plantings have occurred in areas that are clay with no organic matter to gravelly textures. The biggest problem is

digging the holes. The soil texture will often limit the equipment available to dig the holes. In clay bottoms, a small bulldozer or tractor with a ripper tooth can be used to dig lines across the bottom about 8 inches deep.

In general, fertilizer is not necessary, but its use depends on the site and the soils. If during construction the bottoms have been cut down to the subsoil and all of the naturally present nutrients have been removed, fertilization will probably be necessary unless the water coming into the wetland has a high nutrient load.

After planting, release the water into the site slowly. The young plants have not fully developed the aerenchymous material necessary for them to survive in anaerobic soils and standing water. After the initial planting, be careful not to raise the water level to more than about 1 inch above the substrate. Too much water at this time may stress the new plants. Maintain the water at about 1 inch for about one week, to inhibit the germination and growth of any terrestrial species that may be present in the restored wetland. The water level can then be lowered to the substrate surface for 15 to 20 days. This will expose the mud surface, stimulating any wetland seeds that were brought in with your transplants to germinate as well as increase the rate of spread of the transplants. You can then raise the water level 1 to 2 inches for another week. Then lower the water to the substrate surface for another 15 to 20 days. After this period, slowly raise the water level to 4 to 6 inches for three to five days. Continue to gradually increase the water depth to 6 to 8 inches. The aerenchymous tissues in the plant shoots are what supply the roots with oxygen, so be careful not to raise the water over the tops of the emergent vegetation. If the plants are not showing any stress, continue to carefully raise the water level to 12 to 20 inches, if possible. These suggested water level depths must be modified based on the species used. Some species will not tolerate inundation at these suggested depths or durations. When in doubt, defer to the hydrology conditions on natural reference sites where the species occurs. The goal here is to inundate the transition zone between wetland and upland as much as possible to control any invading terrestrial species. After about 20 days lower the water level to about 2 to 3 inches (Hammer 1992). For the rest of the growing season, adjust the water level to maximize the desired community type. The key to determining the appropriate water level is to monitor the emergent wetland plant community. Raise the water level if weed problems surface. Lower the water level to encourage emergent wetland plant growth and spread. The key is to fluctuate the water level. Natural wetlands rarely have a constant water level. Many species cannot tolerate a constant water level and will begin to die out; species more tolerant to standing water will increase, and the plant diversity that was so carefully planned for will be lost.

Management during the establishment year is important to ensure that the plants do not get too much water or too little. Weed control is important especially during the establishment year because of the low water levels and exposed, unvegetated areas. A good weed control plan needs to be in place before planting. Monitoring the planting for three to five years after the establishment year will help maintain the planting and provide useful information for future plantings.

Recommendations

- Always match the plant species to the hydrology associated with that species. In general, purchase the largest plugs you can. Planting technique will often determine the size of the plugs and the ease of planting.
- Plant the plugs on 18 to 24 inch centers. Plant in patches rather than wider spacing.
- Fertilizer is generally not necessary unless the water coming into the site is relatively clean or construction has cut into the subsoil.
- Plants will spread faster under saturated soil conditions than in standing water. However, terrestrial weeds will move in to saturated soils much faster than flooded soils. Fluctuating the water level helps the plants spread and decreases terrestrial weed establishment.

- Water control is extremely important during the establishment year.
- Weed control must be planned and budgeted at the beginning of the project.
- Monitoring is essential for the success of the project. Monitoring requires time and money allocated in the budget, and a specific person identified to carry it out.
- Successful wetland plantings take significant planning and a good understanding of the hydrology at each site.

Upland Seeding

There are three main factors to consider when planning the upland seeding phase of a stormwater basin: season of seeding, seeding rates, and method of application. Season of seeding is important because some seed may require stratification before germination. Other seed, such as legume species, should probably not be seeded until spring. Seeding rate concerns both economics and plant competition. Too much seed on a site puts unnecessary cost into the total process and, at the same time, a thinner stand will emerge because of plant competition for nutrients traditionally in short supply on disturbed soils. Ideally, the site should have been prepared the previous fall if a spring seeding is desired. Usually, spring seedings are conducted between periods of wet and dry weather (commonly in March to the first of May). There may be a problem getting heavy equipment onto the site to prepare a seedbed in the early spring following a wet winter that has saturated the soil profile. (Refer to the USDA-NRCS Conservation Practice Standard-342 “Critical Area Planting” or the Standards for Soil Erosion and Sediment Control in New Jersey for seed mixtures and mulching information.)

Part 6: Other Considerations in Stormwater BMP Landscaping

Use or Function

In selecting plants, consider their desired function in the landscape. Is the plant needed as ground cover, soil stabilizer, or a source of shade? Will the plant be placed to frame a view, create focus, or provide an accent? Does the location require that you provide seasonal interest to neighboring properties? Does the adjacent use provide conflicts or potential problems and require a barrier, screen, or buffer? Nearly every plant and plant location should be provided to serve some function in addition to any aesthetic appeal.

Plant Characteristics

Certain plant characteristics, such as size and shape, are so obvious they may actually be overlooked in the plant selection. For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block an important line of sight to oncoming vehicular traffic. A small tree, when full grown, could block the view from a second story window. Consider how these characteristics can work for you or against you, today and in the future.

Other plant characteristics must be considered to determine how plants provide seasonal interest and whether plants will fit with the landscape today and through the seasons and years to come. Some of these characteristics are: color, texture, growth rate, and seasonal interest, i.e., flowers, fruit, leaves, and stems/bark.

Growth Rate

If shade is required in large amounts, quickly, a sycamore might be chosen over an oak. In urban or suburban settings, a plant's seasonal interest may be of greater importance. Residents living next to a stormwater system may desire that the facility be appealing or interesting to look at throughout the year. For example, willows are usually the first trees to grow leaves signaling the coming of spring. Pink and white dogwoods bloom in mid-spring to early summer, while witch hazel has a yellow bloom every fall, which can be contrasted with the red fall foliage of a sugar maple. Careful attention to the design and planting of a facility can result in greater public acceptance and increased property value.

Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. Many plants listed in landscape books are not readily available from local nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all needs will be wasted. That plant may require shipping, making it more costly than the budget may allow. Some planting requirements may require a special effort to find the specific plant that fulfills the needs of the site and the functions of the plant in the landscape. In some cases, it may be cost effective to investigate nursery suppliers for the availability of wetland seed mixtures. Specifications of the seed mix should include wetland seed types and the relative proportion of each species. Some suppliers provide seed mixtures suitable for specific wetland, upland, or riparian habitat conditions. This option may best be employed in small stormwater facilities, such as pocket wetlands and open swales, or to complement woody vegetation plantings in larger facilities. A complete listing of wetland plant suppliers is available on the USDA-NRCS Plant Materials Program website (www.Plant-Materials.nrcs.usda.gov).

Vegetation Maintenance

To ensure grass vigor, maintain the copse as an upland meadow, which includes cutting no shorter than 6 to 8 inches high. If a more manicured lawn setting is desired, more mowing and special attention to turf health will be needed. Some communities consider the tall wetlands-type vegetation (typically, cattails or rushes) that may grow in dry ponds to be unaesthetic. Some of this vegetation is actually beneficial as it provides water quality benefits and wildlife habitat. Some vegetative needs include:

- pH adjustment (as required);
- pruning;
- pest control;
- reseeding;
- thatch removal; and
- weed removal.

Sediment Filtration

Vegetative cover outside of an embankment filters sediment from runoff as it flows into a pond. It also prevents erosion of the pond banks. A minimum vegetated filter strip BMP is ideal around wet ponds.

Surrounding Vegetation Fertilization (not recommended, except in special cases)

It is important not to over-fertilize the surrounding vegetation. Doing so could result in excess nutrients being washed into the pond, which can contribute to excessive algae growth. As a general rule, the nutrient needs of the surrounding vegetation should be evaluated by testing the pH and nutrient content of the soil prior to fertilization. The adjustment of pH may be necessary to maintain vegetation. Fertilization of all turf areas should occur in the fall.

Purple Loosestrife

If your wetland and/or stormwater management area becomes invaded with purple loosestrife, there are methods to reduce its presence. It is important to catch its presence early, which is evident by the long purple flowering head or inflorescence. To manually rid the wetland and/or stormwater management area of purple loosestrife, it is important to ensure that the rhizomes (large tuberous root systems) are removed as well as the plant (above ground portion) prior to flowering (June through September). Plant parts, immediately upon removal, should be placed in a bag to prevent further spread of the species. If it is not possible to do this, regularly remove the flower heads before the seeds are dispersed. This will help keep this plant at bay. Digging is not recommended as it creates disturbance, which may favor the spread of the species. Herbicides are generally not effective for purple loosestrife as its seeds are long-lived and this solution is therefore short-term. If herbicide applications are used, they will need to be repeated for several years. As a caution, purple loosestrife may be available at local nurseries. Do not introduce this plant into pond areas.

Cattails and Common Reeds (phragmites)

It is important to determine which plants were originally planted when the pond or stormwater wetland was constructed. Cattails planted in these areas are one of the most beneficial plants in improving water quality. It must be noted that ponds and stormwater wetlands were originally designed with the intent of retaining

stormwater and/or treating stormwater. The concept of wildlife habitat was an ancillary benefit at best and not generally the goal prior to the mid-1990s.

Shallow water (less than 2 feet) will often be taken over by water loving plants. Dense, tall emergent vegetation, most commonly cattails and phragmites, may limit waterfowl use of a pond. Cattails provide good wildlife habitat, but can take over a shallow pond. Phragmites is much more invasive, taller, and generally does not provide for a scenic view. Once established, phragmites is very difficult to completely eradicate.

Dense stands of cattails and phragmites can reduce populations of invertebrates, amphibians, and reptiles, and may possibly increase mosquito populations. It is important to keep some areas of open water. Eradication of these species generally requires assistance from a natural resource professional. A natural resource professional is a person who has been trained in ecology and/or environmental assessment, including soils, plants, animals, air quality, human involvement, and water quantity and quality.

With respect to diversity, research has shown that lower pollutant inputs generally yield greater plant diversity. Conversely, higher pollutant inputs yield lower plant diversity. Hence, if your pond becomes populated with phragmites, cattails or both, it may indicate a high pollutant load. These species, among others, are two of the best plants for improving water quality.

Stormwater Plant Lists

The following pages present lists of herbaceous and woody vegetation native to New Jersey and suitable for planting in stormwater management facilities. The lists are intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology.

The planting lists are in alphabetical order according to the common name, with the scientific name also provided. Life forms indicate whether a plant species is an annual, perennial, grass, grass-like, fern, tree, or shrub.

Each plant species has a corresponding hydrology zone to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrological conditions.

The wetland indicator status has been included to show “the estimated probability of a species occurring in wetlands versus nonwetlands.” The indicator categories are defined as follows:

- Obligate wetland (OBL): Plants that nearly always (more than 99 per cent of the time) occur in wetlands under natural conditions.
- Facultative Wetland (FACW): Plants that usually occur in wetlands (from 67 to 99 per cent of the time), but are occasionally found in nonwetlands.
- Facultative (FAC): Plants that are equally likely to occur in wetlands and nonwetlands and are found in wetlands from 34 to 66 per cent of the time.
- Facultative Upland (FACU): Plants that usually occur in nonwetlands (from 67 to 99 per cent of the time), but are occasionally found in wetlands (from 1 to 33 per cent of the time).
- Upland (UPL): Plants that almost always (more than 99 per cent of the time), under natural conditions, occur in nonwetlands.

A given indicator status shown with a “+” or a “-” means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the “+” or “-” designation.

Since the wetland indicator status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the “Inundation Tolerance” section is designed to provide further guidance. Where a plant species is capable of surviving in standing water, a “Yes” is designated in this column. Additional information is provided for depth of inundation for aquatic vegetation and tolerance for seasonal inundation, saturated soil conditions, or tolerance to salt. Because individual plants often have unique life requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Commercial availability indicates whether the plant is available as seed, plant form (bare-root, plug, or container), or both. The plant form listed first is the most common form supplied by nurseries. The availability of some species varies from one year to the next. It is best to determine the quantity needed and the plant form desired for each individual species well ahead of time (at least six months).

Table 7-9, a list of herbaceous stormwater plants, begins on the next page, followed by Table 7-10, a list of woody vegetation.

Table 7-9: Stormwater Plant List – Herbaceous Vegetation

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Arrow arum	<i>Peltandra virginica</i>	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Arrowhead, bull-tongue	<i>Sagittaria lancifolia</i>	Perennial	[1,2],3	OBL	Yes	Plants
Arrowhead, duck potato	<i>Sagittaria latifolia</i>	Perennial	[1,2],3	OBL	0-2'	Plants, Bare-root, Seed
Arrowhead, grass-leaf	<i>Sagittaria graminea</i>	Perennial	[1,2],3	OBL	0-1'	Plants
Aster, calico	<i>Aster lateriflorus</i>	Perennial	[2,3,4]	FACW-	Seasonal	Seed, Plants
Aster, New England	<i>Aster novae-angliae</i>	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Aster, New York	<i>Aster novibelgil</i>	Perennial	[2,3],4	FACW+	Yes	Seed, Plants
Aster, panicled	<i>Aster simplex (lanceolatus)</i>	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Aster, white heath	<i>Aster ericoides</i>	Perennial	3,[4,5,6]	FACU	No	Seed
Aster, white wood	<i>Aster divercatus</i>	Perennial	4,[5,6]	NI	No	Plants
Beachgrass, American	<i>Ammophila breviligulata</i>	Grass	4[5,6]	FACU-	No	Dormant culms Plants
Beardtongue	<i>Penstemon digitalis</i>	Perennial	3,4,5	FAC	No	Plants, Seed
Beebalm	<i>Monarda didyma</i>	Perennial	3,[4,5]	FAC+	Saturated	Plants, Seed
Beggars-tick	<i>Bidens connata</i>	Annual	[2,3],4	FACW+	Yes	Seed
Beggars-tick	<i>Bidens frondosa</i>	Annual	2,[3,4]	FACW	Yes	Seed
Bentgrass, creeping	<i>Agrostis palustris</i>	Grass	[2,3],4	FACW	Yes	Seed
Bergamot, wild	<i>Monarda fistulosa</i>	Perennial	[4,5,6]	UPL	No	Plants, Seed
Black-eyed susan	<i>Rudbeckia hirta</i>	Perennial	4,[5,6]	FACU-	No	Plugs, Seed
Bladderwort, common	<i>Utricularia macrorhiza</i>	Perennial	[1,2],3	OBL	Yes	Plants
Blue lobelia	<i>Lobelia siphilitica</i>	Perennial	1,[2,3],4	FACW+	Yes	Plants, Seed
Bluebells, Virginia	<i>Mertensia virginica</i>	Perennial	[2,3],4	FACW	Yes	Plants, Seed
Bluegrass, fowl	<i>Poa palustris</i>	Grass	[2,3],4	FACW	Yes	Seed
Bluegrass, rough	<i>Poa trivialis</i>	Grass	2,[3,4],5	FACW	Seasonal	Seed
Bluestem, big	<i>Andropogon gerardii</i>	Grass	[4,5],6	FAC	No	Seed, Plants
Bluestem, little	<i>Schizachyrium scoparium</i>	Grass	6	FACU	No	Seed, Plants
Boneset	<i>Eupatorium perfoliatum</i>	Perennial	[2,3],4	FACW+	Yes	Plants, Seed
Broomsedge	<i>Andropogon virginicus</i>	Grass	[4,5],6	FACU	No	Seed
Broomsedge, lowland	<i>Andropogon glomeratus</i>	Grass	[2,3],4	FACW+	Yes	Plants
Bulrush, alkali	<i>Scirpus robustus</i>	Grass-like	1,[2],3	OBL	Salt, edge	Plants
Bulrush, chairmakers	<i>Scirpus americanus</i>	Grass-like	[1,2],3	OBL	0-6"	Plants, Seed
Bulrush, green	<i>Scirpus atrovirens</i>	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Bulrush, hardstemmed	<i>Scirpus acutus</i>	Grass-like	[1,2],3	OBL	0-3'	Plants, Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Bulrush, river	<i>Scirpus fluviatilis</i>	Grass-like	[1,2],3	OBL	0-1'	Seed
Bulrush, softstem	<i>Scirpus tabermontanii</i>	Grass-like	[1,2],3	OBL	0-1'	Plants, Seed
Bulrush, three-square	<i>Scirpus pungens</i>	Grass-like	[2,3],4	FACW+	0-6"	Plants, Seed
Burnet, Canada	<i>Sanguisorba canadensis</i>	Perennial	4,[5,6]	FACW+	Yes	Plants
Burreed, American	<i>Sparganium americanum</i>	Emergent Perennial	[1,2],3	OBL	0-1'	Plants, Seed
Burreed, giant	<i>Sparganium eurycarpum</i>	Emergent Perennial	[1,2],3	OBL	Yes	Plants, Seed
Bushclover, roundheaded	<i>Lespedeza capitata</i>	Legume	4,5,6	FACU	No	Seed, Plants
Butter-cup, yellow water	<i>Ranunculus flabellaris</i>	Perennial	[2,3,4]	FACW	Yes	Plants
Butterflyweed	<i>Asclepias tuberosa</i>	Perennial	[5,6]	NI	No	Plants, Seed
Cardinal flower	<i>Lobelia cardinalis</i>	Perennial	1,[2,3],4	FACW+	Yes	Plants, Seed
Celery, wild	<i>Vallisneria americana</i>	Perennial	[1,2],3	OBL	Yes	Plants, Seed
Club, golden	<i>Orontium aquaticum</i>	Perennial	[1,2],3	OBL	Yes	Plants
Columbine, wild	<i>Aquilegia canadensis</i>	Perennial	[3,4],5	FAC	No	Plants, Seed
Coneflower, brown-eyed	<i>Rudbeckia triloba</i>	Perennial	4,[5,6]	FACU	No	Plants, Seed
Coneflower, cut-leaf	<i>Rudbeckia laciniata</i>	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Coneflower, orange	<i>Rudbeckia fulgida</i>	Perennial	[3,4],5	FAC	No	Seed
Cordgrass, big	<i>Spartina cynosuroides</i>	Grass	[1,2],3	OBL	Tidal-fresh	Plugs
Cordgrass, prairie	<i>Spartina pectinata</i>	Grass	[1,2],3	OBL	Tidal-fresh	Plants, Seed
Cordgrass, saltmarsh	<i>Spartina alterniflora</i>	Grass	[1,2],3	OBL	Salt, edge	Plants, Seed
Cordgrass, saltmeadow	<i>Spartina patens</i>	Grass	1,[2,3],4	FACW+	Salt, edge	Plants
Coreopsis, dwarf plains	<i>Coreopsis tinctoria</i>	Annual	3,[4,5],6	FAC-	No	Seed, Plants
Coreopsis, lance-leaved	<i>Coreopsis lanceolata</i>	Perennial	5,6	FACU	No	Seed, Plants
Coreopsis, pink	<i>Coreopsis rosea</i>	Perennial	2,[3,4]	FACW	Yes	Seed, Plants
Coreopsis, tall	<i>Coreopsis tripteris</i>	Perennial	[2,3],4	FAC	Yes	Plants, Seed
Cutgrass, rice	<i>Leersia oryzoides</i>	Grass	[1,2],3	OBL	0-6"	Plants, Seed
Dragon-head, false (obedient plant)	<i>Physostegia virginiana</i>	Perennial	2,[3,4],5	FAC+	Saturated	Plants, Seed
False-hellebore, American	<i>Veratrum viride</i>	Perennial	[2,3,4]	FACW+	Yes	Plants, Seed
False-solomon's-seal	<i>Smilacina racemosa</i>	Perennial	[4,5],6	FACU-	No	Seed
Fern, cinnamon	<i>Osmunda cinnamomea</i>	Fern	[2,3],4	FACW	Saturated	Plants
Fern, New York	<i>Thelypteris noveboracensis</i>	Fern	[3,4],5	FAC	Saturated	Plants, Seed
Fern, royal	<i>Osmunda regalis</i>	Fern	[1,2],3	OBL	Saturated	Plugs
Fern, sensitive	<i>Onoclea sensibilis</i>	Fern	[2,3],4	FACW	Saturated	Plants, Seed
Fescue, hard	<i>Festuca duriuscula</i>	Grass	[3,4,5,6]	NI	No	Seed
Fescue, red	<i>Festuca rubra</i>	Grass	[4,5]	FACU	No	Seed
Fescue, sheeps	<i>Festuca ovina</i>	Grass	[4,5],6	NI	No	Seed
Gamagrass, eastern	<i>Tripsacum dactyloides</i>	Grass	2,[3,4],5	FACW	Yes	Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Goldenrod, roughleaf	<i>Solidago patula</i>	Perennial	1,[2,3,]	OBL	Yes	Seed
Goldenrod, seaside	<i>Solidago sempervirens</i>	Perennial	[2,3],4	FACW	Yes	Plants, Seed
Goldenrod, silverrod	<i>Solidago bicolor</i>	Perennial	5,6	NI	No	Plants, Seed
Goldenrod, stiff	<i>Solidago rigida</i>	Perennial	5,6	UPL	No	Plants, Seed
Goldenrod, wrinkleleaf	<i>Solidago rugosa</i>	Perennial	3,[4,5]	FAC	No	Plants, Seed
Grass, alkali	<i>Puccinellia distans</i>	Grass	[1,2],3	OBL	Yes	Seed
Grass, deertongue	<i>Dichanthelium clandestinum</i>	Grass	[2,3],4	FAC+	Seasonal	Seed
Grass, Japanese millet	<i>Echinochloa frumentcea</i>	Annual Grass	[2,3],4	NI	Yes	Seed
Grass, redtop	<i>Agrostis gigantea</i>	Grass	[2,3,],4	FACW	Yes	Seed
Hornwort, common	<i>Ceratophyllum demersum</i>	Perennial	[1,2],3	OBL	1-5	Plants
Horsetail, rough	<i>Equisetum hyemale</i>	Fern-like	[2,3],4	FACW	Yes	Plants
Indiangrass	<i>Sorghastrum nutans</i>	Grass	5,6	UPL	No	Seed, Plants
Iris, blue flag	<i>Iris versicolor</i>	Perennial	[1,2],3	OBL	0-6"	Plants, Seed
Iris, yellow flag	<i>Iris pseudacorus</i>	Perennial	[3,4],5	FAC	No	Plants, Seed
Ironweed, New York	<i>Vernonia noveboracensis</i>	Perennial	[2,3],4	FACW+	Yes	Plants, Seed
Jack-in-the-pulpit, swamp	<i>Arisaema triphyllum</i>	Perennial	[2,3],4	FACW	Seasonal	Plants
Jacob's ladder	<i>Polemonium reptans</i>	Perennial	[4,5],6	FACU	No	Seed
Jacob's-ladder, bog	<i>Polemonium vancouvericum</i>	Perennial	[3,4],5	FAC+	Saturated	Plants
Joe-pye, purple	<i>Eupatorium purpureum</i>	Perennial	3,[4,5]	FAC	Yes	Plants, Seed
Joe-pye, spotted	<i>Eupatorium maculatum</i>	Perennial	2,[3,4]	FACW	Yes	Plants, Seed
Lily, turk's-cap	<i>Lilium superbum</i>	Perennial	[2,3,4]	FACW+	Yes	Plants, Seed
Lizards tail	<i>Saururus cernuus</i>	Perennial	2,3,4	OBL	0-1'	Plants
Lotus, American	<i>Nelumbo lutea</i>	Perennial	[1,2],3	OBL	1-5'	Plants, Seed
Lovegrass, purple/tumble	<i>Eragrostis spectabilis</i>	Grass	[5,6]	NI	No	Plants, Seed
Mallow, swamp rose	<i>Hibiscus moscheutos</i>	Perennial	2,3	OBL	0-3"	Plants
Mallow, Virginia seashore	<i>Kosteletzkya virginica</i>	Perennial	[1,2],3	OBL	Yes, salted	Plants
Managrass, American	<i>Glyceria grandis</i>	Grass	[1,2],3	OBL	Yes	Plants, Seed
Managrass, Atlantic	<i>Glyceria obtusa</i>	Grass	[1,2],3	OBL	0-1'	Plants, Seed
Managrass, fowl	<i>Glyceria striata</i>	Grass	[1,2],3	OBL	Seasonal	Plants, Seed
Managrass, rattlesnake	<i>Glyceria canadensis</i>	Grass	[1,2],3	OBL	0-1'	Plants, Seed
Marsh marigold	<i>Caltha palustris</i>	Perennial	3,4	OBL	6", saturated	Plants, Seed
Marsh-mallow, common	<i>Althaea officinalis</i>	Perennial	[1,2,3]	FACW+	Yes	Plants, Seed
Meadow-rue, tall	<i>Thalictrum pubescens</i>	Perennial	[2,3,4]	FACW+	Yes	Seed, Plants
Milkweed, swamp	<i>Asclepias incarnata</i>	Perennial	2,3	OBL	Saturated	Plants, Seed
Monkey-flower	<i>Mimulus ringens</i>	Perennial	[1,2],3	OBL	Yes	Plants, Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Mountain-mint, slender	<i>Pycnanthemum tenuifolium</i>	Perennial	[2,3,4]	FACW	Yes	Plants, Seed
Nutsedge/ chufa	<i>Cyperus esculentus</i>	Grass-like	[2,3],4	FACW	Yes	Seed, Plants
Panicgrass, coastal	<i>Panicum amarulum</i>	Grass	3,4,[5,6]	FACU-	Yes	Seed, Plants
Partridge-berry	<i>Mitchella repens</i>	Groundcover	[4,5],6	FACU	No	Plants
Pennsylvania smartweed	<i>Polygonum pennsylvanicum</i>	Annual	[2,3]	FACW	0-6"	Plants, Seed
Phlox, meadow	<i>Phlox maculata</i>	Perennial	[2,3,4]	FACW	Yes	Plants
Phlox, thick-leaf	<i>Phlox carolina</i>	Perennial	4,[5,6]	FACU	No	Plants
Pickernelweed	<i>Pontederia cordata</i>	Perennial	2,3	OBL	0-1'	Plants, Seed
Pondweed, long-leaf	<i>Potamogeton nodosus</i>	Perennial	[1,2]	OBL	1' min-6'	Plants
Pondweed, sago	<i>Potamogeton pectinatus</i>	Perennial	[1,2]	OBL	1' min-24'	Plants
Primrose, evening	<i>Oenothera biennis</i>	Perennial	4,[5,6]	FACU-	No	Seed
Reedgrass, bluejoint	<i>Calamagrostis canadensis</i>	Grass	1,[2,3]	FACW+	6", saturated	Seed, Plants
Reedgrass, wood	<i>Cinna arundinacea</i>	Perennial	2,[3,4]	FACW+	Yes	Plants, Seed
Rush, baltic	<i>Juncus balticus</i>	Grass	[2,3],4	FACW	Yes	Plants, Seed
Rush, bayonet	<i>Juncus militaris</i>	Grass-like	[2,3],4	OBL	Yes	Plants, Seed
Rush, blackgrass	<i>Juncus gerardili</i>	Grass-like	[2,3],4	FACW+	Yes, saltedge	Plants, Seed
Rush, Canada	<i>Juncus canadensis</i>	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Rush, needlegrass	<i>Juncus roemerianus</i>	Grass-like	[1,2],3	OBL	Yes, saltedge	Plants, Seed
Rush, soft	<i>Juncus effusus</i>	Grass-like	[2,3],4	FACW+	0-1	Plants, Seed
Saltgrass, seashore	<i>Distichlis spicata</i>	Grass	[2,3],4	FACW+	Salt, edge	Plants
Sedge, awl	<i>Carex stipata</i>	Grass-like	[4,5],6	NI	No	Plants, Seed
Sedge, bearded	<i>Carex comosa</i>	Grass-like	[1,2],3	OBL	6" , saturated	Plants, Seed
Sedge, bladder	<i>Carex intumescens</i>	Grass-like	1,[2,3]	FACW+	Yes	Plants, Seed
Sedge, broom	<i>Carex scoparia</i>	Grass-like	[3,4],5	FACW	Yes	Plants, Seed
Sedge, fox	<i>Carex vulpinoidea</i>	Grass-like	[1,2],3	OBL	Sat. 0-6"	Plants, Seed
Sedge, fringed	<i>Carex crinita</i>	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Sedge, hop	<i>Carex lupulina</i>	Grass-like	[1,2],3	OBL	Yes	Seed
Sedge, lakebank	<i>Carex lacustris</i>	Grass-like	[1,2],3	OBL	Sat. 0-2	Plants, Seed
Sedge, pennsylvania	<i>Carex pennsylvanica</i>	Grass-like	[5,6]	NI	No	Plants
Sedge, shallow	<i>Carex lurida</i>	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Sedge, short's	<i>Carex shortiana</i>	Grass-like	3,[4,5]	FAC	Yes	Plants
Sedge, three-sided	<i>Dulichium arundinaceum</i>	Grass-like	1,[2,3]	OBL	Yes	Plants, Seed
Sedge, tussock	<i>Carex stricta</i>	Grass-like	[1,2],3	OBL	Sat, 0-6"	Plants, Seed
Sedge, yellow-fruit	<i>Carex annectens</i>	Grass-like	[2,3]4	FACW+	Yes	Plants, Seed
Seedbox	<i>Ludwigia x lacustris</i>	Annual	[1,2],3	OBL	Yes	Plants, Seed
Senna, Maryland	<i>Cassia marilandica</i>	Legume	3,[4,5]	FAC	Saturated	Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Sneezeweed, common	<i>Helenium autumnale</i>	Perennial	[2,3],4	FACW+	Yes	Seed
Solomon's-seal, small	<i>Polygonatum biflorum</i>	Perennial	[4,5],6	FACU	No	Plants
Spikerush, blunt	<i>Eleocharis obtusa</i>	Grass-like	[1,2],3	OBL	0-6"	Plants
Spikerush, creeping	<i>Eleocharis palustris</i>	Grass-like	[1,2],3	OBL	Seasonal	Plants,Seed
Spikerush, square-stem	<i>Eleocharis quadrangulata</i>	Grass-like	[1,2],3	OBL	0-1'	Plants
St. John'swort, marsh	<i>Triadenum virginicum</i>	Perennial	[1,2],3	OBL	Yes	Seed
Swamp-loosestrife, hairy	<i>Decodon verticillatus</i>	Perennial	[1,2],3	OBL	Yes	Plants
Sweetflag	<i>Acorus americanus</i>	Perennial	1,[2,3]	OBL	Yes	Plants, Seed
Switchgrass	<i>Panicum virgatum</i>	Grass	2,[3,4],5	FAC	Seasonal	Seed & Plants
Turtlehead, red	<i>Chelone obliqua</i>	Perennial	[1,2],3	OBL	Yes	Plants
Turtlehead, white	<i>Chelone glabra</i>	Perennial	[1,2],3	OBL	Yes	Plants, Seed
Vervain, blue	<i>Verbena hastata</i>	Perennial	[2,3],4	FACW+	Yes	Plants, Seed
Virginia/riparian wild rye	<i>Elymus virginicus/riparius</i>	Grass	2,[3,4]	FACW-	Yes	Seed & Plants
Water-lily, white	<i>Nymphaea odorata</i>	Perennial	[1,2],3	OBL	1-3'	Plants
Water-lily, yellow (spatterdock)	<i>Nuphars luteum</i>	Perennial	[1,2],3	OBL	1-3'	Plants
Water-plantain	<i>Alisma plantago-aquatica</i>	Perennial	[2,3],4	OBL	Yes	Plants, Seed
Woolgrass	<i>Scirpus cyperinus</i>	Grass-like	[2,3],4	FACW	Yes	Plants, Seed

Table 7-10: Stormwater Plant List – Woody Vegetation

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Alder, brook-side	<i>Alnus serrulata</i>	Tree	[1,2],3	OBL	0-3"	Yes
Alder, speckled	<i>Alnus rugosa</i>	Tree	[2,3]	FACW+	Yes	Yes
Arrow-wood, southern	<i>Viburnum dentatum</i>	Shrub	[3,4],5	FAC	Seasonal	Yes
Ash, black	<i>Fraxinus nigra</i>	Tree	[2,3],4	FACW	Saturated	Yes
Ash, green	<i>Fraxinus pennsylvanica</i>	Tree	[2,3],4	FACW	Seasonal	Yes
Ash, white	<i>Fraxinus americana</i>	Tree	[4,5],6	FACU	No	Yes
Aspen, big-tooth	<i>Populus grandidentata</i>	Tree	[4,5,6]	FACU	No	Yes, limited
Aspen, quaking	<i>Populus tremuloides</i>	Tree	[4,5],6	FACU	Yes	Yes, limited
Azalea, dwarf	<i>Rhododendron atlanticum</i>	Shrub	[2,3,4],5	FAC	Yes	No
Azalea, smooth	<i>Rhododendron arborescens</i>	Shrub	[3,4],5	FAC	Yes	Yes
Azalea, swamp	<i>Rhododendron viscosum</i>	Shrub	[1,2,3],4	OBL	Seasonal	Yes
Basswood, American	<i>Tilia americana</i>	Tree	3,[4,5],6	FACU	No	Yes
Bayberry, northern	<i>Myrica pennsylvanica</i>	Shrub	[3,4],5	FAC	Seasonal	Yes
Bayberry, southern	<i>Myrica cerifera</i>	Shrub	2,[3,4],5	FAC	Reg.inunda	Yes
Beech, American	<i>Fagus grandifolia</i>	Tree	[4,5],6	FACU	No	Yes
Birch, gray	<i>Betula populifolia</i>	Tree	[3,4],5	FAC	Seasonal	Yes
Birch, river	<i>Betula nigra</i>	Tree	[2,3],4	FACW	Seasonal	Yes
Birch, yellow	<i>Betula lutea</i>	Tree	[3,4],5	FAC	Yes	No
Black gum, swamp tupelo	<i>Nyssa sylvatica</i>	Tree	1,[2,3]	FACW+	Seasonal	Yes
Black-haw	<i>Viburnum prunifolium</i>	Shrub	[3,4,5],6	FACU	Yes	Yes
Blueberry, bog	<i>Vaccinium uliginosum</i>	Shrub	2,3,4,5,6	FACU+	Yes	No
Blueberry, highbush	<i>Vaccinium corymbosum</i>	Shrub	[2,3]	FACW-	Seasonal	Yes
Blueberry, lowbush	<i>Vaccinium angustifolium</i>	Shrub	3,[4,5,6]	FACU-	No	Yes
Box-elder	<i>Acer negundo</i>	Tree	2,[3,4]	FAC+	Seasonal	Yes
Butternut	<i>Juglans cinerea</i>	Tree	[3,4,5,6]	FACU+	Yes	Yes
Buttonbush, common	<i>Cephalanthus occidentalis</i>	Shrub	[1,2],3	OBL	0-3'	Yes
Cedar, atlantic white	<i>Chamaecyparis thyoides</i>	Tree	[1,2],3	OBL	Saturated	Yes
Cedar, eastern red	<i>Juniperus virginiana</i>	Shrub	4,5,6	FACU	No	Yes
Cedar, northern white	<i>Thuja occidentalis</i>	Tree	[2,3],4	FACW	Seasonal	Yes
Cherry, black	<i>Prunus serotina</i>	Tree	[4,5],6	FACU	No	Yes
Cherry, choke	<i>Prunus virginiana</i>	Tree	4,5,6	FACU	Yes	Yes
Cotton-wood, eastern	<i>Populus deltoides</i>	Tree	[3,4],5	FAC	Seasonal	Yes
Dangle-berry	<i>Gaylussacia frondosa</i>	Shrub	2,[3,4],5	FAC	Yes	Yes, limited

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Dog-hobble, coastal	<i>Leucothoe axillaris</i>	Shrub	[2,3,4],5	FACW+	Yes	Yes, limited
Dogwood, flowering	<i>Cornus florida</i>	Shrub-Tree	4,5,6	FACU-	No	Yes
Dogwood, gray	<i>Cornus racemosa</i>	Shrub	[3,4],5	UPL	Seasonal	Yes
Dogwood, redbud	<i>Cornus sericea</i>	Shrub	1,2[3,4],5	FACW+	Yes	Yes
Dogwood, silky	<i>Cornus amomum</i>	Shrub	[2,3],4	FACW	Seasonal	Yes
Elm, slippery	<i>Ulmus rubra</i>	Tree	[3,4],5	FAC	Yes	Yes
Fetterbush	<i>Leucothoe racemosa</i>	Shrub	3,[4,5],6	FACW	Yes	Yes, limited
Fetter-bush	<i>Lyonia lucida</i>	Shrub	[2,3,4],5	FACW	Yes	Yes, limited
Germander, American	<i>Teucrium canadense</i>	Shrub	[2,3,4],5	FACW	Yes	No
Groundsel tree	<i>Baccharis halimifolia</i>	Shrub	[2,3],4	FACW	0-6"	Yes
Gum, sweet	<i>Liquidambar styraciflua</i>	Tree	[3,4],5	FAC	Yes	Yes
Hackberry, common	<i>Celtis occidentalis</i>	Shrub-Tree	4,5,6	FACU	Seasonal	Yes
Hawthorn, cockspur	<i>Crataegus crus-galli</i>	Tree	2,[3,4,5],6	FACU	Yes	No
Hawthorn, downy	<i>Crataegus mollis</i>	Tree	1,2,[3,4,5]	FACU	Yes	Yes, limited
Hawthorn, parsley	<i>Crataegus marshallii</i>	Tree	[1,2,3,4],5,	FACU+	Yes	Yes, limited
Hazel-nut, American	<i>Corylus americana</i>	Shrub	3,[4,5,6]	FACU-	No	Yes
Hazel-nut, beaked	<i>Corylus cornuta</i>	Shrub	3,[4,5,6]	FACU-	No	No
Hemlock, eastern	<i>Tsuga canadensis</i>	Tree	4,5,6	FACU	No	Yes
Hickory, big shellbark	<i>Carya laciniosa</i>	Tree	[3,4],5	FAC	Yes	Yes
Hickory, bitter-nut	<i>Carya cordiformis</i>	Tree	4,[5,6]	FACU+	No	Yes
Hickory, pecan	<i>Carya illinoensis</i>	Tree	[4,5],6	FACU	Yes	Yes
Hickory, red	<i>Carya ovalis</i>	Tree	4,[5,6]	FACU-	No	No
Hickory, shag-bark	<i>Carya ovata</i>	Tree	4,[5,6]	FACU-	Yes	Yes
Hickory, sweet pignut	<i>Carya glabra</i>	Tree	[4,5],6	FACU-	No	No
Holly, American	<i>Ilex opaca</i>	Shrub	4,5,6	FACU	Limited	Yes
Holly, deciduous	<i>Ilex decidua</i>	Shrub	1,[2,3,4,5]	FACW-, FACW	Seasonal	Yes
Hop-hornbeam, eastern	<i>Ostrya virginiana</i>	Shrub-Tree	[3,4,5,6]	FACU-	Seasonal	Yes
Hornbeam, American	<i>Carpinus caroliniana</i>	Tree	[3,4],5	FAC	Some	Yes
Huckleberry, black	<i>Gaylussacia baccata</i>	Shrub	3,[4,5],6	FACU	No	No
Huckleberry, dwarf	<i>Gaylussacia dumosa</i>	Shrub	2,[3,4],5	FAC	Yes	No
Hydrangea, wild	<i>Hydrangea arborescens</i>	Shrub	3,[4,5,6]	UPL, FACU	No	No
Inkberry	<i>Ilex glabra</i>	Shrub	[2,3],4	FACW-	Seasonal	Yes
Laurel, mountain	<i>Kalmia latifolia</i>	Shrub	4,5,6	FACU	No	Yes
Locust, black	<i>Robinia pseudoacacia</i>	Tree	4,[5,6]	FACU	Yes	Yes
Magnolia, sweet bay	<i>Magnolia virginiana</i>	Tree	[3,4],5	FAC	Yes	Yes
Maleberry	<i>Lyonia ligustrina</i>	Shrub	[2,3,4],5	FACW	Yes	Yes, limited
Maple, mountain	<i>Acer spicatum</i>	Tree	4,5,6	FACU	No	No
Maple, red	<i>Acer rubrum</i>	Tree	[3,4],5	FAC	Seasonal	Yes
Maple, silver	<i>Acer saccharinum</i>	Tree	[2,3],4	FACW	Seasonal	Yes

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Maple, striped	<i>Acer pensylvanicum</i>	Shrub-Tree	3,[4,5,6]	FACU	No	No
Marsh elder	<i>Iva frutescens</i>	Shrub	1,[2,3]	FACW+		Yes
Meadow-sweet, broad-leaf	<i>Spiraea latifolia</i>	Shrub	[2,3,4]	FACW+	Yes	Yes
Meadow-sweet, narrow-leaf	<i>Spiraea alba</i>	Shrub	[1,2,3,4],5	FACW+	Yes	No
Nannyberry	<i>Vi burn urn lentago</i>	Shrub	[3,4],5	FAC	Seasonal	Yes
Ninebark, eastern	<i>Physocarpus opulifolius</i>	Shrub	[2,3],4	FACW-	Yes	Yes
Oak, bur	<i>Quercus macrocarpa</i>	Tree	3,[4,5],6	FAC-	Yes	Yes
Oak, chestnut	<i>Quercus prinus</i>	Tree	4,5,6	FACU	No	Yes
Oak, chinkapin	<i>Quercus muhlenbergii</i>	Tree	[3,4],5	FAC	Yes	Yes
Oak, overcup	<i>Quercus lyrata</i>	Tree	[1,2],3	OBL	Yes	Yes
Oak, pin	<i>Quercus palustris</i>	Tree	[2,3],4	FACW	Seasonal	Yes
Oak, post	<i>Quercus stellata</i>	Tree	3,[4,5,6]	NI	No	Yes, limited
Oak, red	<i>Quercus rubra</i>	Tree	6	FACU-	No	Yes
Oak, scarlet	<i>Quercus coccinea</i>	Tree	6		No	Yes
Oak, shumard	<i>Quercus shumardii</i>	Tree	2,[3,4]	FAC+	Yes	Yes
Oak, swamp chestnut	<i>Quercus michauxii</i>	Tree	1,[2,3,4,5]	FACW	Yes	Yes
Oak, swamp white	<i>Quercus bicolor</i>	Tree	1,[2,3]	FACW+	Seasonal	Yes
Oak, water	<i>Quercus nigra</i>	Tree	[3,4],5	FAC	Seasonal	Yes
Oak, white	<i>Quercus alba</i>	Tree	[4,5,6]	FACU	Yes	Yes
Oak, willow	<i>Quercus phellos</i>	Tree	2,[3,4]	FAC+	Seasonal	Yes
Pepper-bush, sweet	<i>Clethra alnifolia</i>	Shrub	2[3,4]	FAC+	Seasonal	Yes
Pine, eastern white	<i>Pinus strobus</i>	Tree	4,5,6	FACU	No	Yes
Pine, loblolly	<i>Pinus taeda</i>	Tree	3,[4,5],6	FAC-	Seasonal	Yes
Pine, pitch	<i>Pinus rigida</i>	Tree	4,5,6	FACU	Seasonal	Yes
Pine, pond	<i>Pinus serotina</i>	Tree	[1,2],3	OBL	Yes	No
Pine, virginia	<i>Pinus virginiana</i>	Tree	6		No	Yes
Redbud, eastern	<i>Cercis canadensis</i>	Shrub-Tree	3[4,5,6]	UPL, FACU	No	Yes
Rhododendron, rosebay	<i>Rhododendron maximum</i>	Shrub	[3,4],5	FAC	Yes	No
Rhododendron	<i>Rhododendron canadense</i>	Shrub	1,[2,3,4],5	FACW	Yes	Yes, limited
Rose, pasture	<i>Rosa carolina</i>	Shrub	[5,6]	NI	No	Yes
Rose, swamp	<i>Rosa palustris</i>	Shrub	[2,3]4	OBL	Yes	Yes
Rose, virginia	<i>Rosa virginiana</i>	Shrub	[3,4]5	FAC	Seasonal	Yes
Rosemary, bog	<i>Andromeda polifolia</i>	Shrub	[1,2],3	OBL	Yes	No
Sand-myrtle	<i>Leiophyllum buxifolium</i>	Shrub	3,4[5,6]	FACU-	No	No
Sassafras	<i>Sassafras albidum</i>	Tree	3,[4,5,6]	FACU-	No	Yes
Service-berry, downy	<i>Amelanchier arborea</i>	Shrub-Tree	2,[3,4,5]	FAC-	Yes	Yes
Sheep-laurel	<i>Kalmia angustifolia</i>	Shrub	3,[4,5],6	FAC	Yes	Yes

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Silver-berry, American	<i>Elaeagnus commutata</i>	Shrub	[6]	NI	No	No
Stagger-bush, piedmont	<i>Lyonia mariana</i>	Shrub	[3,4],5,6	FAC-	Yes	Yes, limited
Steeple-bush	<i>Spiraea tomentosa</i>	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Strawberry-bush, American	<i>Euonymus americanus</i>	Shrub	1,[2,3,4,5]	FAC	Yes	Yes
Sugar-berry	<i>Celtis laevigata</i>	Shrub	1,[2,3,4,5],6	FACW	Yes	Yes
Sycamore, american	<i>Platanus occidentalis</i>	Tree	[2,3],4	FACW-	Saturated	Yes
Teaberry	<i>Gaultheria procumbens</i>	Shrub	3,[4,5],6	FACU	No	Yes
Tree, tulip	<i>Liriodendron tulipifera</i>	Tree	[4,5],6	FACU	Yes	Yes
Viburnum, maple-leaf	<i>Viburnum acerifolium</i>	Shrub	3,[4,5,6]	NI	No	Yes
Viburnum, possum-haw	<i>Viburnum nudum</i>	Shrub	[1,2],3	OBL	Yes	Yes
Willow, black	<i>Salix nigra</i>	Tree	[2,3]	FACWI-	Seasonal	Yes
Willow, pussy	<i>Salix discolor</i>	Shrub	[2,3],4	FACW	Yes	Yes
Willow, silky	<i>Salix sericea</i>	Shrub	[1,2],3	OBL	Yes	Yes
Willow, tall prairie	<i>Salix humilis</i>	Shrub	3,[4,5],6	FACU	No	No
Willow, virginia	<i>Itea virginica</i>	Shrub	[1,2],3	OBL	0-6~	Yes
Winterberry, common	<i>Ilex verticillata</i>	Shrub	1,[2,3]	FACW+	Seasonal	Yes
Witch-alder, dwarf	<i>Fothergilla gardenii</i>	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Witch-hazel, American	<i>Hamamelis virginiana</i>	Shrub-Tree	3,[4,5],6	FAC-	No	Yes
Withe-rod	<i>Viburnum cassinoides</i>	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Yew, American	<i>Taxus canadensis</i>	Shrub	[3,4,5],6	FAC	Yes	Yes

References

The following is a list of resources used in compiling these guidelines and lists of plant materials, including references from the Maryland Stormwater Design Manual, from which some parts were adopted.

American Nursery and Landscape Association. 1996. American Standard for Nursery Stock. Washington, D.C.

Art, Henry W. 1986. A Garden of Wildflowers, 101 Native Species and How to Grow Them. Storey Communications, Inc. Pownal, VT.

Bentrup, G and J.C. Hoag. 1998. The practical streambank bioengineering guide: a user's guide for natural streambank stabilization techniques in the arid and semi-arid west. USDA-NRCS Plant Materials Center.

Carlson, J.R. 1992. "Selection, production, and use of riparian plant materials for the Western United States." Intermountain Forest Nursery Association, T. Landis, compiler, USDA for. Serv. Gen. Tech. Rep. RM-211, Fort Collins, CO.

Clausen, Ruth Rogers and Ekstrom, Nicolas, H. 1989. Perennials for American Gardens. Random House. New York, NY.

Claytor, Richard A. and Schueler, Thomas R. 1997. Design of Stormwater Filtering Systems: Appendix B and C. Chesapeake Bay Consortium. Silver Spring, MD.

Dirr, Michael A. 1990. Manual of Woody Landscape Plants, Their Identification, Ornamental Characteristics, Culture, Propagation, and Uses. 4th Edition. Stipes Publishing Company. Champaign, IL.

Engineering Technology Associates Inc. and Biohabitats, Inc. (ETA&B). 1993. Design Manual for Use of Bioretention in Stormwater Management. Prince Georges County Dept. of Environmental Resources. Upper Marlboro, MD.

Fournier, Michael. 1996. Observations of Wetland Species. Wetland Technical Note. USDA-NRCS, Cape May Plant Materials Center.

Fournier, Michael, Glennon, Robert, Miller, C.F. 1996. Interspecies Competition of Native Wetland Plants. Society for Ecological Restoration International Meeting-poster presentation. Rutgers University.

Greenlee, John. 1992. The Encyclopedia of Ornamental Grasses, How to Grow and Use Over 250 Beautiful and Versatile Plants. Rodale Press. Emmaus, PA.

Grelsson, G. and C. Nilsson. 1991. Vegetation and seed-bank relationships on lakeshores. Freshwater Biol. 26: 199-207.

Hammer, D.A. 1992. Creating Freshwater Wetlands. Lewis Publishers, Boca Raton, FL.

Hill, Steven R. and Duke, Peggy K. 1985-86. 100 Poisonous Plants of Maryland. Bulletin No. 314. University of Maryland Cooperative Extension Services. Ellicott City, MD.

Hoag, J.C. 1994. Seed collection and hydrology of six different species of wetland plants. USDA NRCS Plant Materials Center, Riparian/Wetland Project Information Series 6, Aberdeen, ID.

- Hoag, J.C. and M.E. Sellers. 1995. Use of greenhouse propagated wetland plants versus live transplants to vegetate constructed or created wetlands. USDA NRCS Plant Materials Center, Riparian/Wetland Project Information Series 7, Aberdeen, ID.
- Hoag, J.C. and T.A. Landis. (Manuscript in preparation) 2000. Plant Materials for Riparian Revegetation. Native Plant Journal, Vol. 2, Issue 1, January 2001.
- Hoag, J.C., M. Sellers and M. Zierke. 1992. Interagency Riparian/Wetland Plant Development Project: 4th quarter FY1992 progress report. USDA-NRCS Aberdeen Plant Materials Center, Aberdeen, ID.
- Hoag, J.C., M.E. Sellers, and M. Zierke. 1995. Wetland plant propagation tips. View from a wetland, No. 1 (1994-1995). USDA NRCS Plant Materials Center, Riparian/Wetland Project Newsletter, Aberdeen, ID.
- Hough, Mary Y. 1983. New Jersey Wild Plants. Harmony Press. Harmony, NJ.
- Leck, M.A. 1989. Wetland seed banks. In: Ecology of Soil Seed Banks, Leck, M.A., V.T. Packer, and R.L. Simpson (eds.), Academic Press, Inc.: San Diego, CA. p. 283-305.
- Longenecker, G. 1983. Woody Plant List for West Virginia. Landscape Architecture Department, Division of Resource Management, West Virginia University. Morgantown, WV.
- Manning, M.E., S.R. Swanson, T. Svejcar, and J. Trent. 1989. Rooting characteristics of four intermountain meadow community types. Journal of Range Management 42:309-312.
- Maryland Natural Heritage Program, Department of Natural Resources. 1994. Invasive and Exotic Plants of Wetlands and Floodplains in Maryland. Maryland Natural Heritage Program, Department of Natural Resources, Tawes State Office Building. Annapolis, MD.
- Maryland Natural Heritage Program, Department of Natural Resources. 1994. Rare Species of Submerged Aquatic Vegetation in Maryland. Maryland Natural Heritage Program, Department of Natural Resources, Tawes State Office Building. Annapolis, MD.
- Miles, B. 1996. Wildflower Perennials for Your Garden, A Detailed Guide to Years of Bloom from America's Native Heritage. Stackpole Books. Mechanicsburg, PA.
- Newcomb, L. 1977. Newcomb's Wildflower Guide. Little Brown and Company. Boston, MA.
- New Jersey Department of Agriculture, July, 1999, Standards for Soil Erosion and Sediment Control in New Jersey, New Jersey Department of Agriculture, Trenton, NJ.
- Ogle, D. and J.C. Hoag. 2000. Stormwater plant materials, a resource guide. Detailed information on appropriate plant materials for Best Management Practices. City of Boise, Public Works Department, Boise, ID.
- Robichaud, Beryl and Anderson, Karl 1994, Plant Communities of New Jersey, Rutgers University Press, New Brunswick, NJ.
- Robichaud, Beryl and Murray F. Buell. 1973. Vegetation of New Jersey: a study of landscape diversity. New Brunswick, N.J.: Rutgers University Press.
- Reed, Porter B. Jr. 1998. National List of Plant Species that Occur in Wetlands: Northeast (Region 1), For National Wetlands Inventory. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.
- Salisbury, E. 1970. The pioneer vegetation of exposed muds and its biological features. Phil. Trans. Royal Soc. London, Ser. B 259: 207-255.

- Schueler, Thomas R. 1996. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region. Department of Environmental Programs Metropolitan Washington Council of Governments, Metropolitan Information Center. Washington, D.C.
- Schueler, Thomas R. 1992. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region. Department of Environmental Programs Metropolitan Washington Council of Governments, Metropolitan Information Center. Washington, D.C.
- Schueler, Thomas R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Department of Environmental Programs Metropolitan Washington Council of Governments, Metropolitan Information Center. Washington, D.C.
- Schueler, Thomas R. and Claytor, Richard A. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.
- The Pennsylvania State University, College of Agriculture, Cooperative Extension Service. Weed Identification. File No. IVC9 10M386, U. Ed. 85-439 and File No. IVC9 10M587 U.Ed. 86-356. The Pennsylvania State University, College of Agriculture, Cooperative Extension Service. University Park, PA.
- Thunhorst, Gwendolyn A. 1993. Wetland Planting Guide for the Northeastern United States: Plants for Wetland Creation, Restoration, and Enhancement, Environmental Concern, Inc. St. Michael, MD.
- Tiner, Ralph W. Jr. 1988. Field Guide to Non-Tidal Wetland Identification. U.S. Fish and Wildlife Service and New Jersey Department of Natural Resources and New Jersey Geological Survey. Annapolis, MD.
- USDA-Natural Resources Conservation Service & Environmental Protection Agency. A Handbook of Constructed Wetlands. Vol. 1 General Considerations and Vol. 5 Stormwater. Interagency Core Group.
- USDA-Natural Resources Conservation Service. 2003. Wetland Restoration, Enhancement, and Management Handbook. Wetland Science Institute.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 8

Maintenance and Retrofit of Stormwater Management Measures

Maintenance of Stormwater Management Measures

Research and experience have demonstrated that regular and thorough maintenance is necessary for stormwater management measures to perform effectively and reliably. They have also demonstrated that failure to perform such maintenance can lead to diminished performance, deterioration, and failure, in addition to a range of health and safety problems including mosquito breeding, vermin, and the potential for drowning. The potential for such problems to develop is accentuated by many of the very features and characteristics that allow stormwater management measures to do their job, including standing or slowing moving water, dense vegetation, forebays, trash racks, dams, and the need to continually function in all types of weather. As implied by their name, stormwater management measures are also expected to become the repositories for sediment, nutrients, trash, debris, and other pollutants targeted by the NJDEP Stormwater Management Rules. For this reason, stormwater management measures share maintenance requirements with more mundane items as vacuum cleaner bags, car motor filters, and floor mats, all of which require regular inspection and cleaning, sediment and debris removal, and periodic replacement.

In recognition of these needs and potential problems, the NJDEP Stormwater Management Rules require that a maintenance plan be developed for all stormwater management measures incorporated into the design of a major development. This maintenance plan must contain specific preventative and corrective maintenance tasks, schedules, cost estimates, and the name, address, and telephone number of the person or persons responsible for the measures' maintenance.

In accordance with the Rules, this section of Chapter 8 has been developed to provide guidelines for the development of such maintenance plans. Specific maintenance guidance for structural stormwater management measures is presented in *Chapter 9: Structural Stormwater Management Measures*. Additional maintenance information is also provided in the NJDEP Stormwater Management Facility Maintenance Manual, including maintenance tasks and equipment, inspection procedures and schedules, ownership responsibilities, and design recommendations to minimize and facilitate inspection and maintenance tasks.

Finally, it should be noted that a stormwater management measure that includes a dam as defined in the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also have an operations and maintenance manual for the dam as described at 7:20-1.11.

Maintenance Plan Contents

According to the NJDEP Stormwater Management Rules, all maintenance plans for stormwater management measures must include the following:

1. The name, address, and telephone number of the person or persons responsible for the preventative and corrective maintenance of the stormwater management measure. If the plan identifies a party other than the owner or developer as having responsibility for maintenance, i.e., a public entity or homeowners' association, the plan must include a copy of the other party's written agreement to assume this responsibility. This agreement must include a copy of any ordinance or regulation that requires the owner or developer to dedicate the stormwater management measure and/or its maintenance to the other party.
2. Specific preventative and corrective maintenance tasks such as removal of sediment, trash, and debris; mowing, pruning, and restoration of vegetation; restoration of eroded areas; elimination of mosquito breeding habitats; control of aquatic vegetation; and repair or replacement of damaged or deteriorated components. Detailed maintenance information for specific structural stormwater management measures is presented in Chapter 9. Maintenance needs of nonstructural measures are discussed in *Chapter 2: Low Impact Development Techniques*.
3. A schedule of regular inspections and tasks. Detailed inspection tasks and schedules for specific structural stormwater management measures are presented in Chapter 9.
4. Cost estimates of maintenance tasks, including sediment, trash, and debris removal.
5. Detailed logs of all preventative and corrective maintenance performed at the stormwater management measure, including all maintenance-related work orders.

In addition, as described in the NJDEP Stormwater Management Facility Maintenance Manual, the following items should also be included in the maintenance plan:

1. Maintenance equipment, tools, and supplies necessary to perform the various preventative and corrective maintenance tasks specified in the plan. Sources of specialized, proprietary, and nonstandard equipment, tools, and supplies should also be provided.
2. Recommended corrective responses to various emergency conditions that may be encountered at the stormwater management measure. It should be noted that, if the stormwater management measure includes a Class I or II dam as defined in the NJDEP Dam Safety Standards at N.J.A.C. 7:20, an emergency action plan for the dam is also required. See N.J.A.C. 7:20-1.7(f) for more information.
3. Maintenance, repair, and replacement instructions for specialized, proprietary, and nonstandard measure components, including manufacturers' product instructions and user manuals.
4. Procedures and equipment required to protect the safety of inspection and maintenance personnel.
5. Approved disposal and recycling sites and procedures for sediment, trash, debris, and other material removed from the measure during maintenance operations.
6. Originals or copies of manufacturers' warranties on pertinent measure components.
7. As-built construction plans of the stormwater management measure and copies of pertinent construction documents such as laboratory test results, permits, and completion certificates.

Maintenance Plan Considerations

In addition to the plan contents described above, a maintenance plan should address the following important aspects of stormwater management measure maintenance.

Access

All stormwater management measures' components must be readily accessible for inspection and maintenance. Therefore, trees, shrubs, and underbrush must be pruned or trimmed as necessary to maintain access to the stormwater management measure via roadways, paths, and ramps. This includes paths through perimeter vegetation to permanent pools, aquatic benches, and safety ledges to allow for the inspection and control of mosquito breeding. In addition, the exact limits of inspection and maintenance easements and rights-of-way should be specified on stormwater management measure plans and included in the maintenance plan.

Training of Maintenance Personnel

Maintenance training begins with a basic description of the purpose and function of the overall stormwater management measure and its major components. Such understanding will enable maintenance personnel to provide more effective component maintenance and more readily detect maintenance-related problems. Depending on the size, character, location, and components of a stormwater management measure, maintenance personnel may also require training in specialized inspection and maintenance tasks and/or the operation and care of specialized maintenance equipment. Training should also be provided in the need for and use of all required safety equipment and procedures.

Aesthetics

The impacts of the aesthetics of the stormwater management measures on the surrounding community should be included in the consideration for the design and selection of the stormwater management measure.

Required Maintenance Plan Procedures

Once the maintenance plan is completed, the NJDEP Stormwater Management Rules require that the following procedures be followed:

1. Copies of the maintenance plan must be provided to the owner and operator of the stormwater management measure. Copies must also be submitted to all reviewing agencies as part of each agency's approval process. In addition, a copy should be provided to the local mosquito control or extermination commission upon request.
2. The title and date of the maintenance plan and the name, address, and telephone number of the person with stormwater management measure maintenance responsibility as specified in the plan must be recorded on the deed of the property on which the measure is located. Any change in this information due, for example to a change in property ownership, must also be recorded on the deed.
3. The person with maintenance responsibility must evaluate the maintenance plan for effectiveness at least annually and revise as necessary.
4. A detailed, written log of all preventative and corrective maintenance performed at the stormwater management measure must be kept, including a record of all inspections and copies of maintenance-related work orders.
5. The person with maintenance responsibility must retain and, upon request, make available the maintenance plan and associated logs and other records for review by a public entity with administrative, health, environmental, or safety authority over the site.

Retrofit of Existing Stormwater Management Measures

Retrofitting can be defined as expanding, modifying, or otherwise upgrading existing stormwater management measures. As such, retrofitting stormwater management measures can reduce some of the adverse groundwater recharge and stormwater quantity and quality impacts caused by existing land developments. In many instances, existing stormwater management measures can be dramatically improved, and downstream water bodies protected, through effective retrofitting.

Beginning in the 1970s, many new developments were constructed with stormwater detention facilities. Many of these facilities were built to control the stormwater quantity impacts of 10-year, 25-year, and/or 100-year storms. However, smaller storm events that are typically responsible for the majority of stormwater quality and streambank erosion problems may not have been addressed. Therefore, retrofitting such facilities to also control these smaller storm events can begin to address these problems.

Another important benefit of retrofitting stormwater management facilities is the opportunity to correct site nuisances, maintenance problems, and aesthetic concerns. Retrofitting also allows a community to keep pace with new stormwater management regulations or objectives. It can help a community address a particular stormwater quantity or quality problem that has developed as a result of deficiencies in its existing or past stormwater regulations or a problem that has been identified through a regional plan or TMDL. Addressing such problems through the construction of new stormwater management measures at future land developments may be impractical or even impossible, leaving retrofitting as the only effective technique.

In addition to such basic considerations as need and cost, three important factors must be considered when evaluating retrofit possibilities: health and safety, effectiveness, and maintenance. All three should be thoroughly reviewed before undertaking a stormwater management measure retrofit to help justify the cost and effort and ensure the retrofitted measure's long-term success.

Health and Safety

A retrofit must not increase health and safety risks in any way. For example, the storage volume in an existing detention basin presently used for stormwater quantity control must not be reduced to provide new stormwater quality enhancement without ensuring that the lost quantity storage will not adversely increase peak basin outflows and cause downstream flooding or erosion. Similarly, an existing, well-functioning wet pond must not be converted to a constructed stormwater wetland for enhanced stormwater quality control if the potential for mosquito breeding will increase significantly without adequate additional control measures.

Effectiveness

In many retrofit situations, it may not be possible to upgrade the stormwater management measure to meet all current groundwater recharge and stormwater quality and quantity standards. This means that relative performance improvements for a range of retrofits must be evaluated to determine which one represents the optimum combination of effectiveness, viability, and cost. As a result, the final retrofit selected for an existing stormwater measure will have to be based on its relative rather than absolute effectiveness. In such relative determinations, both the costs and benefits of the evaluated retrofits become more influential factors than when an absolute performance standard is used.

Maintenance

It should be expected that if a retrofit will increase a stormwater management measure's pollutant removal capability, it will also increase the rate and total volume of sediment, trash, debris, and other stormwater pollution that will accumulate in the measure. In addition, the chemical or biological composition of this sediment may be of significantly lower quality, and potentially either hazardous or toxic,

than the sediment previously captured. Finally, the retrofit may increase the number and/or complexity of components in an existing stormwater management measure. All of these factors can cause increases in the level, frequency, complexity, and/or cost of the present inspection and maintenance efforts performed at the stormwater management measure. Increased staffing, improved equipment, and more specialized training may be required to properly maintain the new, retrofitted measure. Therefore, the extent and impacts of any increased inspection and/or maintenance requirements should be determined and thoroughly evaluated.

Once a retrofit has been determined to be safe, effective, and manageable, two basic approaches can be followed: modify an existing stormwater management measure or construct a new or additional one. Basins designed primarily for flood control may be retrofitted to enhance stormwater quality and groundwater recharge benefits. For example, the pollutant removal rates of an existing detention basin can be improved by creating an extended detention wetland. However, as noted above, the retrofit must maintain the basin's existing flood and erosion control capabilities. As a result, the basin's total storage volume may need to be increased. In addition, new measures such as infiltration systems, permeable paving, and bioretention systems can be introduced at sites where the soil permeability and depth to the seasonal high water table are suitable. Areas for such new measures include parking lot islands, vacant land, and roadside swales.

In addition to structural measures, nonstructural stormwater management measures can be used to enhance the stormwater management of an existing development site. Roofs are one of the largest sources of concentrated runoff from commercial developments. Clean roof runoff can be directed by downspouts to a dry well, disconnecting a portion of the runoff from the storm sewer system and both reducing runoff volume and restoring groundwater recharge. Flat roofs can be retrofitted with vegetation, which can reduce the stormwater impacts of the building. Overflow parking areas and fire lanes can utilize pervious paving systems, which can also reduce runoff and enhance recharge. Vegetative filters can be incorporated into existing developments where runoff from paved or intensely managed turf areas can be discharged across the filters. This may require the removal or slotting of existing curbs along the edge of parking lots or roads. Parking lots with vegetated aisle dividers may be particularly amendable to this type of filter strip application.

In addition, catch basins and drain inlets that are part of a traditional curb and gutter stormwater collection system can be retrofitted with one of several different manufactured treatment devices that catch sediments, trash, organic matter, and other particulates. These proprietary devices are particularly useful in areas with limited space. Several varieties of manufactured treatment devices are available for installation at strategic locations near a discharge point or as a pre-treatment to an existing basin. Additional information regarding manufactured treatment devices is provided in *Chapter 9: Structural Stormwater Management Measures*.

Finally, education should be considered as a retrofit component. Control of household waste, fertilizers, and pesticides can dramatically reduce concentrations or problem pollutants that adversely affect downstream water quality. Prevention is most often the best method for eliminating pollutants from stormwater runoff. *Chapter 2: Low Impact Development Techniques* provides important information regarding stormwater pollution prevention.

References

- Livingston E.H., H.E. Shaver, R.R. Horner and J.J. Skupien. May 1997. Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 0

Structural Stormwater Management Measures

This chapter presents specific planning, design, construction, and maintenance information about a range of structural stormwater management measures that may be used to address the groundwater recharge and stormwater quality and quantity requirements of the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. The specific structural measures, also known as structural Best Management Practices (BMPs), included in this chapter are:

- 9.1 – Bioretention Systems
- 9.2 – Constructed Stormwater Wetlands
- 9.3 – Dry Wells
- 9.4 – Extended Detention Basins
- 9.5 – Infiltration Basins
- 9.6 – Manufactured Treatment Devices
- 9.7 – Pervious Paving Systems
- 9.8 – Rooftop Vegetated Cover (Reserved)
- 9.9 – Sand Filters
- 9.10 – Vegetative Filters
- 9.11 – Wet Ponds

Information regarding each BMP is presented in a separate subchapter, which consists of the following sections.

Definition – Most if not all BMPs are actually rather complex stormwater management systems that have multiple components and utilize several physical, chemical, and biological processes. In addition, many of these components and processes are shared by multiple BMPs. This can often cause confusion over where in the manual users can find information regarding a specific BMP. To prevent this confusion, the

Definition section provides a definitive description of the BMP, including its major components and processes. It also presents the BMP's adopted TSS removal rate.

Purpose – This section describes the uses for which the BMP is particularly suited. This includes groundwater recharge and runoff quality and quantity control as well as ancillary uses such as recreation, wildlife habitat, and open space preservation. This information is intended to help manual users decide whether a particular BMP is capable of meeting their project needs.

Conditions Where Practice Applies – In addition to sharing many components and processes, all BMPs also have unique features and requirements. These must be recognized and met during a BMP's planning, design, and review phases if the BMP is to provide effective, efficient, and enduring service. This section concisely presents these BMP features and requirements so that manual users can decide whether a particular BMP is appropriate for their project

Design Criteria – This section presents specific BMP design criteria that must be met for a particular BMP to achieve the TSS removal rates adopted in the Stormwater Management Rules at N.J.A.C. 7:8. The design criteria also provides the information necessary to address groundwater recharge and stormwater quantity performance standards. The criteria presented in this section vary with each BMP and can range from required runoff storage volumes to maximum drainage area size to minimum soil permeabilities.

Maintenance – Effective BMP performance requires regular and effective maintenance. In addition, the NJDEP Stormwater Management Rules require that all structural BMPs have a specific maintenance plan that must be followed by those responsible for its operation and maintenance. This section provides specific maintenance information which, in combination with *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures*, can be used to develop such a plan and to help ensure the effective, efficient, and enduring service envisioned by the BMP designer.

Considerations – This section presents valuable information that should be considered during a particular BMP's planning, design, review and/or construction phases. While not mandatory, this information is intended to promote BMPs that comprehensively meet the expectations of their designers, reviewers, owners, and maintenance personnel.

Recommendations – As noted above, all BMPs have unique features, requirements, ancillary functions, and maintenance needs. This section identifies various factors that, while not necessarily a mandatory design criteria, should nevertheless be included in the development of a BMP's design whenever possible.

References – This section identifies the major published sources of technical information that were used by the NJDEP in the development of each BMP's subchapter.

Regarding references, it is important to note that the information presented in each BMP subchapter was developed not only from published sources, but also through detailed technical discussions held at numerous BMP Manual Technical and Advisory Committee meetings hosted by the NJDEP. The information and conclusions developed at these meetings reflect the technical knowledge of the committee members, which was derived, in part, from numerous published and unpublished sources.

In recognition of the continued growth of our stormwater management knowledge, it should also be noted that compliance with the NJDEP Stormwater Management Rules is not limited to the BMPs presented in this chapter. Other BMPs that possess similar levels of effectiveness, efficiency, and endurance may also be utilized provided that such levels can be similarly demonstrated.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 1

Standard for Bioretention Systems

Definition

A bioretention system consists of a soil bed planted with native vegetation located above an underdrained sand layer. It can be configured as either a bioretention basin or a bioretention swale. Stormwater runoff entering the bioretention system is filtered first through the vegetation and then the sand/soil mixture before being conveyed downstream by the underdrain system. Runoff storage depths above the planting bed surface are typically shallow. The adopted TSS removal rate for bioretention systems is 90 percent.

Purpose

Bioretention systems are used to remove a wide range of pollutants, such as suspended solids, nutrients, metals, hydrocarbons, and bacteria from stormwater runoff. They can also be used to reduce peak runoff rates and increase stormwater infiltration when designed as a multi-stage, multi-function facility.

Conditions Where Practice Applies

Bioretention systems can be used to filter runoff from both residential and nonresidential developments. Runoff inflow should preferably be overland flow to prevent disturbance to the vegetation and soil bed. Concentrated inflow from a drainage pipe or swale must include adequate erosion protection and energy dissipation measures.

Bioretention systems are most effective if they receive runoff as close to its source as possible. They can vary in size and can receive and treat runoff from a variety of drainage areas within a land development site. They can be installed in lawns, median strips, parking lot islands, unused lot areas, and certain easements. They are intended to receive and filter storm runoff from both impervious areas and lawns.

A bioretention system must not be placed into operation until the contributing drainage area is completely stabilized. Therefore, system construction must either be delayed or upstream runoff diverted around the system until such stabilization is achieved. Such diversions must continue until stabilization is achieved. Additional information is provided in the section on Recommendations, Construction Specifications.

The elevation of the Seasonal High Water Table (SHWT) is critical to ensure proper functioning of the bioretention basin, and must be evaluated to ensure that the SHWT is at least 1 foot below the bottom of the bioretention basin's underdrain system during non-drought conditions. Finally, both the SHWT and the permeability of the soil below the system are critical for bioretention systems that utilize infiltration rather than an underdrain system. See 9.5 *Infiltration Basins* for more information on the requirements and design of this type of bioretention system.

Finally, a bioretention system must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The basic design parameters for a bioretention system are its storage volume, the thickness, character, and permeability rate of its planting soil bed, and the hydraulic capacity of its underdrain. The system must have sufficient storage volume above the surface of the bed to contain the design runoff volume without overflow. The thickness and character of the bed itself must provide adequate pollutant removal, while the bed's permeability rate must be sufficient to drain the stored runoff within 72 hours. The underdrain must also have sufficient hydraulic capacity. Details of these and other design parameters are presented below. The components of a typical bioretention system are shown in Figure 9.1-1.

A. Storage Volume, Depth, and Duration

Bioretention systems shall be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. The maximum water depth during treatment of the stormwater quality design storm shall be 12 inches in a bioretention basin and 18 inches in a bioretention swale. The minimum diameter of any outlet or overflow orifice is 2.5 inches.

The bottom of a bioretention system, including any underdrain piping or gravel layer, must be a minimum of 1 foot above the seasonal high groundwater table. The planting soil bed and underdrain system shall be designed to fully drain the stormwater quality design storm runoff volume within 72 hours.

B. Permeability Rates

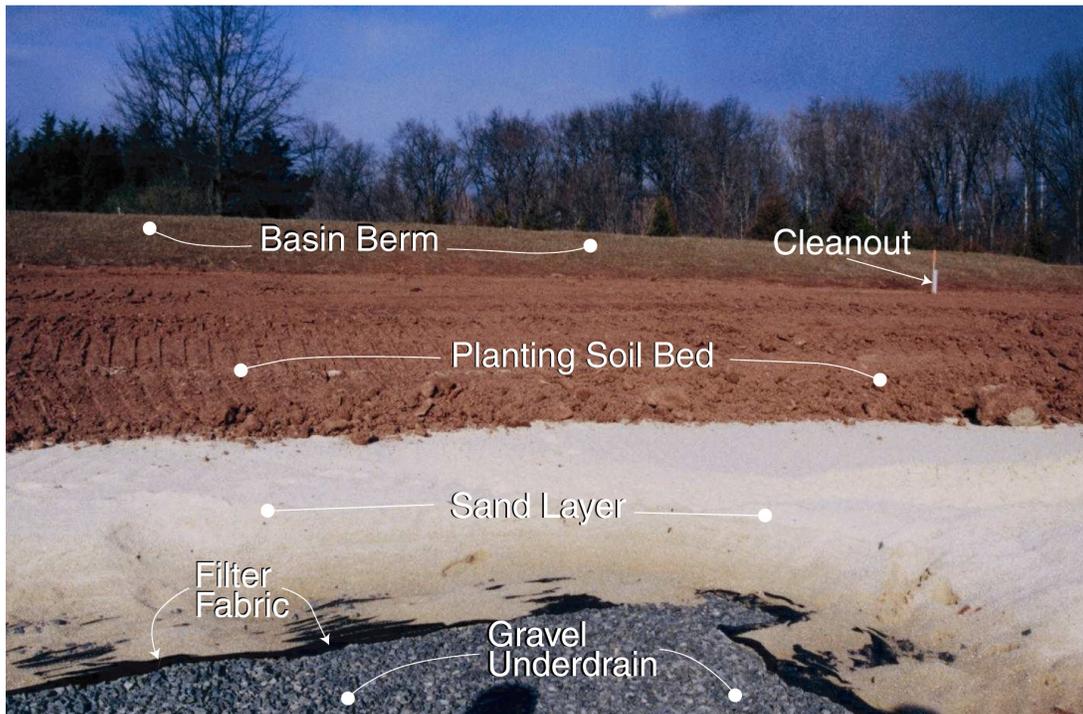
The design permeability rate through the planting soil bed must be sufficient to fully drain the stormwater quality design storm runoff volume within 72 hours. This permeability rate must be determined by field or laboratory testing. Since the actual permeability rate may vary from test results and may also decrease over time due to soil bed consolidation or the accumulation of sediments removed from the treated stormwater, a factor of safety of two shall be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soil bed material is 4 inches/hour, the design rate would be 2 inches/hour (i.e., 4 inches per hour/2). This design rate would then be used to compute the system's stormwater quality design storm drain time.

C. Planting Soil Bed

The planting soil bed provides the environment for water and nutrients to be made available to the vegetation. The soil particles can adsorb some additional pollutants through cation exchange, and voids within the soil particles can store a portion of the stormwater quality design storm runoff volume. The planting soil bed material should consist of 10 to 15 percent clays, a minimum 65 percent sands, with the balance as silts. The material's pH should range from 5.5 to 6.5. The material shall be placed in 12 to 18 inch lifts. The total depth or thickness of the planting soil bed should be a minimum of 3 feet.

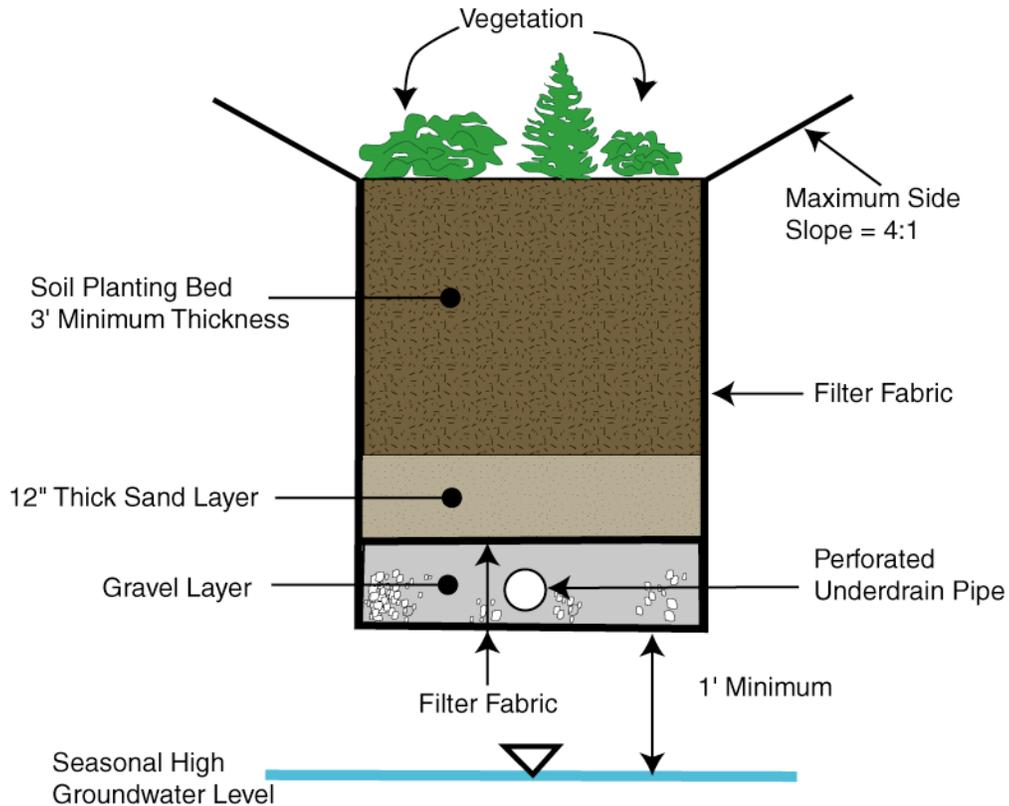
As noted above, the design permeability rate of the soil bed material must be sufficient to drain the stormwater quality design storm runoff volume within 72 hours. Filter fabric should be placed along the sides of the planting soil bed to prevent the migration of soil particles from the adjacent soil into the planting soil bed.

Figure 9.1-1: Bioretention System Components



This figure can be viewed in color in the PDF version of this chapter available at <http://www.state.nj.us/dep/watershedmgmt/bmpmanualfeb2004.htm>
 Source: Adapted from Claytor and Schueler, 1996.

Figure 9.1-2 Bioretention Systems Details



D. Vegetation

The vegetation in a bioretention system removes some of the nutrients and other pollutants in the stormwater inflow. The environment around the root systems breaks down some pollutants and converts others to less harmful compounds. The use of native plant material is recommended for bioretention systems wherever possible. The goal of the planting plan should be to simulate a forest-shrub community of primarily upland type. As there will be various wetness zones within a well-designed and constructed bioretention system, plants must be selected and placed appropriately. In general, trees should dominate the perimeter zone that is subject to less frequent inundation. Shrubs and herbaceous species that are adapted to moister conditions and expected pollutant loads should be selected for the wetter zones. The number of stems per acre should average 1,000, with tree spacing of 12 feet and shrub spacing of 8 feet.

E. Sand Layer

The sand layer serves as a transition between the planting soil bed and the gravel layer and underdrain pipes. It must have a minimum thickness of 12 inches and consist of clean medium aggregate concrete sand (AASHTO M-6/ASTM C-33). To ensure proper system operation, the sand layer must have a permeability rate at least twice as fast as the design permeability rate of the planting soil bed.

F. Gravel Layer and Underdrain

The gravel layer serves as bedding material and conveyance medium for the underdrain pipes. It must have sufficient thickness to provide a minimum of 3 inches of gravel above and below the pipes. It should consist of 0.5 to 1.5 inch clean broken stone or pea gravel (AASHTO M-43).

The underdrain piping must be rigid Schedule 40 PVC pipe (AASHTO M-278) laid at a minimum slope of 0.50 percent. The portion of drain piping beneath the planting soil bed and sand layer must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. All joints must be secure and watertight. Cleanouts must be located at the upstream and downstream ends of the perforated section of the underdrain and extend to or above the surface of the planting soil bed. Additional cleanouts should be installed as needed, particularly at underdrain pipe bends and connections. Cleanouts can also serve to drain standing water stored above clogged or malfunctioning planting soil beds.

The underdrain piping must connect to a downstream storm sewer manhole, catch basin, channel, swale, or ground surface at a location that is not subject to blockage by debris or sediment and is readily accessible for inspection and maintenance. Blind connections to downstream storm sewers are prohibited. To ensure proper system operation, the gravel layer and perforated underdrain piping must have a conveyance rate at least twice as fast as the design permeability rate of the sand layer.

G. Inflows

To reduce the potential for erosion, scour, and disturbance to vegetation, stormwater inflows to a bioretention system should occur as sheet flow where practical. Stone strips or aprons may be used at the downstream edge of upstream impervious surfaces to further dissipate sheet flow velocities and flow patterns. All points of concentrated inflow to a bioretention system must have adequate erosion protection measures designed in accordance with the Standards for Soil Erosion and Sediment Control in New Jersey.

H. Overflows

All bioretention systems must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Bioretention systems classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards. Overflow capacity can be provided by a hydraulic structure such as a drain inlet, weir, or catch basin, or a surface feature such as a swale or open channel as site conditions allow. See *Chapter 9.4: Standard for Extended Detention Basins* for details of outflow and overflow structures in multi-purpose bioretention systems that also provide stormwater quantity control.

I. Tailwater

The hydraulic design of the underdrain and overflow systems, as well as any stormwater quantity control outlets, must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-line and Off-line Systems

Bioretention systems may be constructed on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an overflow. Multi-purpose on-line systems also store and attenuate these larger

storms to provide runoff quantity control. In such systems, the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface. In off-line bioretention systems, most or all of the runoff from storms larger than the stormwater quality design storm bypasses the system through an upstream diversion. This not only reduces the size of the required system storage volume, but also reduces the system's long-term pollutant loading and associated maintenance.

Maintenance

Effective bioretention system performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including bioretention systems. Specific maintenance requirements for bioretention systems are presented below. These requirements must be included in the system's maintenance plan.

A. General Maintenance

All bioretention system components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include bottoms, trash racks, low flow channels, outlet structures, riprap or gabion aprons, and cleanouts.

Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the bioretention system. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the ground surface in the bioretention system. This normal drain time should then be used to evaluate the system's actual performance. If significant increases or decreases in the normal drain time are observed or if the 72 hour maximum is exceeded, the system's planting soil bed, underdrain system, and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the system.

The planting soil bed at the bottom of the system should be inspected at least twice annually. The permeability rate of the soil bed material may also be retested. If the water fails to infiltrate 72 hours after the end of the storm, corrective measures must be taken.

Considerations

A. Optional Surface Mulch Layer

The mulch layer on the surface of the planting soil bed provides an environment for plant growth by maintaining moisture, providing microorganisms, and decomposing incoming organic matter. The mulch layer may also act as a filter for finer particles still in suspension and maintain an environment for the microbial community to help break down urban runoff pollutants. The mulch layer should consist of standard 1 to 2 inch shredded hardwood or chips. It should be applied to a depth of 2 to 4 inches and replenished as necessary. However, prior to utilizing a mulch layer, consideration should be given to problems caused by scour and floatation during storm events and the potential for mosquito breeding.

Recommendations

A. Site Considerations

The planning of a bioretention system should consider the topography and geologic and ecological characteristics of both the proposed system site and contiguous areas. Bioretention systems should not be planned in areas where mature trees would have to be removed or where Karst topography is present.

B. Construction

During basin construction, precautions must be taken to prevent planting soil bed compaction by construction equipment and sediment contamination by runoff. Basin excavation and planting soil placement should be performed with equipment placed outside the basin bottom whenever possible. Light earth moving equipment with oversized tires or tracks should be utilized when the basin must be entered.

Bioretention basins are susceptible to clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Therefore, using a bioretention basin site for construction sediment control is discouraged. When unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the basin bottom. Sediment can then accumulate and be removed during site construction without disturbing the final basin bottom, which should be established only after all other construction within its drainage area is completed and the drainage area stabilized. If basin construction cannot be delayed until then and the basin will not be used for sediment control, diversion berms should be placed around the basin's perimeter during all phases of construction to divert all sediment and runoff

completely away from the basin. These berms should not be removed until all construction within the basin's drainage area is completed and the area stabilized.

To prevent compaction of the soil below the basin that will reduce its infiltration capacity, bioretention basins designed for infiltration (instead of an underdrain system) should be excavated with light earth moving equipment, preferably with tracks or over-sized tires located outside the basin bottom. Once the basin's final construction phase is reached, the floor of the basin must be deeply tilled with a rotary tiller or disc harrow and smoothed over with a leveling drag or equivalent grading equipment.

Upon stabilization of the bioretention basin and its drainage area, the infiltration rate of the planting soil bed must be retested to ensure that the rate assumed in the computations is provided at the basin. The permeability rate of the subsoil below the basin must also be retested after construction at bioretention basins that utilize infiltration rather than an underdrain system.

C. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a bioretention system. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filter, a forebay, or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

Forebays can be included at the inflow points to a bioretention system to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

References

- Claytor, R. and T. Schueler. December 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Ellicott City, MD.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- Lucas, William C. March 2003. Draft Green Technology: The Delaware Urban Runoff Management Approach. TRC Omni Environmental Corporation.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Pennsylvania Association of Conservation Districts, CH2MHill et al. 1998. Bioretention Standard and Specification, Pennsylvania Handbook of Best Management Practices for Developing Areas. Harrisburg, PA.
- Schueler, Thomas R. and Richard A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 2

Standard for Constructed Stormwater Wetlands

Definition

Constructed stormwater wetlands are wetland systems designed to maximize the removal of pollutants from stormwater runoff through settling and both uptake and filtering by vegetation. Constructed stormwater wetlands temporarily store runoff in relatively shallow pools that support conditions suitable for the growth of wetland plants. The adopted removal rate for constructed stormwater wetlands is 90 percent.

Purpose

Constructed stormwater wetlands are used to remove a wide range of stormwater pollutants from land development sites as well as provide wildlife habitat and aesthetic features. Constructed stormwater wetlands can also be used to reduce peak runoff rates when designed as a multi-stage, multi-function facility.

Conditions Where Practice Applies

Constructed stormwater wetlands require sufficient drainage areas and dry weather base flows to function properly. The minimum drainage area to a constructed stormwater wetland is 10 acres to 25 acres, depending on the type of wetland. See text below for details.

Constructed stormwater wetlands should not be located within natural wetland areas, since they will typically not have the same full range of ecological functions. While providing some habitat and aesthetic values, constructed stormwater wetlands are designed primarily for pollutant removal and erosion and flood control.

It is important to note that a constructed stormwater wetland must be able to maintain its permanent pool level. If the soil at the wetland site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary.

Finally, a constructed stormwater wetland must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The basic design parameters for a constructed stormwater wetland are the storage volumes within its various zones. In general, the total volume within these zones must be equal to the design runoff volume. An exception to this requirement is made for an extended detention wetland. In addition, the character, diversity, and hardiness of the wetland vegetation must be sufficient to provide adequate pollutant removal. Details of these and other design parameters are presented below.

Constructed stormwater wetlands typically consist of three zones: pool, marsh, and semi-wet. Depending upon their relative size and the normal or dry weather depth of standing water, the pool zone may be further characterized as either a pond, micropond, or forebay. Similarly, the marsh zone may be further characterized as either high or low marsh based again upon the normal standing water depth in each.

Depending on the presence and relative storage volume of the pool, marsh, and semi-wet zones, a constructed stormwater wetland may be considered to be one of three types: pond wetland, marsh wetland, or extended detention wetland. As described in detail below, a pond wetland consists primarily of a relatively deep pool with a smaller marsh zone outside it. Conversely, a marsh wetland has a greater area of marsh than pool zone. Finally, an extended detention wetland consists of both pool and marsh zones within an extended detention basin.

Table 9.2-1 below presents pertinent design criteria for each type of constructed stormwater wetland. As shown in the table, each type (i.e., pond, marsh, and extended detention wetland) allocates different percentages of the total stormwater quality design storm runoff volume to its pool, marsh, and semi-wet zones. In a pond wetland, this volume is distributed 70 percent to 30 percent between the pool and marsh zones. Conversely, in a marsh wetland, the total runoff volume is distributed 30 percent to 70 percent between the pool and marsh zones. Both of these zone volumes are based on their normal standing water level.

However, in an extended detention wetland, only 50 percent of the stormwater quality design storm runoff volume is allocated to the pool and wetland zones, with 40 percent of this amount (or 20 percent of the total stormwater quality design storm runoff volume) provided in the pool zone and 60 percent (or 30 percent of the total runoff volume) provided in the marsh zone. The remaining 50 percent of the stormwater quality design storm runoff volume is provided in the wetland's semi-wet zone above the normal standing water level, where it is temporarily stored and slowly released similar to an extended detention basin. As noted in Table 9.2-1, the detention time in the semi-wet zone of an extended detention wetland must meet the same detention time requirements as an extended detention basin. These requirements are presented in *Chapter 9.4: Standard for Extended Detention Basins*. The minimum diameter of any outlet orifice in all wetland types is 2.5 inches.

The components of a typical stormwater wetland are illustrated in Figure 9.2-1. Pertinent design criteria for each component are presented in Table 9.2-1. Additional details of each type of constructed stormwater wetland and the components of each are described below.

A. Pool Zone

Pools generally have standing water depths of 2 to 6 feet and primarily support submerged and floating vegetation. Due to their depths, support for emergent vegetation is normally limited. As noted above, the pool zone may consist of a pond, micropond, and/or forebay, depending on their relative sizes and depths. Descriptions of these pool types are presented below.

1. Pond

Ponds generally have standing water depths of 4 to 6 feet and, depending on the type, may comprise the largest portion of a constructed stormwater wetland. Ponds provide for the majority of particulate settling in a constructed stormwater wetland.

2. Micropond

In general, a micropond also has a standing water depth of 4 to 6 feet, but is smaller in surface area than a standard pond. A micropond is normally located immediately upstream of the outlet from a constructed stormwater wetland. At that location, it both protects the outlet from clogging by debris and provides some degree of particulate settling. Since a micropond does not provide the same degree of settling as a standard pond, it is normally combined with a larger area of marsh than a standard pond.

3. Forebay

Forebays are located at points of concentrated inflow to constructed stormwater wetlands. As such, they serve as pretreatment measures by removing coarser sediments, trash, and debris. They typically have normal standing water depths of 2 to 4 feet.

B. Marsh Zone

Marshes have shallower standing water depths than ponds, generally ranging from 6 to 18 inches. At such depths, they primarily support emergent wetland vegetation. As noted above, a marsh is classified as either a high or low marsh, depending on the exact depth of standing water.

1. Low Marsh

A low marsh has a standing water depth of 6 to 18 inches. It is suitable for the growth of several emergent wetland plant species.

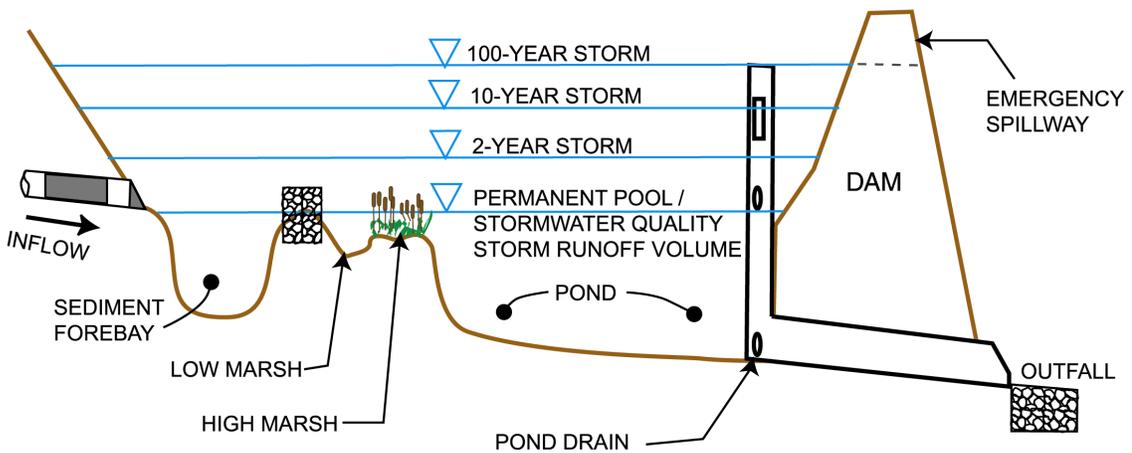
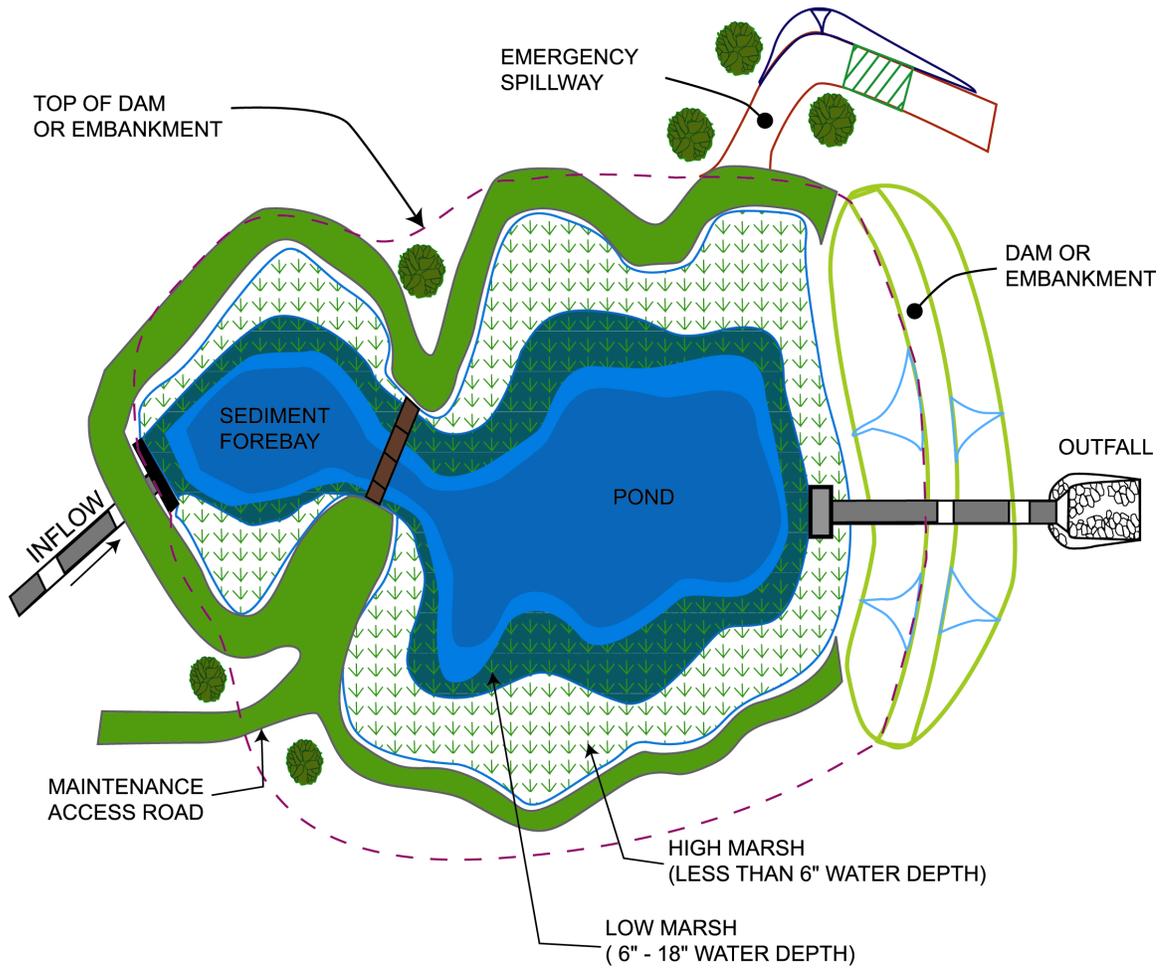
2. High Marsh

A high marsh has a maximum standing water depth of 6 inches. Due to its shallower depth, it will have a higher standing water surface area to volume ratio than a low marsh. It will normally support a greater density and diversity of emergent wetland species than a low marsh.

C. Semi-Wet Zone

The semi-wet zone in a constructed stormwater wetland is located above the pool and marsh zones and is inundated only during storm events. As a result, it can support both wetland and upland plants.

Figure 9.2-1: Constructed Stormwater Wetland Components



Source: Adapted from Schueler and Claytor 2000.

This figure can be viewed in color in the PDF version of this chapter available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Table 9.2–1: Design Criteria for Constructed Stormwater Wetlands

Wetland Design Feature	Type of Constructed Stormwater Wetland		
	Pond	Marsh	Extended Detention
Minimum Drainage Area (Acres)	25	25	10
Minimum Length to Width Ratio	1:1	1:1	1:1
Allocation of Stormwater Quality Design Storm Runoff Volume (Pool / Marsh / Semi-Wet*)	70 / 30 / 0	30 / 70 / 0	20 / 30 / 50*
Pool Volume (Forebay / Micropond / Pond)	10 / 0 / 60	10 / 20 / 0	10 / 10 / 0
Marsh Volume (Low / High)	20 / 10	45 / 25	20 / 10
Sediment Removal Frequency (Years)	10	2 to 5	2 to 5
Outlet Configuration	Reverse-Slope Pipe or Broad Crested Weir	Reverse-Slope Pipe or Broad Crested Weir	Reverse-Slope Pipe or Broad Crested Weir
* In an Extended Detention Wetland, 50 percent of the stormwater quality design storm runoff volume is temporarily stored in the semi-wet zone. Release of this volume must meet the detention time requirements for extended detention basins (see text above and Chapter 9.4).			

D. Types of Constructed Stormwater Wetlands

1. Pond Wetlands

Pond wetlands consist primarily of ponds with standing water depths ranging from 4 to 6 feet in normal or dry weather conditions. Pond wetlands utilize at least one pond component in conjunction with high and low marshes. The pond is typically the component that provides for the majority of particulate pollutant removal. This removal is augmented by a forebay, which also reduces the velocity of the runoff entering the wetland. The marsh zones provide additional treatment of the runoff, particularly for soluble pollutants.

Pond wetlands require less site area than marsh wetlands and generally achieve a higher pollutant removal rate than the other types of constructed stormwater wetland. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component.

2. Marsh Wetlands

Marsh wetlands consist primarily of marsh zones with standing water depths ranging up to 18 inches during normal or dry weather conditions. These zones are further configured as low and high marsh components as described above. The remainder of the stormwater quality design storm runoff volume storage is provided by a micropond. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component.

Marsh wetlands should be designed with sinuous pathways to increase retention time and contact area. Marsh wetlands require greater site area than other types of constructed stormwater wetlands. In order to have the base and/or groundwater flow rate necessary to support emergent plants and

minimize mosquito breeding, marsh wetlands may also require greater drainage areas than the other types. This is due to the relatively larger area of a marsh wetland as compared with either a pond or extended detention wetland. This larger area requires greater rates of normal inflow to generate the necessary flow velocities and volume changeover rates.

3. Extended Detention Wetlands

Unlike pond and marsh wetlands, an extended detention wetland temporarily stores a portion of the stormwater quality design storm runoff volume in the semi-wet zone above its normal standing water level. This temporary runoff storage, which must be slowly released in a manner similar to an extended detention basin, allows the use of relatively smaller pool and marsh zones. As a result, extended detention wetlands require less site area than pond or marsh wetlands. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component. See *Chapter 9.4: Standard for Extended Detention Basins* for the required detention times for the temporary semi-wet zone storage.

Due to the use of the semi-wet zone, water levels in an extended detention wetland will also increase more during storm events than pond or marsh wetlands. Therefore, the area of wetland vegetation in an extended detention wetland can expand beyond the normal standing water limits occupied by the pool and marsh zones. Wetland plants that tolerate intermittent flooding and dry periods should be selected for these areas.

E. Drainage Area

The minimum drainage area to a constructed stormwater wetland generally varies from 10 to 25 acres, depending on the type of constructed stormwater wetland. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater inflow is available. See Table 9.2-1 for details. See also *D. Types of Constructed Stormwater Wetlands* above and *B. Water Budget* in the *Recommendations* section below for discussions of base and groundwater flow needs.

F. Overflows

All constructed stormwater wetlands must be able to convey overflows to downstream drainage systems in a safe and stable manner. Constructed stormwater wetlands classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards.

G. Tailwater

The design of all hydraulic outlets must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-Line and Off-Line Systems

Constructed stormwater wetlands may be constructed on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an outlet or overflow. Multi-purpose on-line systems also store and attenuate these larger storms to provide runoff quantity control. In such systems, the invert of the lowest stormwater quantity control outlet is set at or above the normal permanent pool level. In off-line constructed stormwater wetlands, most or all of the runoff from storms larger than the stormwater quality design storm bypass the basin through an upstream diversion. This not only reduces the size of the required

basin storage volume, but reduces the basin's long-term pollutant loading and associated maintenance. In selecting an off-line design, the potential effects on wetland vegetation and ecology of diverting higher volume runoff events should be considered.

I. Safety Ledges

Safety ledges must be constructed on the slopes of all constructed stormwater wetlands with a permanent pool of water deeper than 3 feet. Two ledges must be constructed, each 4 to 6 feet in width. The first or upper ledge must be located between 1 and 1.5 feet above the normal standing water level. The second or lower ledge must be located approximately 2.5 feet below the normal standing water level.

Maintenance

Effective constructed stormwater wetland performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including constructed stormwater wetlands. Specific maintenance requirements for constructed stormwater wetlands are presented below. These requirements must be included in the wetland's maintenance plan.

A. General Maintenance

All constructed stormwater wetland components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include forebays, bottoms, trash racks, outlet structures, and riprap or gabion aprons.

Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

The types and distribution of the dominant plants must also be assessed during the semi-annual wetland inspections described above. This assessment should be based on the health and relative extent of both the original species remaining and all volunteer species that have subsequently grown in the wetland. Appropriate steps must be taken to achieve and maintain an acceptable balance of original and volunteer species in accordance with the intent of the wetland's original design.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the constructed stormwater wetland. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff and return the various wetland pools to their normal standing water levels. This drain or drawdown time should then be used to evaluate the wetland's actual performance. If significant increases or decreases in the normal drain time are observed, the wetland's outlet structure, forebay, and groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the wetland.

Considerations

Constructed stormwater wetlands are limited by a number of site constraints, including soil types, depth to groundwater, contributing drainage area, and available land area at the site.

A. Construction

The following minimum setback requirements should apply to stormwater wetland installations:

Distance from a septic system leach field = 50 feet.

Distance from a septic system tank = 25 feet.

Distance from a property line = 10 feet.

Distance from a private well = 50 feet.

A seven-step process is recommended for the preparation of the wetland bed prior to planting (Schueler 1992).

1. Prepare final pondscaping and grading plans for the stormwater wetland. At this time order wetland plant stock from aquatic nurseries.
2. Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, safety ledge, marshes, etc.).
3. After the mulch or topsoil has been added, the stormwater wetland needs to be graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.
4. After grading to final elevations, the pond drain should be closed and the pool allowed to fill. Usually nothing should be done to the stormwater wetland for six to nine months or until the next planting season. A good design recommendation is to evaluate the wetland elevations during a standing period of approximately six months. During this time the stormwater wetland can experience storm flows and inundation, so that it can be determined where the pondscaping zones are located and whether the final grade and microtopography will persist overtime.
5. Before planting, the stormwater wetland depths should be measured to the nearest inch to confirm planting depth. The pondscape plan may be modified at this time to reflect altered depths or availability of plant stock.

6. Erosion controls should be strictly applied during the standing and planting periods. All vegetated areas above the normal pool elevation should be stabilized during the standing period, usually with hydroseeding.
7. The stormwater wetland should be de-watered at least three days before planting since a dry wetland is easier to plant than a wet one.

Topsoil and/or wetland mulch is added to the stormwater wetland excavation. Since deep subsoils often lack the nutrients and organic matter to support vigorous plant growth, the addition of mulch or topsoil is important. If it is available, wetland mulch is preferable to topsoil.

B. Site Constraints

Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an impermeable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners is recommended. At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible.

C. Design Approach

A pondscaping plan should be developed for each constructed stormwater wetland. This plan should include hydrological calculations (or water budget), a wetland design and configuration, elevations and grades, a site/soil analysis, and estimated depth zones. The plan should also contain the location, quantity, and propagation methods for the wetland plants. Site preparation requirements, maintenance requirements, and a maintenance schedule are also necessary components of the plan.

The water budget should demonstrate that there will be a continuous supply of water to sustain the constructed stormwater wetland. The water budget should be developed during site selection and checked after preliminary site design. Drying periods of longer than two months have been shown to adversely effect plant community richness, so the water balance should confirm that drying will not exceed two months.

D. Effectiveness

A review of the existing performance data indicates that the removal efficiencies of constructed stormwater wetlands are slightly higher than those of conventional pond systems, e.g. as wet ponds or dry extended detention ponds. Of the three designs described above, the pond/wetland system has shown the most reliable terms of overall performance.

Studies have also indicated that removal efficiencies of constructed stormwater wetlands decline if they are covered by ice or receive snow melt. Performance also declines during the non-growing season and during the fall when the vegetation dies back. Until vegetation is well established, pollutant removal efficiencies may be lower than expected.

E. Regulatory Issues

A constructed stormwater wetlands, once constructed, may be regulated by the Freshwater Wetlands Protection Act, and require additional permits for subsequent maintenance or amendment of the constructed stormwater wetland.

Recommendations

A. Vegetation

Establishment and maintenance of the wetland vegetation is an important consideration when planning a stormwater wetland. The following is a series of recommendations (Horner et al. 1994) for creating constructed stormwater wetlands.

In selecting plants, consider the prospects for success more than selection of native species. Since diversification will occur naturally, use a minimum of adaptable species. Give priority to perennial species that establish rapidly. Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod). Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available. Match site conditions to the environmental requirements of plant selections. Avoid using only species that are foraged by the wildlife expected on site.

Establishment of woody species should follow herbaceous species. Add vegetation that will achieve other objectives, in addition to pollution control. Monoculture planting should be avoided due to increased risk of loss from pests and disease. When possible field collected plants should be used in lieu of nursery plants. Plants collected from the field have already adapted and are acclimated to the region. These plants generally require less care than greenhouse plants. If nursery plants are used they should be obtained locally, or from an area with similar climatic conditions as the eco-region of the constructed wetland. Alternating plant species with varying root depths have a greater opportunity of pollutant removal.

Stormwater wetland vegetation development can also be enhanced through the natural recruitment of species from nearby wetland sites. However, transplanting wetland vegetation is still the most reliable method of propagating stormwater wetland vegetation, and it provides cover quickly. Plants are commercially available through wetland plant nurseries.

The plant community will develop best when the soils are enriched with plant roots, rhizomes, and seed banks. Use of wetlands mulch enhances the diversity of the plant community and speeds establishment. Wetlands mulch is hydric soil that contains vegetative plant material. The upper 6 inches of donor soil should be obtained at the end of the growing season, and kept moist until installation. Drawbacks to using constructed stormwater wetlands mulch are its unpredictable content.

During the initial planting precautions should be undertaken to prevent and prohibit animals from grazing until plant communities are well established. Such precautions could be deer fencing, muskrat trapping, planting after seasonal bird migrations, or attracting birds of prey and bats to control nutria populations

B. Water Budget

The water budget should demonstrate that there will be a continuous supply of water to sustain the stormwater wetland. The water budget should demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate. As discussed above, drying periods of longer than two months have been shown to adversely affect plant community richness, so the water balance should confirm that drying will not exceed two months (Schueler 1992).

C. Wetlands Area

The constructed wetlands should have a minimum surface area in relation to the contributing watershed area. The reliability of pollutant removal tends to increase as the stormwater wetland to watershed ratio increases, although this relationship is not always consistent. Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland.

D. Outlet Configuration

A hooded outlet is recommended with an invert or crest elevation at least 1 foot below the normal pool surface.

A bottom drain pipe with an inverted elbow to prevent sediment clogging should be installed for complete draining of the constructed stormwater wetland for emergency purposes or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outlet ends to regulate flows. Spillways should be designed in conformance with state regulations and criteria for dam safety.

E. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a constructed stormwater wetland. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filter and/or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

As shown in Figure 9.2-1, forebays at the inflow points to a constructed stormwater wetland can capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized in accordance with Table 9.2-1 to hold the sediment volume expected between clean-outs.

References

- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., Anacostia Restoration Team. October 1992. Design of Stormwater Wetland Systems – Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 3

Standard for Dry Wells

Definition

A dry well is a subsurface storage facility that receives and temporarily stores stormwater runoff from roofs of structures. Discharge of this stored runoff from a dry well occurs through infiltration into the surrounding soils. A dry well may be either a structural chamber and/or an excavated pit filled with aggregate. Due to the relatively low level of expected pollutants in roof runoff, a dry well cannot be used to directly comply with the suspended solids and nutrient removal requirements contained in the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. However, due to its storage capacity, a dry well may be used to reduce the total stormwater quality design storm runoff volume that a roof would ordinarily discharge to downstream stormwater management facilities.

Purpose

Dry wells can be used to reduce the increased volume of stormwater runoff caused by roofs of buildings. While generally not a significant source of runoff pollution, roofs are one of the most important sources of new or increased runoff volume from land development sites. Dry wells can also be used to indirectly enhance water quality by reducing the amount of stormwater quality design storm runoff volume to be treated by the other, downstream stormwater management facilities.

Dry wells can also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of dry wells and other groundwater recharge facilities to meet them.

Conditions Where Practice Applies

The use of dry wells is applicable only where their subgrade soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, dry wells are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination. Specifically, dry wells must not be used in the following locations:

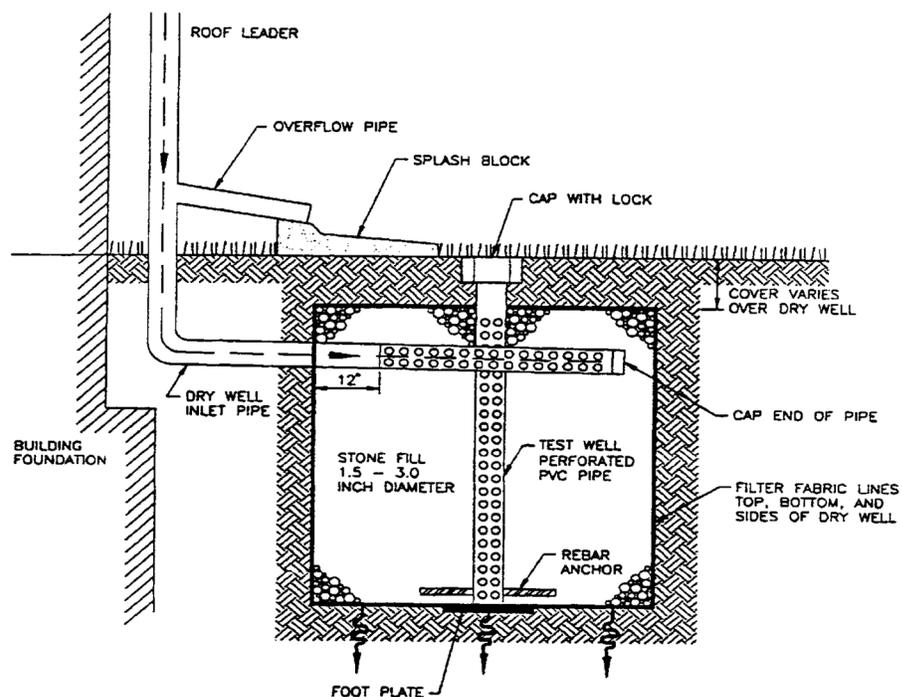
- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied; or pesticides are loaded, unloaded, or stored.

- Areas where hazardous materials are expected to be present in greater than “reportable quantities” as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where dry well use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is 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, that could be a source of pollutants in any industrial stormwater discharge to groundwater. 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.

In addition, as required by the NJDEP Stormwater Management Rules, dry wells must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Dry wells must be located and configured where their construction will not compact the soils below the dry well. Finally, a dry well must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Figure 9.3-1: Dry Well Components



Source: Adapted from Standards for Soil Erosion and Sediment Control in New Jersey

Design Criteria

The basic design parameters for a dry well are its storage volume and the permeability rate of the subgrade soils. A dry well must have sufficient storage volume to contain the design runoff volume without overflow, while the subgrade soils' permeability rate must be sufficient to drain the stored runoff within 72 hours. Details of these and other design parameters are presented below. The components of a typical dry well are shown above in Figure 9.3-1.

A. Storage Volume, Depth, and Duration

A dry well must be designed to treat the total runoff volume generated by the dry well's maximum design storm. This may either be the groundwater recharge or stormwater quality design storm, depending upon the dry well's proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. A dry well must also fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the dry well ineffective and may result in anaerobic conditions, odor, and both water quality and mosquito breeding problems. The bottom of the dry well must be at least 2 feet above seasonal high water table or bedrock and be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

As discussed in *Considerations* below, construction of a dry well must be done without compacting the dry well's subgrade soils. As such, all excavation must be performed by equipment placed outside the dry well whenever possible. This requirement should be considered when designing the dimensions and total storage volume of a dry well.

It is important to note that the use of dry wells is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of dry wells for larger storm events and the requirements by which such dry wells are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

B. Permeability Rates

The minimum design permeability rate of the subgrade soils below a dry well will depend upon the dry well's location and maximum design storm. The use of dry wells for stormwater quality or quantity control is feasible only where the soils are sufficiently permeable to allow a reasonable rate of infiltration. Therefore, dry wells designed for storms greater than the groundwater recharge storm can be constructed only in areas with Hydrologic Soil Group A and B soils. Additional permeability requirements are presented below in Table 9.3-1.

Table 9.3-1: Minimum Design Permeability Rates for Dry Wells

Maximum Design Storm	Minimum Design Permeability Rate (Inches/Hour)
Groundwater Recharge*	0.2
Stormwater Quality	0.5
*See text for required diversion of runoff from greater storms.	

It is important to note that, for dry wells that are used only for groundwater recharge (see Table 9.3-1 above), all runoff from storms greater than the dry well's groundwater recharge storm must be directed around the dry well by a diversion structure or device located upstream of the dry well. If the dry well does receive runoff and associated pollutants from greater storm events, a minimum permeability rate of 0.5 inches/hour must be used. Minor basin inflows from greater storms during normal operation of the diversion are permissible provided they represent a small percentage of the total storm runoff volume. For example, the dry well overflow pipe shown in Figure 9.3-1 can serve as such a diversion if it is located vertically as close to the ground surface as practical. Details of a dry well's groundwater recharge storm are presented in Chapter 6.

In addition to the above, the design permeability rate of the subgrade soils must be sufficient to fully drain the dry well's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See A. *Soil Characteristics* in *Considerations* below for more information. Since the actual permeability rate may vary from test results and may also decrease over time due to soil bed consolidation or the accumulation of sediments removed from the treated stormwater, a factor of safety of two must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the subgrade soils is 4 inches/hour, the design rate would be 2 inches/hour (i.e., 4 inches per hour/2). This design rate would then be used to compute the dry well's maximum design storm drain time.

C. Drainage Area

The maximum drainage area to a dry well is 1 acre.

D. Overflows

All dry wells must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. The downstream drainage system must have sufficient capacity to convey the overflow from the dry well.

Maintenance

Effective dry well performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including dry wells. Specific maintenance requirements for dry wells are presented below. These requirements must be included in the dry well's maintenance plan.

A. General Maintenance

A dry well should be inspected at least four times annually as well as after every storm exceeding 1 inch of rainfall. The water level in the test well should be the primary means of measuring infiltration rates and drain times. Pumping stored runoff from an impaired or failed dry well can also be accomplished through the test well. Therefore, adequate inspection and maintenance access to the test well must be provided.

Disposal of debris, trash, sediment, and other waste material removed from a dry well should be done at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

B. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume from the dry well. This normal drain time should then be used to evaluate the dry well's actual performance. If significant increases in the normal drain time are observed or if it exceeds the 72 hour maximum, appropriate measures must be taken to comply with the drain time requirements and maintain the proper functioning of the dry well.

Considerations

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for the planning and preliminary design of dry wells. However, for final design and construction, soil tests are required at the exact location of a proposed dry well in order to confirm its ability to function properly without failure or interference.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed dry well. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the drywell or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further soil requirements.

In addition, the results of a dry well's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed dry well, to ensure reasonable data consistency. If significant differences exist between the dry well's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

For dry wells, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the dry well should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During dry well construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the dry well.

To help prevent subgrade soil contamination and clogging by sediment, dry well construction should be delayed until all other construction areas that may temporarily or permanently drain to the dry well are stabilized. This delayed construction emphasizes the need, as described above, to cordon off the dry well area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of the dry well as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the dry well bottom. Accumulated sediment can then be removed without disturbing the subgrade soils at the dry well bottom, which should be established only after all construction within the dry well's drainage area is completed and the drainage area stabilized.

If dry well construction cannot be delayed until its drainage area is stabilized, diversion piping or other suitable measures should be installed during all phases of construction to divert all runoff and sediment away from the dry well. These diversion measures should not be removed until all construction within the dry well's drainage area is completed and the drainage area stabilized.

Stone fill aggregate should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of dry wells with the contractor.

Recommendations

A. Pretreatment

As with all other best management practices, pretreatment can extend the functional life of a dry well. While generally not a significant source of runoff pollution, roofs can nevertheless be the source of particulates and organic matter and, during site construction, sediment and debris. Therefore, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to a dry well should be included wherever practical to minimize the amount of sediment and other particulates that can enter the dry well.

References

- Horner, R.R., Skupien, J.J., Livingston E.H. and Shaver, H.E., August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 4

Standard for Extended Detention Basins

Definition

An extended detention basin is a facility constructed through filling and/or excavation that provides temporary storage of stormwater runoff. It has an outlet structure that detains and attenuates runoff inflows and promotes the settlement of pollutants. An extended detention basin is normally designed as a multi-stage facility that provides runoff storage and attenuation for both stormwater quality and quantity management. The adopted TSS removal rate for extended detention basins is 40 to 60 percent, depending on the duration of detention time provided in the basin.

Purpose

Extended detention basins are used to address both the stormwater runoff quantity and quality impacts of land development. The lower stages of an extended detention basin can detain runoff from the stormwater quality design storm for extended periods of time, thereby promoting pollutant removal through sedimentation. Higher stages in the basin can also attenuate the peak rates of runoff from larger storms for flood and erosion control. Extended detention basins are designed for complete evacuation of runoff and normally remain dry between storm events. However, to enhance soluble pollutant removal, the lower stages of an extended detention basin may also be designed with a permanent pool and partially function as either a wetland or retention basin (see *Chapter 9.2: Standard for Constructed Stormwater Wetlands* and *Chapter 9.11: Standard for Wet Ponds*).

Conditions Where Practice Applies

Extended detention basins may be used at sites where significant increases in runoff are expected from site development. In addition, standard detention basins may be retrofitted or converted to extended detention by increasing the time over which the basin releases the stormwater quality design storm runoff volume, provided that erosion and flood control volumes and outflow rates are not adversely altered.

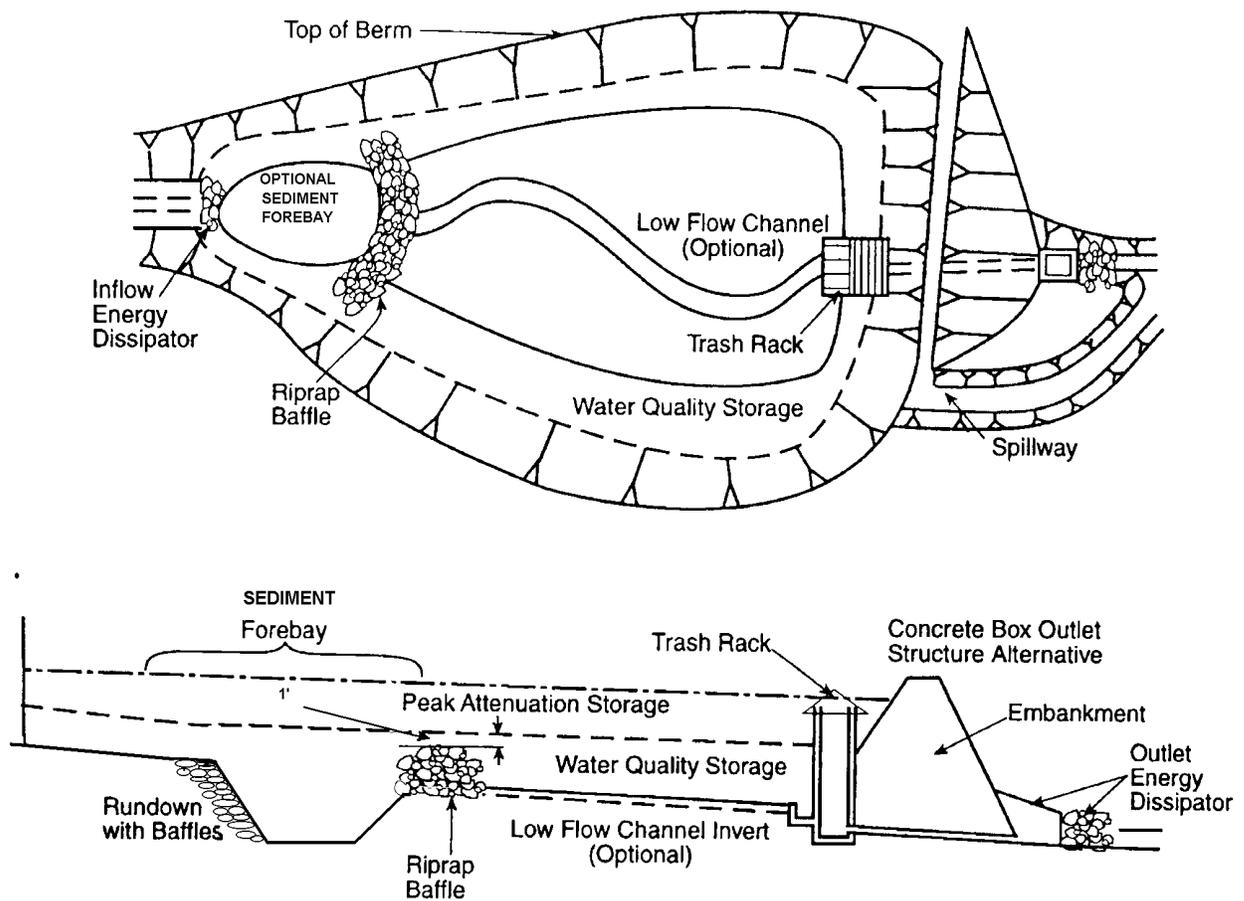
Extended detention basins can be used at residential, commercial, and industrial development sites. However, their limited effectiveness in removing both particulate and soluble pollutants may limit their use for water quality treatment.

Finally, an extended detention basin must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The basic design parameters for an extended detention basin are its storage volume and detention time. An extended detention basin must have the correct combination of storage volume and outflow capacity to contain and slowly discharge the design runoff volume over a prescribed period of time. Details of these and other design parameters are presented below. The components of a typical extended detention basin are shown in Figure 9.4-1.

Figure 9.4-1: Extended Detention Basin Components



Source: Adopted from Pennsylvania Handbook of Best Management Practices for Developing Areas, which adapted the figure from Dam Design and Construction Standards, Fairfax County, Virginia.

A. Storage Volume, Depth, and Duration

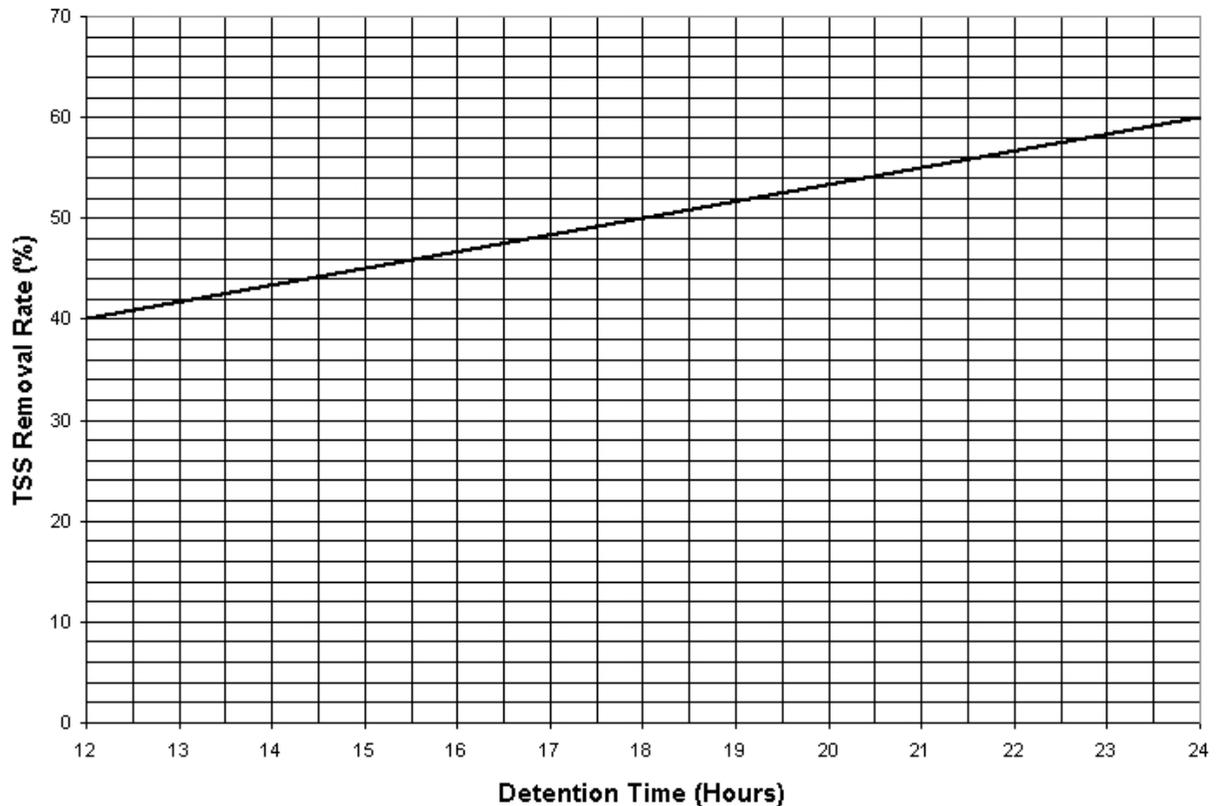
Extended detention basins should be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. To achieve a 60 percent TSS removal rate, a minimum of 10 percent of this runoff volume must remain in the basin 24 hours after the peak basin water surface and maximum runoff storage volume is achieved. This applies to all types of land developments.

It should be noted that the time from when the maximum storage volume is achieved until only 10 percent of that volume remains in an extended detention basin is defined as the basin's detention time. As noted above, a 24-hour detention time is required in an extended detention basin in order to achieve a 60 percent TSS removal rate. Figure 9.4-2 below can be used to determine the TSS removal rates at extended detention basins with detention times of 12 to 24 hours. The minimum diameter of any outlet orifice must be 2.5 inches.

The lowest elevation in an extended detention basin, excluding low flow channels, must be at least 1 foot above the seasonal high groundwater table. The lowest elevation in any low flow channel, including any underdrain pipes and bedding material, must be at or above the seasonal high groundwater table.

To enhance safety by minimizing standing water depths, the vertical distance between the basin bottom and the elevation of the first stormwater quantity control outlet (normally set equal to the maximum stormwater quality design storm water surface) should be no greater than 3 feet wherever practical.

Figure 9.4-2: TSS Removal Rate vs. Detention Time



B. Overflows

All extended detention basins must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Extended detention basins that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards.

C. Tailwater

The hydraulic design of the outlet structure, outlet pipe, emergency spillway, and underdrain systems in an extended detention basin must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

D. Other Components

Information regarding outlet structures, bottom and side slopes, trash racks, low flow channels, conduit outlet protection, and vegetative cover can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

E. Subsurface Extended Detention Basins

A subsurface detention basin is located entirely below the ground surface. Runoff may be stored in a vault, perforated pipe, and/or stone bed. If a stone bed is utilized for any part of the storage volume, all runoff to the subsurface basin must either be pretreated or the basin's storage volume increased to account for the loss of volume in the stone bed due to sediment accumulation. This loss should be based upon the expected life of the basin. This increase is due to the impracticality of removing this sediment from the stone storage bed. This pretreatment must remove at least 50 percent of the TSS in the runoff from the basin's maximum design storm.

Following pretreatment, additional TSS removal can then be provided by the subsurface extended detention basin as the secondary BMP in a treatment train. Computation of the total TSS removal rate is described in *Chapter 4: Stormwater Pollution Removal Criteria. See Recommendations* below for additional information on runoff pretreatment.

Maintenance

Effective extended detention basin performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including extended detention basins. Specific maintenance requirements for extended detention basins are presented below. These requirements must be included in the basin's maintenance plan.

A. General Maintenance

All extended detention basin components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include bottoms, trash racks, low flow channels, outlet structures, riprap or gabion aprons, and inlets.

Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the bottom surface and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides, and other means to assure optimum vegetation health must not compromise the intended purpose of the extended detention basin. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to completely drain the maximum design storm runoff volume from the basin. This normal drain time should then be used to evaluate the basin's actual performance. If significant increases or decreases in the normal drain time are observed, the basin's outlet structure, underdrain system, and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the basin.

Considerations

For effective stormwater quality control, the basin must collect as much site runoff as possible, especially from the site's roadways, parking lots, and other impervious areas. The majority of the key pollutants that are removed by extended detention basins originate on these surfaces.

A typical extended detention basin will range from 3 to 12 feet in depth. Depth is often limited by groundwater conditions or the need for positive drainage from excavated basins. At the location of the proposed extended detention basin, the depth to seasonal high groundwater table must be determined. If the basin intercepts the groundwater, it may result in a loss of runoff storage volume, mosquito breeding, and difficulty maintaining the basin bottom.

When designing an extended detention basin, bottom soils should be examined. If soils are relatively impermeable (USDA Hydrologic Soil Group "D"), a dry extended detention basin may exhibit problems with standing water. Conversely, if soils are very permeable (Group "A") the effects on groundwater should be considered. If bedrock lies close to the surface of the soil, excavation for necessary storage volume may be too costly and difficult. In Karst landscapes, other alternatives to detention basins should be examined.

Recommendations

A. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of an extended detention system. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as vegetative filters, a forebay, or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

Forebays can also be included at the inflow points to an extended detention basin to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

It should be remembered that the runoff to all subsurface extended detention basins that utilize stone beds to store runoff must be pretreated. This pretreatment must provide 50 percent removal of TSS for the maximum design storm runoff to the basin. See *E. Subsurface Extended Detention Basins* in *Design Criteria* above for more information.

B. Sediment Accumulation

A properly designed extended detention basin will accumulate considerable amounts of sediment over time, leading to the loss of the detention volume and, thus, both runoff quality and quantity control effectiveness. Therefore, depending on the clean-out intervals, an increase in an extended detention basin's maximum design storm storage volume should be considered to compensate for this expected loss of storage volume. See *E. Subsurface Extended Detention Basins* in *Design Criteria* above for more information on required volume increases in subsurface basins.

C. Flow Paths

An extended detention basin relies on the process of sedimentation for removal of runoff pollutants. Therefore, the basin should be designed to maximize the degree of sedimentation. Flow path lengths should be maximized and long, narrow basin configurations with length to width ratios from 2:1 to 3:1 should be utilized. Basins that are shallow and have larger surface area to depth ratios will provide better pollutant removal efficiencies than smaller, deeper basins.

D. Wetland Creation

It may be possible to establish a wetland area in the bottom stage of an extended detention basin to increase the pollutant removal rate. See *Chapter 9.2: Standard for Constructed Stormwater Wetlands* for more information.

References

- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Pennsylvania Handbook of Best Management Practices for Developing Area. 1998. Prepared by CH2M Hill for Pennsylvania Association of Conservation Districts. Pennsylvania Department of Environmental Protection, and Natural Resources Conservation Service.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 5

Standard for Infiltration Basins

Definition

An infiltration basin is a facility constructed within highly permeable soils that provides temporary storage of stormwater runoff. An infiltration basin does not normally have a structural outlet to discharge runoff from the stormwater quality design storm. Instead, outflow from an infiltration basin is through the surrounding soil. An infiltration basin may also be combined with an extended detention basin to provide additional runoff storage for both stormwater quality and quantity management. The adopted TSS removal rate for infiltration basins is 80 percent.

It should be noted that a dry well is a specialized infiltration facility intended only for roof runoff. See *Chapter 9.3: Standard for Dry Wells* for further details.

Purpose

Infiltration basins are used to remove pollutants and to infiltrate stormwater back into the ground. Such infiltration also helps to reduce increases in both the peak rate and total volume of runoff caused by land development. Pollutant removal is achieved through filtration of the runoff through the soil as well as biological and chemical activity within the soil.

Infiltration basins may also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of infiltration basins and other groundwater recharge facilities to meet them.

Conditions Where Practice Applies

The use of infiltration basins is applicable only where the soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, infiltration basins are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination.

Specifically, infiltration basins must not be used in the following locations:

- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied or pesticides are loaded, unloaded, or stored.
- Areas where hazardous materials are expected to be present in greater than “reportable quantities” as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where infiltration basin use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is 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, that could be a source of pollutants in any industrial stormwater discharge to groundwater. 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.

In addition, as required by the Stormwater Management Rules, infiltration basins must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Infiltration basins must be configured and located where their construction will not compact the soils below the basin. In addition, an infiltration basin must not be placed into operation until the contributing drainage area is completely stabilized. Basin construction must either be delayed until such stabilization is achieved, or upstream runoff must be diverted around the basin. Such diversions must continue until stabilization is achieved.

Finally, an infiltration basin must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The components of a typical infiltration basin are shown in Figure 9.5-1. Additional details of each component are described below.

A. Storage Volume, Depth, and Duration

An infiltration basin must be designed to treat the total runoff volume generated by the basin’s maximum design storm. This may either be the groundwater recharge or stormwater quality design storm, depending upon the basin’s proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. An infiltration basin must also fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the basin ineffective and may result in anaerobic conditions, odor, and both water quality and mosquito breeding problems. The bottom of the infiltration basin must be at least 2 feet above seasonal high water table or bedrock. For surface basins, this distance must be measured from the bottom of the sand layer as shown in Figure 9.5-1. The basin bottom must be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

To enhance safety by minimizing standing water depths, the vertical distance between the basin bottom and the maximum design storm water surface in surface infiltration basins should be no greater than 2 feet.

As discussed in *Considerations* below, construction of an infiltration basin must be done without compacting the basin's subgrade soils. As such, all excavation must be performed by equipment placed outside the basin whenever possible. This requirement should be considered when designing the dimensions and total storage volume of an infiltration basin.

It is important to note that the use of infiltration basins is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of infiltration basins for larger storm events and the requirements by which such basins are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

B. Permeability Rates

The minimum design permeability rate of the soils below an infiltration basin will depend upon the basin's location and maximum design storm. The use of infiltration basins for stormwater quality control is feasible only where soil is sufficiently permeable to allow a reasonable rate of infiltration. Therefore, infiltration basins designed for storms greater than the groundwater recharge storm can be constructed only in areas with Hydrologic Soil Group A and B soils. Additional permeability requirements are presented below in Table 9.5-1.

Table 9.5-1: Minimum Design Permeability Rates for Infiltration Basins

Maximum Design Storm	Basin Location	Minimum Design Permeability Rate (Inches/Hour)
Groundwater Recharge*	Subsurface	0.2
Groundwater Recharge	Surface	0.5
Stormwater Quality	Surface and Subsurface	0.5
*See text for required diversion of runoff from greater storms.		

It is important to note that, for subsurface infiltration basins that are used only for groundwater recharge (see Table 9.5-1 above), all runoff from storms greater than the basin's groundwater recharge storm must be directed around the basin by a diversion structure or device located upstream of the basin. If the basin does receive runoff and associated pollutants from greater storm events, a minimum permeability rate of 0.5 inches/hour must be used. Minor basin inflows from greater storms during normal operation of the diversion are permissible provided they represent a small percentage of the total storm runoff volume. Details of an infiltration basin's groundwater recharge storm are presented in *Chapter 6*. See *E. Online and Offline Systems* below for additional information.

In addition to the above, the design permeability rate of the soil must be sufficient to fully drain the infiltration basin's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See *A. Soil Characteristics* in *Considerations* below for more information. Since the actual permeability rate may vary from test results and may also decrease over time due to soil bed consolidation or the accumulation of sediments removed from the treated stormwater, a

factor of safety of two must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soils is 4 inches/hour, the design rate would be 2 inches/hour (i.e., 4 inches per hour/2). This design rate would then be used to compute the basin's maximum design storm drain time.

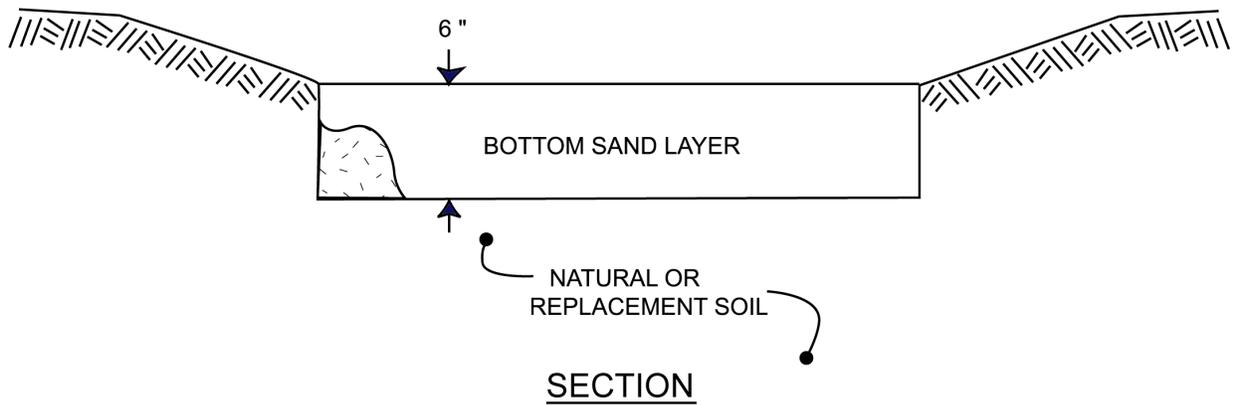
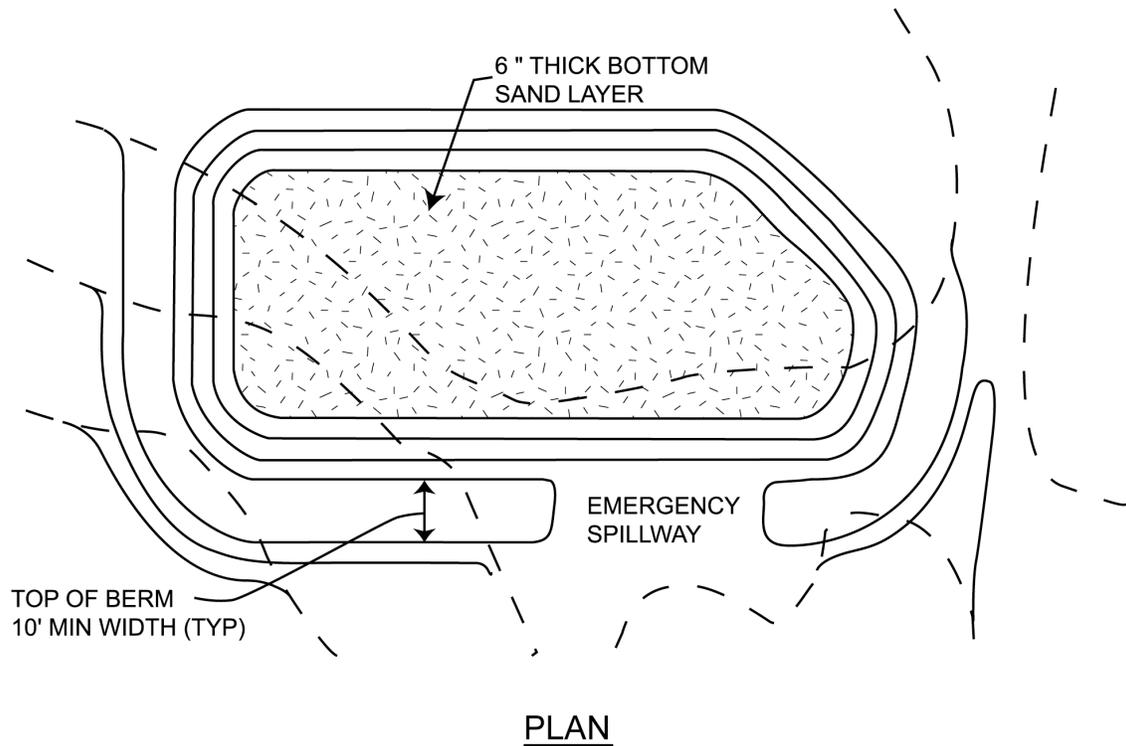
C. Bottom Sand Layer

To help ensure maintenance of the design permeability rate over time, a 6 inch layer of sand must be placed on the bottom of an infiltration basin (see Figure 9.5-1). This sand layer can intercept silt, sediment, and debris that could otherwise clog the top layer of the soil below the basin. The sand layer will also facilitate silt, sediment, and debris removal from the basin and can be readily restored following removal operations. The sand layer must meet the specifications of a K5 soil. This must be certified by a professional engineer licensed in the State of New Jersey.

D. Overflows

All infiltration basins must be able to convey overflows to downstream drainage systems in a safe and stable manner. Infiltration basins that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards.

Figure 9.5-1: Infiltration Basin Components



NOTES

1. BOTTOM SAND LAYER MUST CONSIST OF K5 SAND WITH A MAXIMUM OF 15% FINES AND A MINIMUM PERMEABILITY RATE OF 20 INCHES PER HOUR.
2. BASIN CONSTRUCTION MUST NOT COMPACT SOILS BELOW BASIN BOTTOM.
3. SEE TEXT FOR ADDITIONAL REQUIREMENTS.

Source: Adapted from T&M Associates.

E. On-Line and Off-Line Systems

Infiltration basins may be constructed either on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the maximum design storm and conveying the runoff from larger storms through an overflow. With the proper soil and drainage area conditions, an infiltration basin may also be combined with a detention basin to provide runoff quantity control in the detention portion of the basin. In such systems the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface.

In off-line infiltration basins, most or all of the runoff from storms larger than the maximum design storm bypass the basin through an upstream diversion. This not only reduces the size of the required basin storage volume, but also reduces the basin's long-term pollutant loading and associated maintenance. See *B. Permeability Rates* above for additional information on diversion requirements, particularly for subsurface infiltration basins used only for groundwater recharge.

F. Subsurface Infiltration Basins

A subsurface infiltration basin is located entirely below the ground surface. It may consist of a vault, perforated pipe, and/or stone bed. However, due to the greater difficulty in removing silt, sediment, and debris, all runoff to a subsurface infiltration basin must be pretreated. This pretreatment must remove 80 percent of the TSS in the runoff from the basin's maximum design storm.

Following pretreatment, additional TSS removal can then be provided by the subsurface infiltration basin as the secondary BMP in a treatment train. Computation of the total TSS removal rate is described in *Chapter 4: Stormwater Pollution Removal Criteria*. See *A. Pretreatment in Recommendations* below for information on runoff pretreatment.

G. Basis of Design

The design of an infiltration basin is based upon Darcy's Law:

$$Q = KIA$$

where:

Q = the rate of infiltration in cubic feet per second (cfs)

K = the hydraulic conductivity of the soil in feet per second (fps)

I = the hydraulic gradient

A = the area of infiltration in square feet (sf)

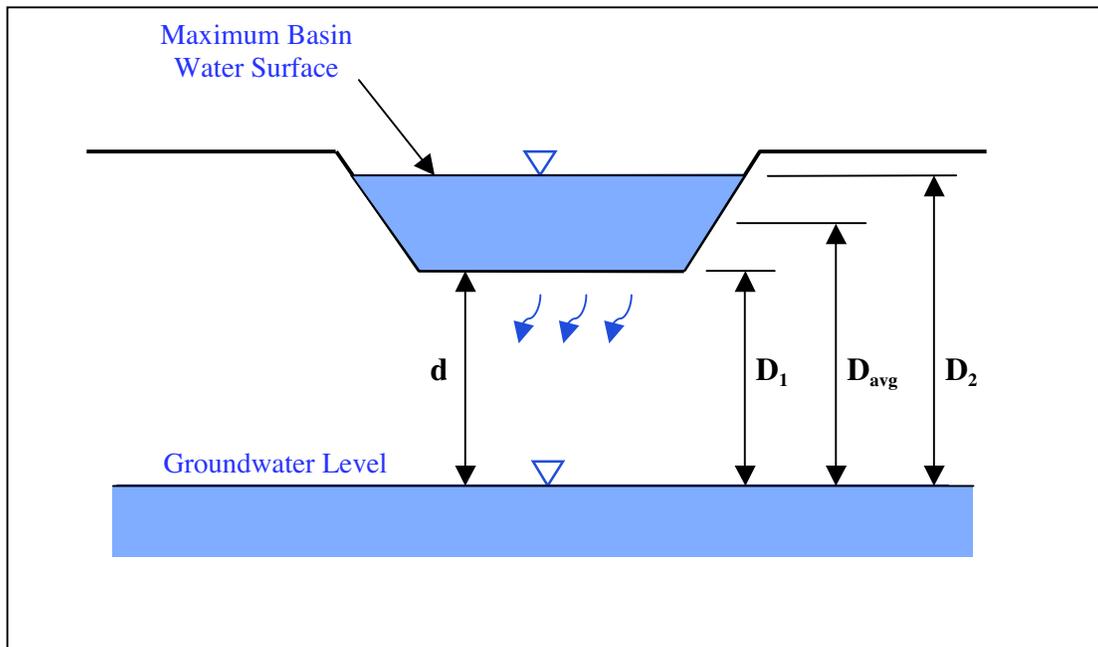
From the variables shown in Figure 9.5-2 below:

Average Hydraulic Gradient = D_{avg}/d

Minimum Hydraulic Gradient = D_1/d

Maximum Hydraulic Gradient = D_2/d

Figure 9.5-2: Schematic of Darcy's Law



The hydraulic conductivity is either field measured or laboratory measured for the soil on site. A number of percolation tests should be done to obtain a reliable measurement of permeability of the underlying soil.

Maintenance

Effective infiltration basin performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* contains information and requirements for preparing a maintenance plan for stormwater management facilities, including infiltration basins. Specific maintenance requirements for infiltration basins are presented below. These requirements must be included in the basin's maintenance plan.

A. General Maintenance

All infiltration basin components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include bottoms, riprap or gabion aprons, and inflow points. This applies to both surface and subsurface infiltration basins.

Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

Studies have shown that readily visible stormwater management facilities like infiltration basins receive more frequent and thorough maintenance than those in less visible, more remote locations. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. The structure must be inspected for unwanted tree growth at least once a year.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing season. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides, and other means to assure optimum vegetation health must not compromise the intended purpose of the infiltration basin. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

All vegetated areas should be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the remaining vegetation and basin subsoil.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the bottom of the basin. This normal drain or drawdown time should then be used to evaluate the basin's actual performance. If significant increases or decreases in the normal drain time are observed, the basin's bottom surface, subsoil, and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the basin. This applies to both surface and subsurface infiltration basins.

The bottom sand layer in a surface infiltration basin should be inspected at least monthly as well as after every storm exceeding 1 inch of rainfall. The permeability rate of the soil below the basin may also be retested periodically. If the water fails to infiltrate 72 hours after the end of the storm, corrective measures must be taken. Annual tilling by light equipment can assist in maintaining infiltration capacity and break up clogged surfaces.

Considerations

Infiltration basins can present some practical design problems. When planning for an infiltration basin that provides stormwater quality treatment, consideration should be given to soil characteristics, depth to the groundwater table, sensitivity of the region, and runoff water quality. Particular care must be taken when constructing infiltration basins in areas underlain by carbonate rocks known as Karst landscapes. See Appendix A10 of the Standards for Soil Erosion and Sediment Control in New Jersey for further guidance in Karst landscape areas.

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for the planning and preliminary design of infiltration basins. However, for final design and construction, soil tests are required at the exact location of a proposed basin in order to confirm its ability to function properly without failure.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed infiltration basin. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the basin or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further subgrade soil requirements.

In addition, the results of a basin's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed infiltration basin, to ensure reasonable data consistency. If significant differences exist between the basin's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

For infiltration basins, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the infiltration basin should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During basin construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the basin.

To help prevent subgrade soil contamination and clogging by sediment, basin construction should be delayed until all other construction within its drainage area is completed and the drainage area stabilized. This delayed construction emphasizes the need, as described above, to cordon off the basin area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of an infiltration basin as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the basin bottom. Accumulated sediment can then be removed without disturbing the subgrade soils at the basin bottom, which should be established only after all construction within the basin's drainage area is completed and the drainage area stabilized.

Once the final grading phase of a surface infiltration basin is reached, the bottom of the basin should be deeply tilled with a rotary tiller or disc harrow and then smoothed out with a leveling drag or equivalent grading equipment. These procedures should preferably be performed with equipment located outside the basin bottom. If this is not possible, it should be performed with light-weight, rubber-tired equipment.

If basin construction cannot be delayed until its drainage area is stabilized, diversion berms or other suitable measures should be placed around the basin's perimeter during all phases of construction to divert all runoff and sediment away from the basin. These diversion measures should not be removed until all construction within the basin's drainage area is completed and the drainage area stabilized.

Broken stone fill used in subsurface infiltration basins should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of infiltration basins with the contractor.

C. Runoff Quality

The quality of runoff entering an infiltration basin is a primary consideration in determining whether infiltration is advisable and, if so, in designing the basin itself. The planning of an infiltration basin must consider which pollutants will be present in the runoff and whether these pollutants will degrade groundwater quality. Certain soils can have a limited capacity for the treatment of bacteria and the soluble forms of nitrogen, phosphorus, and other pollutants like road salts and pesticides. Such pollutants are either attenuated in the soil column or go directly to the water table. Unfortunately, the soils that normally have the highest and, therefore, most suitable permeability rates also have the least ability to treat such pollutants. As a result, pretreatment of soluble pollutants prior to entry into the infiltration basin may be necessary in these soils. Pretreatment measures may include vegetative filters, bioretention systems (where the infiltration basin takes the place of the standard underdrain), and certain sand filters. Alternatively, the existing soil below the infiltration basin bottom may be augmented or replaced by soils with greater soluble pollutant removal rates.

Recommendations

A. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of an infiltration basin. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filters, a forebay, and/or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Subchapters 9.10 and 9.6, respectively.

Forebays can be included at the inflow points to an infiltration basin to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

As described above, it should be remembered that the runoff to all subsurface infiltration basins must be pretreated. This pretreatment must provide 80 percent removal of TSS for the maximum design storm runoff. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for additional pretreatment information for subsurface infiltration basins used for groundwater recharge.

This pretreatment requirement does not apply to roofs and other above-grade surfaces. However, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to a subsurface infiltration basin should be included wherever practical to minimize the amount of sediment and other particulates that can enter the basin.

B. Sensitivity of the Area

The planning of an infiltration basin site should consider the geologic and ecological sensitivity of the proposed site. Sensitive areas include FWI streams, areas near drinking water supply wells, and areas of high aquifer recharge. Infiltration basins should be sited at least 100 feet from a drinking water supply well. They should also be sited away from foundations to avoid seepage problems. Measures should be taken in areas of aquifer recharge to ensure good quality water is being infiltrated to protect ground water supplies. Infiltration basins should be located away from septic systems to help prevent septic system failure and other adverse system interference.

C. Slopes

Topography of the location is an important consideration for basin operation. Ideally, basin construction should not occur where surrounding slopes are greater than 10 percent. The grading of the basin floor should be as level as possible (with the slope approaching zero) to achieve uniform spreading across the breadth and the length of the basin.

Grading and landscaping throughout the infiltration basin and its components must be designed to facilitate mowing, trimming, sediment and debris removal, and other maintenance activities.

References

- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture, November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R.. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 6

Standard for Manufactured Treatment Devices

Definition

A manufactured treatment device is a pre-fabricated stormwater treatment structure utilizing settling, filtration, absorptive/adsorptive materials, vortex separation, vegetative components, and/or other appropriate technology to remove pollutants from stormwater runoff.

The TSS removal rate for manufactured treatment devices is based on the NJDEP certification of the pollutant removal rates on a case-by-case basis. Details are provided below. Other pollutants, such as nutrients, metals, hydrocarbons, and bacteria can be included in the verification/certification process if the data supports their removal efficiencies.

Purpose

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality treatment measure, or waterbody.

Conditions Where Practice Applies

A manufactured treatment device is adequate for small drainage areas that contain a predominance of impervious cover that is likely to contribute high hydrocarbon and sediment loadings, such as small parking lots and gas stations. For larger sites, multiple devices may be necessary. Devices are normally used for pre-treatment of runoff before discharging to other, more effective stormwater quality treatment facilities.

In addition, a manufactured treatment device must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

In addition to its certified pollutant removal rate, the basic design parameters for a manufactured treatment device will depend on the techniques it employs to remove particulate and dissolved pollutants from runoff. In general, the design of devices that treat runoff with no significant storage and flow rate attenuation must be based upon the peak design flow rate. However, devices that do provide storage and flow rate attenuation must be based, at a minimum, on the design runoff volume and, in some instances, on a routing of the design runoff hydrograph. Details of these and other design parameters are presented below.

A. Pollutant Removal Rates

The NJDEP Division of Science, Research & Technology (DSRT) is responsible for certifying final pollutant removal rates for all manufactured treatment devices. This final certification process must be based upon one of the following:

1. Verification of the device's pollutant removal rates by the N.J. Corporation for Advanced Technology (NJCAT) in accordance with the New Jersey Energy and Environmental Technology Verification Program at N.J.S.A. 13:D-134 et seq. This verification must be conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity" as developed under the Environmental Council of States (ECOS) and Technology Acceptance and Reciprocity Partnership (TARP). This stormwater protocol ensures that technologies are evaluated in a uniform manner assuring minimum standards for quality assurance and quality control (QA/QC). In addition, the protocol establishes an interstate reciprocity pathway for technology and regulatory acceptance.
2. Verification of the device's pollutant removal rates by another TARP state, or another state or government agency that is recognized by New Jersey through a formal reciprocity agreement, provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity."
3. Verification of the device's pollutant removal rates by other third party testing organizations (i.e., NSF), provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity." Other testing protocols may be considered if it is determined by the NJDEP to be equivalent to the Tier II Protocol.

It should be noted that the pollutant removal rates for a manufactured treatment device may be granted interim conditional certification by the NJDEP provided that the manufacturer submits an interim verification report through NJCAT and further agrees to apply for and complete the final certification process described above. All interim certifications are effective for a limited time period, as determined on a case-by-case basis by the NJDEP.

B. Flow Rates and Storage Volumes

To achieve its assigned TSS removal rate, a manufactured treatment device must be designed to treat the runoff generated by the stormwater quality design storm. Techniques to compute the runoff rates and volume from this storm event are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Depending on the device's pollutant removal technique(s), the primary design parameter for a manufactured treatment device will normally be either the peak rate and/or total runoff volume from the stormwater quality design storm. Devices that convey inflow with little or no storage and provide pollutant removal only through such techniques as vortex flow, filtration, and/or absorption must be based on the peak rate of

stormwater quality design storm runoff. Devices that store and convey runoff more slowly and provide pollutant removal through such techniques as sedimentation and/or filtration must also be based on the total volume of runoff. Hydraulic losses through a device must be considered in the design of all related upstream and downstream drainage system components.

C. Overflows

All manufactured treatment devices must be able to safely overflow or bypass flows in excess of the stormwater quality design storm to downstream drainage systems. The capacity of the overflow or bypass must be consistent with the remainder of the site's drainage system. All such flows must be conveyed in such a manner that trapped material, including floatables, is not resuspended and released. The designer must also check the capacity of the downstream conveyance system to ensure the adequacy of the overflow or bypass. All manufactured treatment devices must also have similar provisions to safely overflow and/or bypass runoff in the event of internal component clogging, blockage, and/or failure.

D. Tailwater

The hydraulic design of all manufactured treatment devices must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

E. Subsurface Devices

All subsurface or underground devices must be designed for HS-20 traffic loading at the surface. All joints and connections must be watertight. The manhole cover or other approved permanent marker for the treatment device must clearly indicate that it is a pollutant-trapping device. Sufficient and suitable access must be provided for each chamber in the device for inspection and maintenance activities. This must include adequate clearance from adjacent structures to allow for placement and operation of maintenance equipment. All subsurface devices must also be installed a minimum of 20 feet from a septic tank/drainage field. Any subsurface device within 20 feet of a slope greater than 2:1 requires a geotechnical review.

F. On-line and Off-line Devices

Manufactured treatment devices may be constructed on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an overflow. In off-line devices, most or all of the runoff from storms larger than the stormwater quality design storm bypass the device through an upstream diversion. This not only reduces the size of the required device overflow, but also reduces the device's long-term pollutant loading and associated maintenance, and the threat of resuspension and release of trapped material by larger storm inflows.

Maintenance

Effective performance of a manufactured treatment device requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including manufactured treatment devices. Specific maintenance requirements for these devices are presented below. These requirements must be included in the device's maintenance plan.

A. General Maintenance

All manufactured treatment devices should be inspected and maintained in accordance with the manufacturer's instructions and/or recommendations and any maintenance requirements associated with the device's certification by the NJDEP Office of Innovative Technology. In addition, all device components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetation

In those devices utilizing vegetation, trimming of vegetation must be performed on a regular schedule based on specific site conditions. Vegetated areas must be inspected at least annually for erosion and scour as well as unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. All use of fertilizers, mechanical treatments, pesticides, and other means to ensure optimum vegetation health in devices utilizing vegetation should not compromise the intended purpose of the device. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the maximum level of oil, sediment, and debris accumulation allowed before removal is required. These levels should then be monitored during device inspections to help determine the need for removal and other device maintenance.

References

- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture, November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection. Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity. Environmental Council of States (ECOS) and Technology Acceptance and Reciprocity Partnership (TARP)
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 7

Standard for Pervious Paving Systems

Definition

Pervious paving systems are paved areas that produce less stormwater runoff than areas paved with conventional paving. This reduction is achieved primarily through the infiltration of a greater portion of the rain falling on the area than would occur with conventional paving. This increased infiltration occurs either through the paving material itself or through void spaces between individual paving blocks known as pavers.

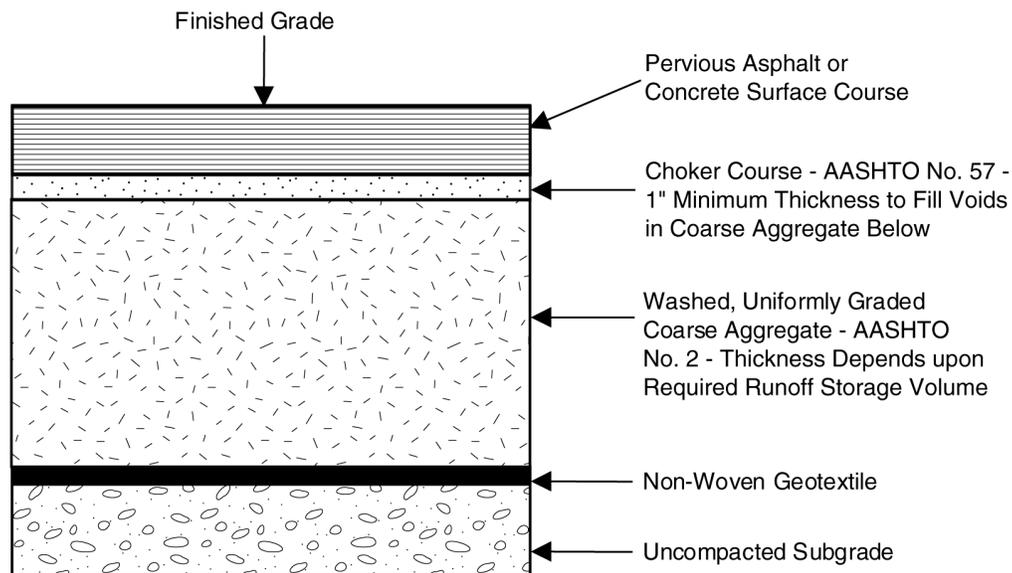
Pervious paving systems are divided into three general types. Each type depends primarily upon the nature of the pervious paving surface course and the presence or absence of a runoff storage bed beneath the surface course. These three types are summarized in Table 9.7-1 and discussed below. Porous paving and permeable paver with storage bed systems treat the stormwater quality design storm runoff through storage and infiltration. Therefore, these systems have adopted TSS removal rates similar to infiltration structures. The adopted TSS removal rate for each type of pervious paving system is presented in Table 9.7-1.

Table 9.7-1: Types of Pervious Paving Systems

Type of Paving System	General Description of Paving System	Adopted TSS Removal Rate
Porous paving	Porous asphalt or concrete paving constructed over runoff storage bed of uniformly graded broken stone	80%
Permeable pavers with storage bed	Impervious concrete pavers with surface voids constructed over runoff storage bed of uniformly graded broken stone	80%
Permeable pavers without storage bed	Impervious concrete pavers with surface voids constructed over structural bed of sand and crushed stone	Volume reduction only

Porous paving systems consist of a porous asphalt or concrete surface course placed over a bed of uniformly graded broken stone. The broken stone bed is placed on an uncompacted earthen subgrade and is used to temporarily store the runoff that moves vertically through the porous asphalt or concrete into the bed. The high rate of infiltration through the porous paving is achieved through the elimination of the finer aggregates that are typically used in conventional paving. The remaining aggregates are bound together with an asphalt or Portland cement binder. The lack of the finer aggregate sizes creates voids in the normally dense paving that allow runoff occurring on the paving to move vertically through the paving and into the void spaces of the broken stone storage bed below. From there, the stored runoff then infiltrates over time into the uncompacted subgrade soils similar to an Infiltration Basin. The depth of the bed, which also provides structural support to the porous surface course, depends upon the volume and rate of rainfall that the porous paving system has been designed to store and infiltrate and the void ratio of the broken stone. A typical detail of a porous paving system is shown in Figure 9.7-1.

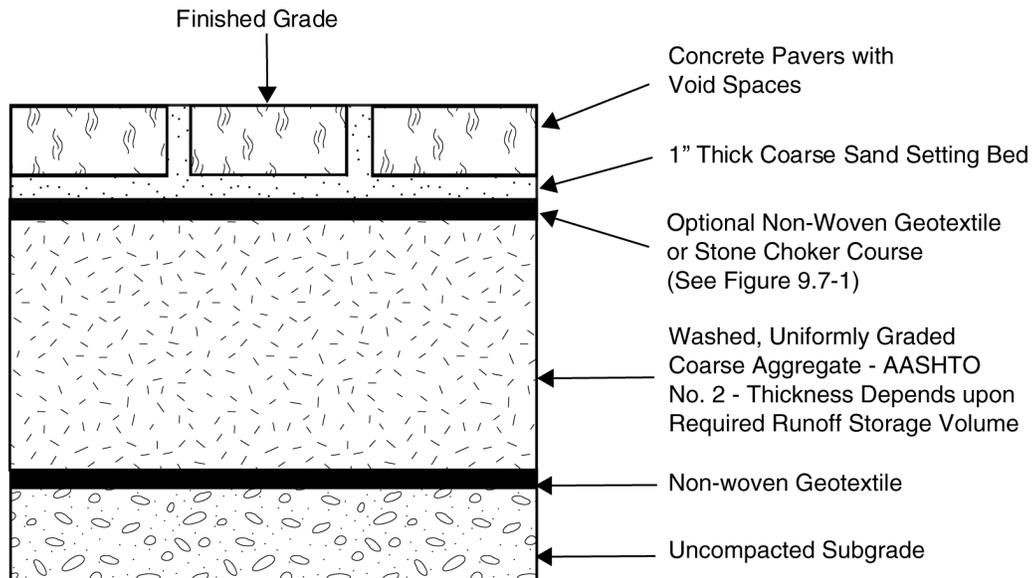
Figure 9.7-1: Porous Paving Details



Source: Cahill Associates.

A permeable paver with storage bed system also has a subsurface storage bed and functions in a similar manner to a porous paving system. However, instead of a continuous porous asphalt or concrete surface course, the system's surface consists of impervious concrete blocks known as pavers that either have void spaces cast into their surfaces or interlock in such a way as to create such void spaces. These void spaces allow runoff from the impervious paver surface to collect and move vertically past the individual pavers into the broken stone storage bed below. Similar to a porous paving system, the runoff stored in the broken stone storage bed, which also provides structural support to the pavers, then infiltrates over time into the uncompacted subgrade soils. A typical detail of a permeable paver with storage bed system is shown in Figure 9.7-2.

Figure 9.7-2: Permeable Pavers with Storage Base

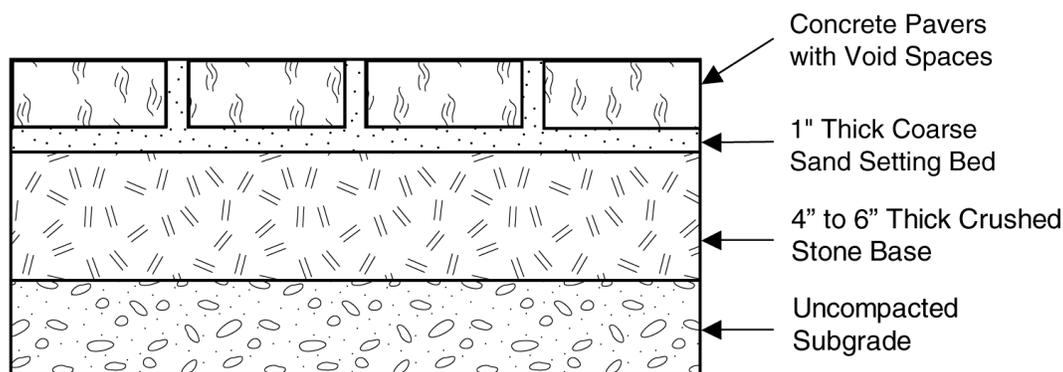


It is important to note that both a porous paving system and a permeable paver with storage bed system function in the same manner as any other infiltration-based BMP such as an infiltration basin or dry well. That is, the fundamental means of runoff quantity control is into and through the subgrade soils below the BMP. Therefore, in terms of runoff quantity control, the porous paving or permeable paver surface course acts solely as a conveyance measure that delivers the surface course runoff to the subgrade soils. In addition, the broken stone storage bed serves only to temporarily store the runoff transmitted through the surface course. For these reasons, the design and use of porous paving and permeable paver with storage bed systems are generally subject to the same design, operation, and maintenance requirements of all other infiltration-based BMPs. Details of these requirements are presented in *Design Criteria* below.

In addition to runoff volume control, porous paving and permeable paver with storage bed systems also provide stormwater quality control through the infiltration process when designed to store and infiltrate the stormwater quality design storm runoff volume. This is again similar to other infiltration-based BMPs such as infiltration basins. In addition, the porous or permeable paver surface course in such systems can be considered to provide pretreatment of the runoff to their respective subsurface storage beds.

Permeable pavers without a storage bed is the third type of pervious paving system. As described by its name, this type of system does not have a broken stone runoff storage bed beneath it. Instead, the permeable pavers are placed on a generally thinner bed of sand and crushed stone that provides only structural support to the paver surface course and has no significant runoff storage volume. This lack of storage volume prevents the system from storing and infiltrating the relatively larger volumes of runoff typically achieved by a porous paving or permeable paver with storage bed system. However, because of the void spaces in the paver surface, a portion of the runoff from the pavers, albeit smaller than the storage bed systems, can still collect in the surface voids spaces and infiltrate through the sand and crushed stone bed and into the subgrade soils. A typical detail of a permeable paver without storage bed system is shown in Figure 9.7-3.

Figure 9.7-3: Permeable Paver without Storage Base



Purpose

In general, pervious paving systems are used to reduce runoff rates and volumes from paved, on-grade surfaces such as patios, walkways, driveways, fire lanes, and parking spaces. Pervious paving systems with runoff storage beds below them achieve these reductions through the delivery and storage of runoff and eventual infiltration into the subgrade soils. Through this infiltration process, these types of pervious paving systems also achieve stormwater quality treatment.

Porous paving and permeable paver with storage bed systems may also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of pervious paving and other groundwater recharge facilities to meet them.

Permeable pavers without storage bed systems also achieve reductions in runoff rates and volumes, primarily by generating less surface runoff than conventional paving. However, due to the lack of a runoff storage bed and significant runoff infiltration, these types of pervious paving systems achieve less runoff reductions than systems with storage beds. For similar reasons, they also do not provide any significant stormwater quality treatment. However, the reduction in runoff rates and volumes they do achieve may reduce the volume of stormwater quality design storm runoff to be treated by other, downstream stormwater management facilities.

Conditions Where Practice Applies

As noted above, porous paving and permeable pavers with storage bed systems function as infiltration facilities. As such, the use of such pervious paving systems is applicable only where their subgrade soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, porous paving and permeable pavers with storage bed systems are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination. Specifically, such systems must not be used in the following locations:

- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied or pesticides are loaded, unloaded, or stored.

- Areas where hazardous materials are expected to be present in greater than “reportable quantities” as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where system use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is 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, that could be a source of pollutants in any industrial stormwater discharge to groundwater. 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.

In addition, as required by the Stormwater Management Rules, porous paving and permeable pavers with storage bed systems must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Porous paving and permeable pavers with storage bed systems must be configured and located where their construction will not compact the soils below the system. In addition, such systems must not be placed into operation until the contributing drainage area is completely stabilized. System construction must either be delayed until such stabilization is achieved, or upstream runoff must be diverted around the system. Such diversions must continue until stabilization is achieved.

Due to the reduced shear strength of the surface course, all pervious paving systems are limited to areas of relatively infrequent use by light vehicles. This includes parking lot spaces and secondary aisles, single family residential driveways, sidewalks and walkways, golf cart paths, fire and emergency access lanes, and overflow parking areas. In general, they should not be used in high traffic areas such as roadways, multiple family and nonresidential driveways, and primary parking lot aisles or in any area subject to use by heavy vehicles and other equipment.

One pervious paving use strategy is to alternate areas with impervious and pervious paving. In these instances, conventional paving would be reserved for the heavily trafficked corridors. A wide variety of concrete and brick permeable paving systems are available. These can be combined with conventional and porous paving systems to achieve functional and aesthetically pleasing designs.

Finally, all three types of pervious paving systems must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The design criteria for pervious paving systems will depend upon the type of system to be used. Details of each system type are presented in Figures 9.7-1, 9.7-2, and 9.7-3 above. Design criteria for each type are presented below.

A. Storage Volume, Depth, and Duration

Porous paving and permeable paver with storage bed systems must be designed to treat the total runoff volume generated by the system's maximum design storm. This may be either the groundwater recharge or stormwater quality design storm depending upon the system's proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Such systems must also all fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the systems ineffective and may result in anaerobic conditions and water quality problems. The bottom of these types of pervious paving systems must be at least 2 feet above seasonal high water table or bedrock. This distance must be measured from the bottom of the storage bed as shown in Figures 9.7-1 and 9.7-2. The system bottom must be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

As discussed in *Considerations* below, construction of all pervious paving systems must be done without compacting the system's subgrade soils. As such, all excavation must be performed by equipment placed outside the system's limits whenever possible. This requirement should be considered when designing the dimensions and total volume of a system's broken stone storage bed or crushed stone base.

It is important to note that the use of both porous paving and permeable pavers with storage bed systems is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of such systems for larger storm events and the requirements by which such systems are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

Since permeable paver without storage bed systems do not rely on significant runoff infiltration, they may be used for all frequency storm events.

B. Permeability Rates

The minimum design permeability rate of the soils below porous and permeable paving systems with storage beds will depend upon the pervious paving system's location and maximum design storm. The use of storage beds for stormwater quality control is feasible only where the soil is sufficiently permeable to allow a reasonable rate of infiltration. Therefore, porous paving and permeable paver with storage bed systems can be constructed only in areas with Hydrologic Soil Group A and B soils.

For porous paving and permeable paver with storage bed systems, the minimum design permeability rate of the subgrade soils below a system's runoff storage bed is 0.5 inches per hour. In addition, the design permeability rate of the soils must be sufficient to fully drain the system's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See *A. Soil Characteristics* in *Considerations* below for more information. Since the actual permeability rate may vary from test results and may also decrease over time due to soil bed consolidation or the accumulation of sediments removed from the treated stormwater, a factor of safety of two must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soils is 4 inches/hour, the design rate would be 2 inches/hour (i.e., 4 inches per hour/2). This design rate would then be used to compute the system's maximum design storm drain time.

Due to its role as a runoff conveyance measure to the storage bed below, the porous surface course of a porous paving system must have a minimum permeability rate at least twice the maximum intensity of the

system's design storm. In the case of systems designed for the stormwater quality design storm, this permeability rate would be 6.4 inches per hour (i.e., 2 X 3.2 inches per hour, which is the stormwater quality design storm's maximum intensity). Similarly, the minimum permeability of the material used to fill the void spaces of a permeable paver with storage bed system must also meet this requirement. However, since the void spaces in a permeable paver system comprise only a portion of the entire system surface, this minimum rate must be multiplied by the ratio of the entire system surface area to the area of the void spaces. Therefore, the void space material in a permeable paver with storage bed system comprised of 20 percent void space must have a minimum permeability of 2 X (1.0/0.2) or 10 times the maximum design storm intensity. For such systems designed for the stormwater quality design storm, this rate would be 3.2 X 10 or 32 inches per hour.

Since a permeable paver without storage bed system does not rely on significant runoff infiltration, its use does not require a minimum subgrade soil or void space material permeability rate. However, as described below, its ability to reduce runoff rates and volumes below those produced by conventional paving will depend upon both of these system characteristics.

To allow pervious paving surface courses to achieve their design permeability rates, the maximum surface course slope of all pervious paving systems is 5 percent.

C. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a pervious paving system that receives runoff from areas other than its own surface course. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life and reduce the required maintenance of the system. This is usually accomplished through the use of a vegetative filter immediately upstream of the pervious paving system. Steps can also be taken during the system's design to limit the amount of runoff from upstream areas that will flow to the system.

Runoff collected from parking lots, driveway, roads, and other on-grade surfaces that is conveyed directly to a porous paving or permeable paver storage bed without passing through the system's surface course must be pretreated in order to prevent the loss of storage volume and/or recharge capacity due to sedimentation and clogging. Such pretreatment must provide 80 percent removal of TSS for the system's maximum design storm runoff. This treatment can also be used to meet the site's overall TSS removal requirements.

This pretreatment requirement does not apply to roofs and other above-grade surfaces. However, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to the system's storage bed should be included wherever practical to minimize the amount of sediment and other particulates that can enter the storage bed.

D. Computing Runoff Rates

In general, runoff to downstream areas from porous paving and permeable paver with storage bed systems will need to be computed under two circumstances. The first occurs when the capacity of the runoff storage bed is exceeded and the water level in the bed rises to the system's surface course. The second circumstance occurs when the intensity of precipitation exceeds the minimum permeability of the system's surface course. See *B. Permeability Rates* above for a discussion of these rates for each type of storage bed system. Once either or both of these circumstances occurs, the resultant system runoff rate to downstream areas for the remainder of the storm can be determined by subtracting the minimum system permeability rate from the rainfall rate. In the case of variable rate storm events such as the stormwater quality design storm or the NRCS Type III Storm, this must be done in a series of appropriate-length time increments over the remaining storm duration.

Runoff from permeable paver without storage bed systems must be computed for all storm events and can be performed by two methods. The first method is based upon a weighted average runoff coefficient (C) for the Rational or Modified Rational Methods or a weighted average Curve Number (CN) for the NRCS methodology. These values should be based upon the relative areas of the impervious pavers and pervious void spaces in the system's surface. The C or CN value for the paver area should be based upon an impervious surface, while the C or CN value for the void space should be based upon the type of material or surface cover in the void space and the Hydrologic Soil Group of the subgrade soil. In selecting this void space coefficient, all void spaces with vegetated covers should be assumed to be in poor hydrologic condition and all void spaces with bare soil or gravel fill should be based upon soil or gravel roadways.

The second method of computing runoff from permeable paver without storage bed systems considers the pavers to be unconnected impervious areas that drain onto the pervious void spaces. The resultant runoff from the system can then be based upon the unconnected impervious surface methods described in *Chapter 5*. In doing so, the criteria for selecting the appropriate CN for the void space must be based upon the criteria described in the preceding paragraph. In addition, it should be noted that the TR-55 method for unconnected impervious areas as described in *Chapter 5* cannot be used if the void space area is less than 70 percent of the total system area (i.e., the impervious portion of the entire system area exceeds 30 percent).

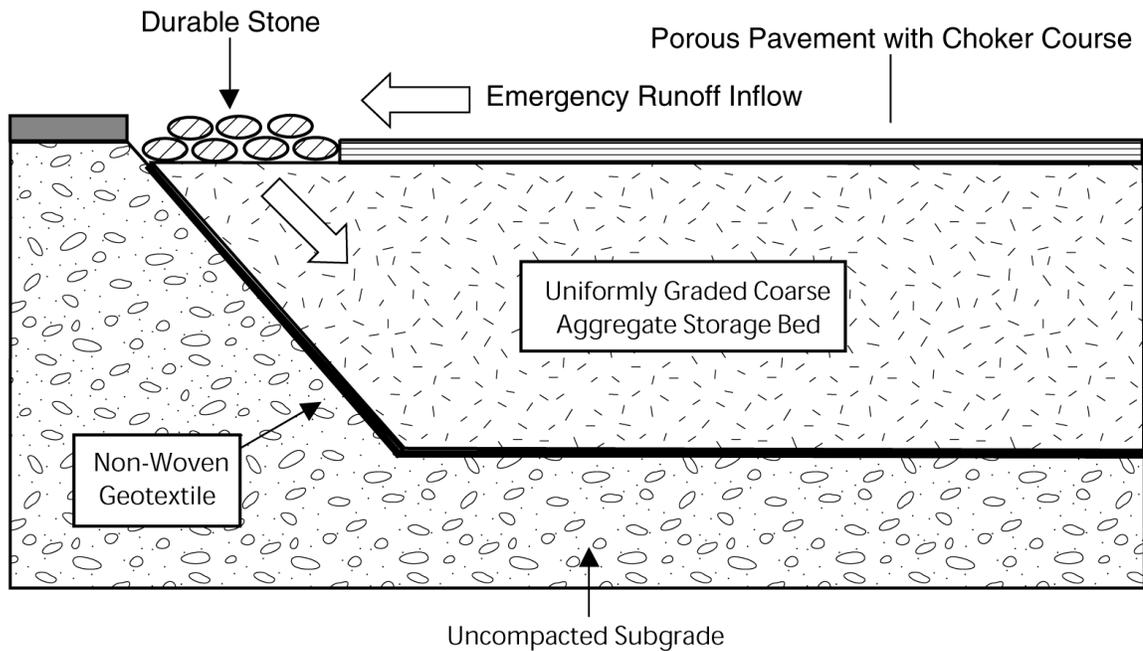
E. Overflows

All porous paving and permeable paver with storage bed systems must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. The downstream drainage system must have sufficient capacity to convey the overflow from the pervious paving system.

F. Emergency Inflows

All porous paving and permeable paver with storage bed systems must have measures that will allow runoff from the maximum design storm to enter the runoff storage bed in the event that the porous or permeable paver surface course becomes clogged or otherwise incapable of conveying the maximum design storm runoff to the bed. This may be accomplished in different ways, including surface drain inlets connected to a series of perforated pipes laid throughout the storage bed or by extending the storage bed beyond the edge of the surface course and connecting it to the surface as shown in Figure 9.7-4.

Figure 9.7-4: Example of Porous Paving Emergency Inflow



Note: Emergency inflow may also be provided by surface drain inlets and perforated pipes in the storage bed. See text for details.

Source: Cahill Associates.

G. System Components

The typical components of each type of pervious paving system are shown in Figures 9.7-1, 9.7-2 and 9.7-3. While variations are permissible based upon specific site conditions, the typical system components shown in these figures should be included in all system designs. This includes the sand and crushed stone base below a permeable paver without storage bed system shown in Figure 9.7-3. All such systems constructed without these components must be treated as conventional paved surfaces for the purpose of all runoff and pollutant load computations.

The recommended aggregate for porous asphalt and concrete paving systems are shown in Table 9.7-2. For porous asphalt systems, the recommended amount of asphalt binder is 5.75 to 6.00 percent by weight. Lower amounts of binder have resulted in inadequate surface course shear strength and durability. As shown in Figures 9.7-1 and 9.7-2, the runoff storage beds in both porous paving and permeable paver with storage bed systems should be clean washed, uniformly graded AASHTO No. 2 broken stone. It is particularly important that this stone be washed to keep stone dust and other fine particles that can clog the surface of the subgrade soils from entering the storage bed. The interface between the porous or permeable paver surface course and the storage bed stone should be leveled with a choker course of AASHTO No. 57 broken stone with a minimum thickness of 1 inch. Finally, as shown in Figures 9.7-1 and 9.7-2, the interface between the storage bed stone and the subgrade soil should be lined with a non-woven geotextile. Additional system details are shown in the figures.

Table 9.7-2 – Porous Asphalt Paving Mix

U.S. Standard Sieve Size	Percent Passing
1/2 inch	100%
3/8 inch	95%
#4	35%
#8	15%
#16	10%
#30	2%

Source: Cahill Associates

Maintenance

Effective pervious paving system performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures* contains information and requirements for preparing a maintenance plan for stormwater management facilities, including pervious paving systems. Specific maintenance requirements for all system types are presented below. These requirements must be included in the system's maintenance plan.

General Maintenance

The surface course of all pervious paving systems must be inspected for cracking, subsidence, spalling, deterioration, erosion, and the growth of unwanted vegetation at least once a year. Remedial measures must be taken as soon as practical.

Care must be taken when removing snow from the pervious paving surface courses. Pervious paving surface courses can be damaged by snow plows or loader buckets that are set too low to the ground. This is particularly true at permeable paver systems where differential settlement of pavers has occurred. Sand, grit, or cinders should not be used on pervious paving surface courses for snow or ice control.

If mud or sediment is tracked onto the surface course of a pervious paving system, it must be removed as soon as possible. Removal should take place when the surface course is thoroughly dry. Disposal of debris, trash, sediment, and other waste matter removed from pervious paving surface courses should be done at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

B. Porous Paving Systems

The surface course of a porous paving system must be vacuum swept at least four times a year. This should be followed by a high pressure hosing. All dislodged sediment and other particulate matter must be removed and properly disposed.

C. Permeable Paver Systems

Maintenance of permeable pavers should be consistent with the manufacturer's recommendations.

D. Vegetation

Mowing and/or trimming of turf grass used with permeable pavers must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. All vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the paver and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of a pervious paving system. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

E. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the pervious paving system's surface course. This normal drain time should then be used to evaluate the system's actual performance. If significant increases or decreases in the normal drain time are observed or if the 72 hour maximum is exceeded, the various system components and groundwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the system.

Considerations

Pervious paving systems can present some practical design problems, particularly those with subsurface runoff storage beds that rely on infiltration to discharge the stored runoff. When planning such systems, consideration should be given to soil characteristics, depth to the seasonal high groundwater table, sensitivity of the region, and runoff quality. Particular care must be taken when constructing all pervious paving systems in areas underlain by carbonate rocks known as Karst landscapes. See Appendix A10 of the Standards for Soil Erosion and Sediment Control in New Jersey for further guidance in Karst areas. Further considerations are presented below.

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for system planning purposes, the preliminary design of all pervious paving systems, and the final design of permeable paver without storage bed systems. However, for the final design and construction of porous paving and permeable paver with storage bed systems, soil tests are required at the exact location of a proposed system in order to confirm its ability to function properly without failure.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed system's storage bed. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the storage bed or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further subgrade soil requirements.

In addition, the results of a system's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed pervious paving system, to ensure reasonable data consistency. If significant differences exist between the system's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

Similar to other infiltration facilities, the construction of all pervious paver systems must follow certain procedures and sequences. Additional construction requirements are also required for specific systems due to their particular nature and components. Details are provided below.

1. All Pervious Paving Systems

For all pervious paving systems, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the pervious paving system should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During system construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the system's storage bed or base.

To help prevent subgrade soil contamination and clogging by sediment, system construction should be delayed until all other construction within its drainage area is completed and the drainage area stabilized. This delayed construction emphasizes the need, as described above, to cordon off the system area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of a pervious paving system area as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the system's storage bed or base. Accumulated sediment can then be removed without disturbing the subgrade soils at the system's bottom, which should be established only after all construction within the system's drainage area is completed and the drainage area stabilized.

If system construction cannot be delayed until its drainage area is stabilized, diversion berms or other suitable measures should be placed around the system's perimeter during all phases of construction to divert all runoff and sediment away from the system. These diversion measures should not be removed until all construction within the system's drainage area is completed and the drainage area stabilized.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of all pervious paving systems with the contractor.

2. Porous Paving Systems

Broken stone in runoff storage beds should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. In addition, the following construction requirements for porous asphalt paving systems are recommended by the USEPA:

- Paving temperature = 240° to 260° F.
- Minimum air temperature for paving = 50° F.
- Compact paving with one to two passes with 10-ton roller.
- No vehicular use for a minimum of two days after paving completed.

3. Permeable Paver Systems

Broken stone in runoff storage beds should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. In order to provide the runoff quantity and quality benefits described above in *Definition*, the subgrade soils below all permeable paver systems cannot be stabilized through compaction or with cement or other stabilizing agents that reduce the soils' permeability. All permeable paver systems constructed with such stabilization must be treated as conventional paved surfaces for the purpose of all runoff and pollutant load computations.

C. Runoff Quality

The quality of the runoff entering a porous paving or permeable paver with storage bed system is a primary consideration in determining whether such systems are advisable and, if so, in designing the systems themselves. The planning of such systems must consider which pollutants will be present in the runoff and whether these pollutants will degrade groundwater quality. Certain soils can have a limited capacity for the treatment of bacteria and the soluble forms of nitrogen, phosphorus, and other pollutants like road salts and pesticides. Such pollutants are either attenuated in the soil column or go directly to the water table. Unfortunately, the soils that normally have the highest and, therefore, most suitable permeability rates also have the least ability to treat such pollutants. As a result, pretreatment of soluble pollutants prior to entry into a pervious paving system's storage bed may be necessary in these soils. Pretreatment measures may include vegetated filter strips, bioretention systems (where the infiltration basin takes the place of the standard underdrain), and certain sand filters. Alternatively, the existing soil below the infiltration basin bottom may be augmented or replaced by soils with greater soluble pollutant removal rates.

Recommendations

A. Sensitivity of the Area

Since they rely on runoff infiltration, the planning of porous paving or permeable paver with storage bed systems should consider the geologic and ecological sensitivity of the proposed site. Sensitive areas include FW1 streams, areas near drinking water supply wells, and areas of high aquifer recharge. Such pervious paving systems should be sited at least 100 feet from a drinking water supply well. They should also be sited away from foundations to avoid seepage problems. Measures should be taken in areas of aquifer recharge to ensure good quality water is being infiltrated to protect groundwater supplies. Porous paving and permeable paver with storage bed systems should also be located away from septic systems to help prevent septic system failure and other adverse system interference.

References

- Adams, Michelle C.. May/June 2003. Porous Asphalt Pavement with Recharge Beds: 20 Years & Still Working. Stormwater, Volume 4, Number 3. Forester Communications. Santa Barbara, CA.
- American Society of Civil Engineers. 1992. Design and Construction of Urban Stormwater Management Systems.
- Boutiette, L. and C. Duerring. 1994. Nonpoint Source Management Manual – Publication No. 17356-500-500G/93-67-00. Commonwealth of Massachusetts, Department of Environmental Protection.
- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- James, W. March/April 2002. Green Roads: Research into Permeable Pavers. Stormwater, Volume 3, Number 2. Forester Communications. Santa Barbara, CA.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- Logsdon, A.D. February 2002. Permeable Pave Stones – Permitting Infiltration and Reducing Storm Water Runoff. CE News, Volume 14, Number 1. Mercor Media. Alpharetta, GA.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Pennsylvania Association of Conservation Districts and Pennsylvania Department of Environmental Protection. 1998. Pennsylvania Handbook of Best Management Practices for Developing Areas.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. 1995. Site Planning for Urban Stream Protection, Chapter 7 – Green Parking Lots. Metropolitan Washington Council of Governments. Published by the Center for Watershed Protection.
- U.S. Environmental Protection Agency. September 1999. Storm Water Technology Fact Sheet – Porous Pavement.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 9

Standard for Sand Filters

Definition

A sand filter consists of a forebay and underdrained sand bed. It can be configured as either a surface or subsurface facility. Runoff entering the sand filter is conveyed first through the forebay, which removes trash, debris, and coarse sediment, and then through the sand bed to an outlet pipe. Sand filters use solids settling, filtering, and adsorption processes to reduce pollutant concentrations in stormwater. The adopted TSS removal rate for sand filters is 80 percent.

Purpose

Sand filters are normally used to remove relatively large amounts of sediments, metals, hydrocarbons, and floatables from stormwater runoff.

Conditions Where Practice Applies

Sand filters are normally used in highly impervious areas with relatively high TSS, heavy metal, and hydrocarbon loadings such as roads, driveways, drive-up lanes, parking lots, and urban areas. However, due to their relatively high sediment removal capabilities, sand filters are not generally recommended in pervious drainage areas where high coarse sediment loads and organic material such as leaves can quickly clog the sand bed. Where such loadings cannot be avoided, pretreatment is recommended. Since sand filters can be located underground, they can also be used in areas with limited surface space.

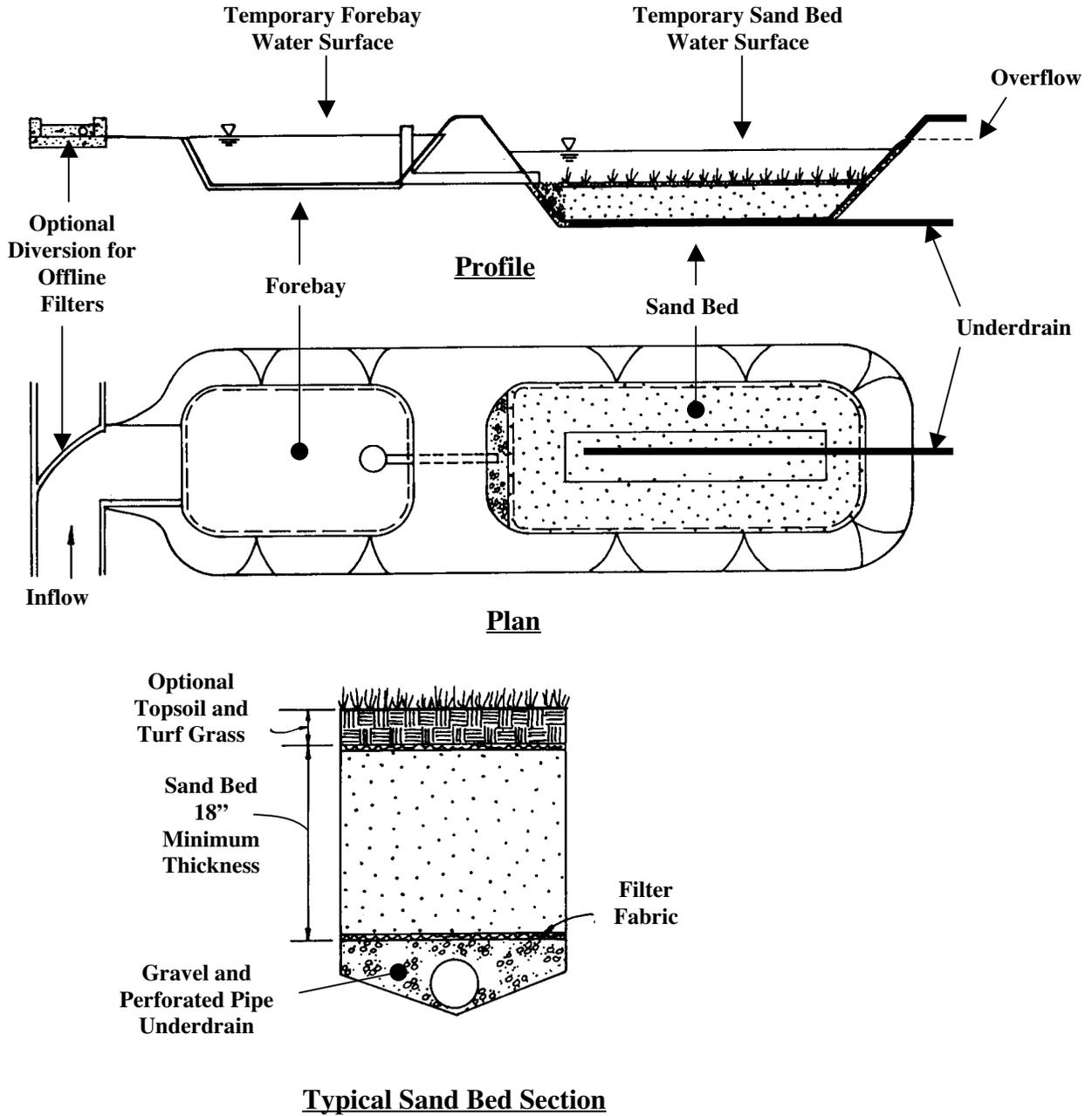
A sand filter must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

In general, all sand filters consist of four basic components or zones: 1) Forebay Zone, 2) Sand Bed Zone, 3) Sand Bed Underdrain, and 4) Overflow. These and other typical sand filter components are shown in Figures 9.9-1, 2, and 3. These figures depict, respectively, a surface, subsurface, and perimeter sand filter, which are the three sand filter types discussed in this manual.

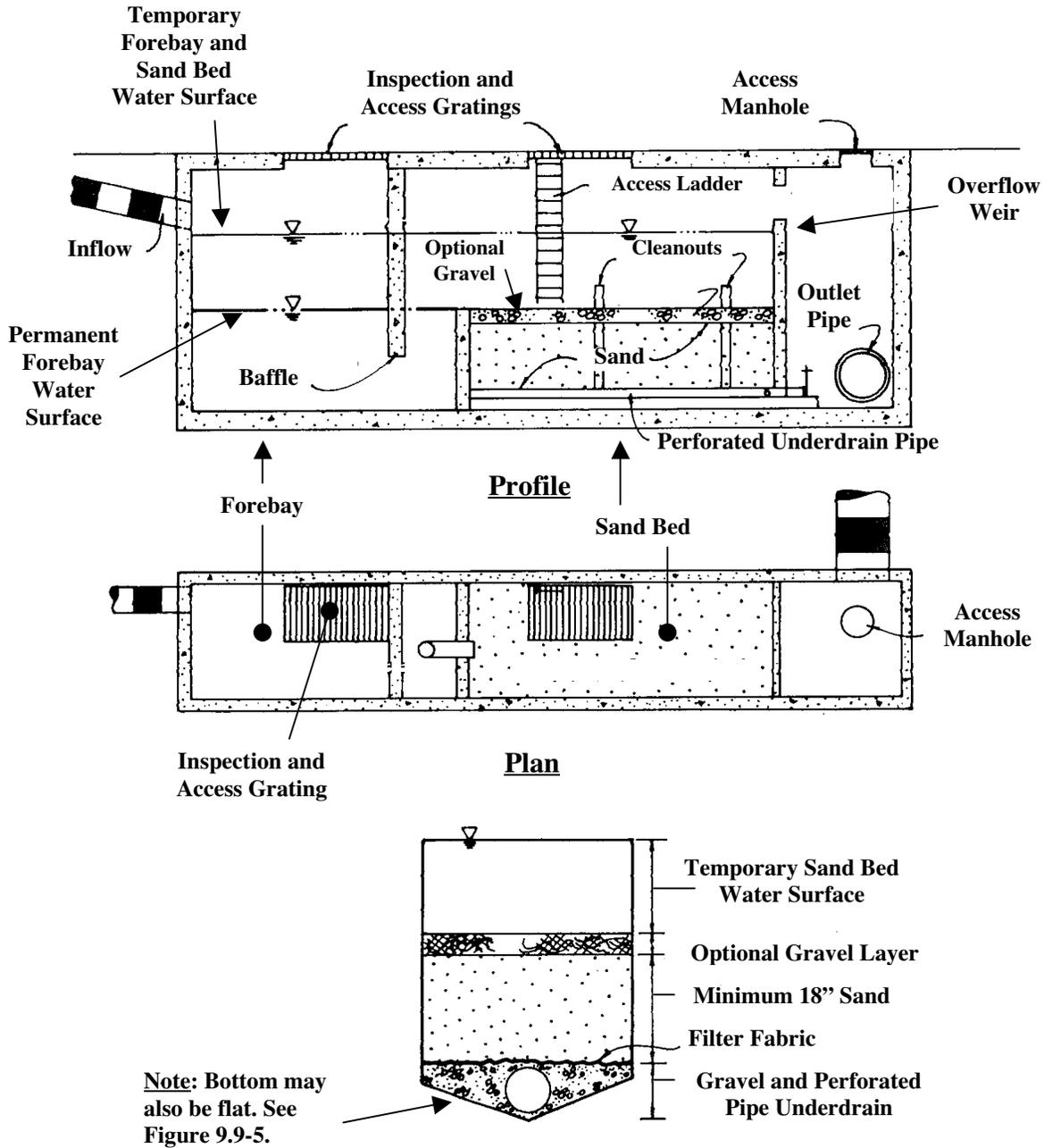
The basic design parameters for all three of these sand filter types are the surface areas and the temporary storage volumes in their forebay and sand bed zones and the thickness and infiltration rate of their sand beds. There must be sufficient total temporary storage volume within the forebay and sand bed zones (including the sand bed itself) to contain the design runoff volume and direct it through the sand bed without overflow. The thickness of the sand bed must provide adequate pollutant removal, while the bed's permeability or infiltration rate must be sufficient to drain the stored runoff within 72 hours. In addition, the capacity of the sand bed underdrain must allow the sand bed to drain freely, while the overflow must safely convey the runoff from storms greater than the design storm. Details of these and other design parameters are presented below.

Figure 9.9-1: Typical Surface Sand Filter Components



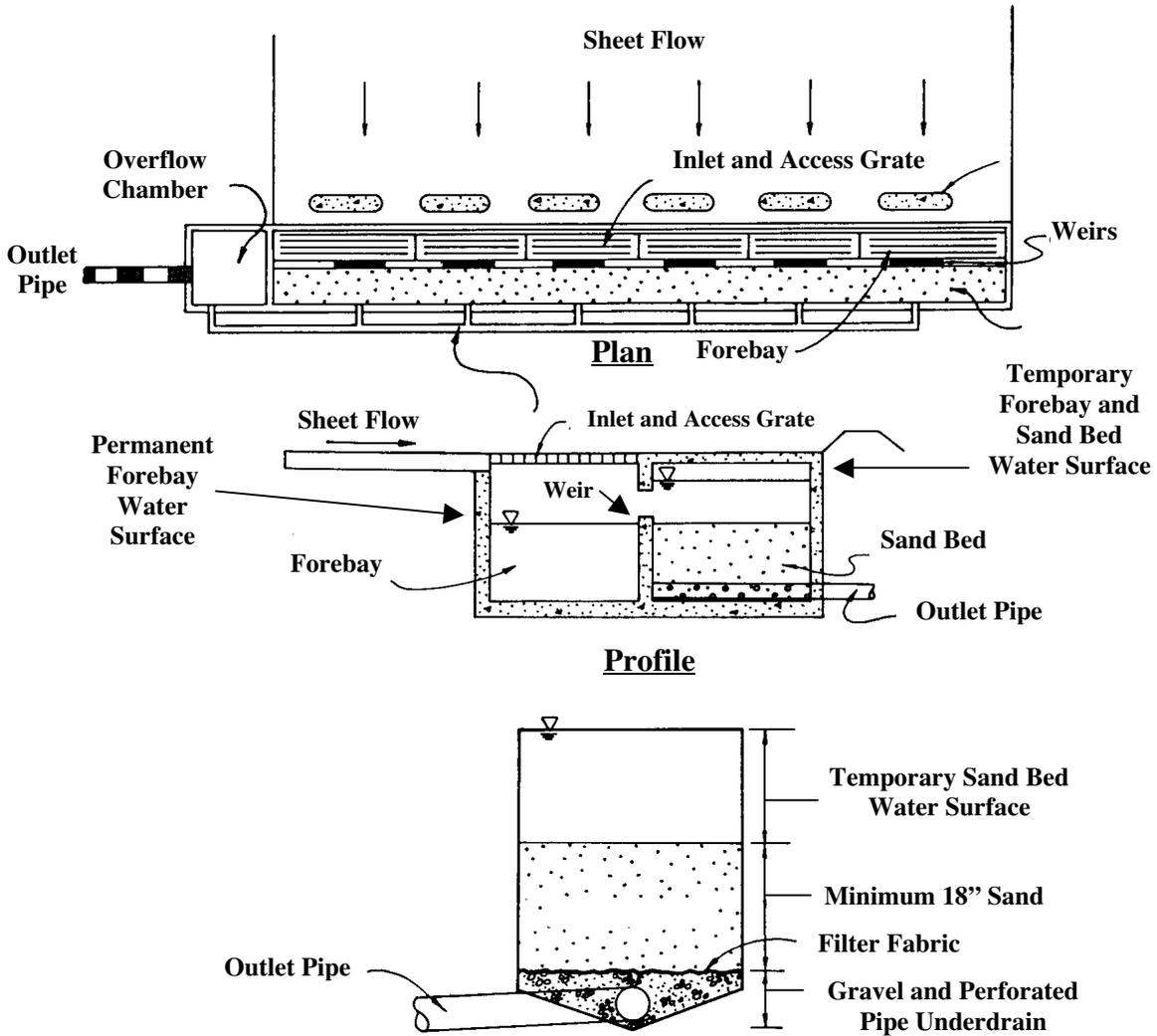
Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-2: Typical Subsurface Sand Filter Components



Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-3: Typical Perimeter Sand Filter Components



Typical Sand Bed Section

**Note: Bottom may also be flat.
See Figure 9.9-5.**

Source: Adapted from Claytor and Schueler, 1996.

A. Storage Volume and Duration

Sand filters must be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. The maximum time required to fully drain the stormwater quality design storm runoff volume is 72 hours. As shown in Table 9.9-1, a design drain time of 36 hours must be used when designing the sand bed.

B. Component Dimensions, Areas, and Volumes

The required volumes, areas, and dimensions of the various sand filter components are shown in Table 9.9-1. Several of these parameters are depicted in Figure 9.9-4.

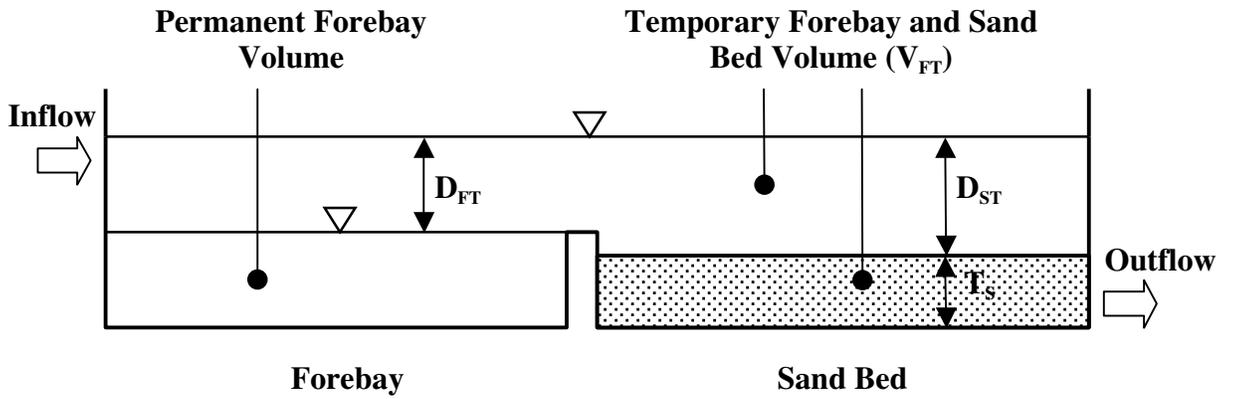
Table 9.9-1: Typical Sand Filter Design Parameters

#	Parameter Description	Parameter	Parameter Value		
			Surface Filter	Subsurface Filter	Perimeter Filter
1	Total Temporary Volume in Forebay and Sand Bed Zones ¹	V_{OS}	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume
2	Approximate Temporary Sand Bed Volume ²	V_{ST}	$(0.5)(V_{OS})$	$(0.5)(V_{OS})$	$(0.5)(V_{OS})$
3	Minimum Sand Bed Thickness	TH_S	18 Inches	18 Inches	18 Inches
4	Sand Bed Design Porosity	n	0.3	0.3	0.3
5	Sand Bed Design Permeability	k	4 Feet per Day	4 Feet per Day	4 Feet per Day
6	Sand Bed Design Drain Time	T_D	1.5 Days	1.5 Days	1.5 Days
7	Minimum Sand Bed Surface Area	A_S	See Equation 9.9-1	See Equation 9.9-1	See Equation 9.9-1
8	Approximate Temporary Forebay Volume ³	V_{FT}	$(0.5)(V_{OS})$	$(0.5)(V_{OS})$	$(0.5)(V_{OS})$
9	Minimum Forebay Surface Area	A_F	$(0.05)(V_{OS})$	$(0.05)(V_{OS})$	$(0.05)(V_{OS})$
10	Minimum Temporary Forebay Depth	D_{FT}	2 Feet	N/A	N/A
11	Minimum Permanent Forebay Depth	D_{FP}	N/A ⁴	2 Feet	2 Feet
12	Overall Minimum Length to Width Ratio	L/W	2	2	N/A

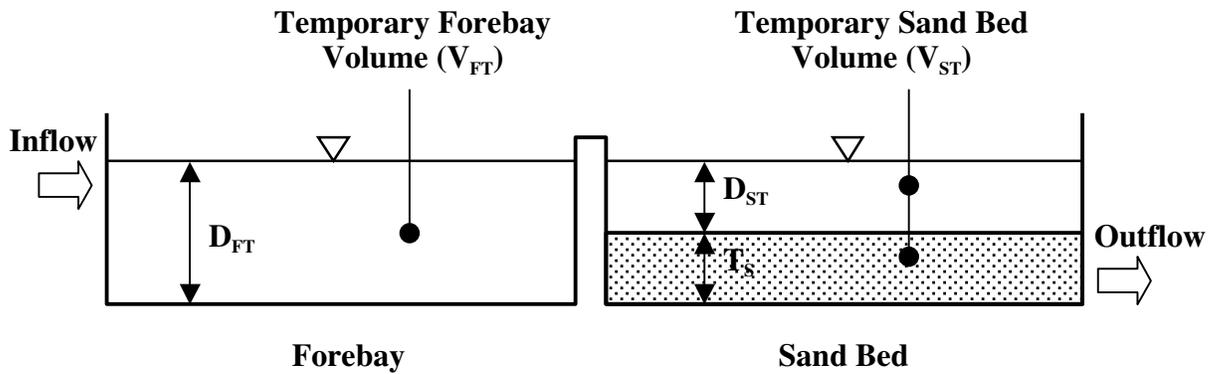
Notes:

1. Includes temporary storage volume in sand, but excludes storage volume in forebay permanent pool.
2. Includes temporary storage volume in sand.
3. Excludes storage volume in forebay permanent pool.
4. Forebay in surface sand filter typically does not have permanent pool.

Figure 9.9-4: Sand Filter Schematics



Schematic for Subsurface and Perimeter Sand Filters



Schematic for Surface Sand Filters

Source: Adapted from Claytor and Schueler, 1996.

C. General Design Procedure

Due to the number of design parameters, the design of a sand filter is generally a trial and error process to some degree. Utilizing the design parameters in Table 9.9-1 and the sand filter schematics shown in Figure 9.9-4, the general design procedure for sand filters is as follows:

1. Determine the runoff volume (V_{QS}) and peak discharge rate (Q_{QDS}) to the sand filter for the stormwater quality design storm. From Line 1 in Table 9.9-1, the total temporary storage volume in the sand filter's forebay and sand bed zones (including the storage volume within the sand bed, but excluding any permanent forebay storage volume) must equal V_{QS} .
2. Determine the approximate required volumes of the sand filter's forebay and sand bed zones. As shown on Lines 2 and 8 in Table 9.9-1, these volumes should each be approximately equal to one half of the stormwater quality design storm runoff volume (V_{QS}).
3. Estimate the maximum temporary depths in the sand bed (D_{ST}) and forebay (D_{FT}) zones for the stormwater quality design storm. This estimate should be based on an analysis of site conditions, including the difference between the invert elevation of the downstream conveyance system and the maximum ground elevation at the filter site. Analysis of this elevation difference should include consideration for the minimum sand bed thickness (TH_S) on Line 3 and either the minimum temporary forebay depth (D_{FT}) for surface filters on Line 10 or the permanent forebay depth (D_{FP}) for subsurface and perimeter filters on Line 11 of Table 9.9-1. As shown in Figure 9.9-4, the maximum temporary depth in the sand bed zone (D_{ST}) is measured from the top of the sand bed, while the maximum temporary forebay depth (D_{FT}) is measured from any permanent forebay water surface.
4. Compute the minimum forebay surface area (A_F). As shown on Line 9 of Table 9.9-1, this minimum area is $(0.05)(V_{QS})$. It should be noted that the 0.05 multiplier in the equation has the units of area per volume or L^2/L^3 . As such, the equation yields square feet of forebay area from cubic feet of stormwater quality design storm runoff volume.
5. From the maximum temporary depth in the forebay (D_{FT}) from Step 3 and the minimum forebay area (A_F) from Step 4, compute the total temporary storage volume in the forebay (V_{FT}). Compare this volume with the approximate required forebay volume computed in Step 2. Adjust the maximum temporary forebay depth (D_{FT}) and/or forebay area (A_F) as necessary to achieve a total temporary forebay storage volume (V_{FT}) as close as practical to the required forebay volume from Step 2. While adjusting the forebay surface area (A_F) by varying its length and width, remember that the forebay will be located immediately adjacent to the sand bed zone and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.
6. As shown on Line 7 of Table 9.9-1, compute the minimum sand bed surface area (A_S) using the following equation:

$$A_S = (V_{QS})(TH_S) / [(k)(D_{ST}/2 + TH_S)(T_D)] \quad \text{(Equation 9.9-1)}$$

Where:

A_S = Minimum Sand Bed Surface Area (in square feet)

V_{QS} = Runoff Volume from the Stormwater Quality Design Storm (in cubic feet)

TH_S = Thickness of Sand in Sand Bed (in feet)

k = Sand Bed Design Permeability (in feet per day)

D_{ST} = Maximum Temporary Sand Bed Depth (in feet)

T_D = Sand Bed Drain Time (in days)

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-1 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Permeability (k) = 4 feet per day
Sand Bed Design Drain Time = 1.5 days

7. Compute the total temporary storage volume in the sand bed zone (V_{ST}) from the following equation:

$$V_{ST} = (A_S)(D_{ST}) + (A_S)(TH_S)(n) \quad (\text{Equation 9.9-2})$$

Where:

V_{ST} = Temporary Sand Bed Storage Volume (in cubic feet)
 A_S = Sand Bed Surface Area (in square feet)
 D_{ST} = Maximum Temporary Sand Bed Depth (in feet)
 TH_S = Thickness of Sand in Sand Bed (in feet)
 n = Sand Bed Design Porosity

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-2 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Porosity (n) = 0.3

8. Compare the total temporary sand bed storage volume (V_{ST}) with the approximate required sand bed zone volume computed in Step 2. As shown on Line 2 of Table 9.9-1, this temporary sand bed storage volume should be approximately one half of the stormwater quality design storm runoff volume (V_{QS}). In addition, add the total temporary sand bed volume (V_{ST}) to the total temporary forebay storage volume (V_{FT}) to determine the total temporary storage volume in the sand filter. As shown on Line 1 of Table 9.9-1, this total temporary storage volume must equal the stormwater quality design storm runoff volume (V_{QS}). Adjust the maximum temporary sand bed depth (D_{ST}) and/or sand bed area (A_S) as necessary to achieve a total temporary sand bed storage volume (V_{ST}) as close as practical to the required sand bed volume from Step 2 and a total filter volume equal to V_{QS} . Once again, while adjusting the sand bed surface area (A_S) by varying its length and width, remember that the sand bed will be located immediately adjacent to the forebay and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.

D. Filter Bed Sand

The sand used in the sand bed must meet the specifications for clean medium aggregate concrete sand in accordance with AASHTO M-6 or ASTM C-33. This must be certified by a professional engineer licensed in the State of New Jersey.

E. Gravel Layer and Underdrain

The gravel layer serves as bedding material for the underdrain pipes. It must have sufficient thickness to provide a minimum of 2 inches of gravel above and below the pipes. It should consist of 0.5" to 1.5" clean broken stone or pea gravel (AASHTO M-43).

The underdrain piping must be rigid Schedule 40 PVC pipe in accordance with AASHTO M278. Perforated underdrain piping should have a minimum of 3/8-inch diameter perforations at 6-inch centers

with four perforations per annular row. The portion of drain piping beneath the sand bed must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. All joints must be secure and watertight. Cleanouts must be located at the upstream and downstream ends of the perforated section of the underdrain and extend to or above the surface of the sand bed. Additional cleanouts should be installed as needed.

The underdrain piping must connect to a downstream storm sewer manhole, catch basin, channel, swale, or ground surface at a location that is not subject to blockage by debris or sediment and is readily accessible for inspection and maintenance. Blind connections to downstream storm sewers are prohibited. To ensure proper system operation, the gravel layer and perforated underdrain piping must have infiltration rates at least twice as fast as the design infiltration rate of the sand bed.

Additional details of typical sand filter underdrains are shown in Figure 9.9-5.

F. Overflows

All sand filters must be able to safely convey overflows to downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Sand filters that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards. Overflow capacity can be provided by a hydraulic structure such as a weir or orifice, or a surface feature such as a swale or open channel, as filter location and site conditions allow.

G. Tailwater

The hydraulic design of the underdrain and overflow systems, as well as any stormwater quantity control outlets, must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-line and Off-line Systems

In general, most sand filters are constructed off-line. In off-line sand filters, most or all of the runoff from storms larger than the stormwater quality design storm bypass the filter through an upstream diversion. This not only reduces the size of the required filter overflow, but also reduces the filter's long-term pollutant loading and associated maintenance and the threat of erosion and scour caused by larger storm inflows. However, sand filters may also be constructed on-line. On-line filters receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an overflow. Multi-purpose on-line filters also store and attenuate these larger storms to provide runoff quantity control. In such filters, the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface.

Maintenance

Effective sand filter performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Practices* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including sand filters. Specific maintenance requirements for sand filters are presented below. These requirements must be included in the filter's maintenance plan.

A. General Maintenance

All sand filter components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include inlets and diversion structures, forebays, sand beds, and overflows.

Sediment removal should take place when all runoff has drained from the sand bed and the sand is reasonably dry. In addition, runoff should be drained or pumped from forebays with permanent pools before removing sediment. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

In surface sand filters with turf grass bottom surfaces, mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. The filter bottom must be inspected for unwanted underbrush and tree growth at least once a year.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the sand filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the top of the filter's sand bed. This normal drain or drawdown time should then be used to evaluate the filter's actual performance. If significant increases or decreases in the normal drain time are observed, the filter's sand bed, underdrain system, and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the filter.

The sand bed should be inspected at least twice annually. The infiltration rate of the sand bed material may also be retested. If the water fails to infiltrate 72 hours after the end of the stormwater quality design storm, corrective measures must be taken.

Considerations

A. Forebay and Sand Bed Drains

Wherever possible in subsurface and perimeter filters, a drain and valve should be provided in the forebay to permit draining of all standing water and facilitate sediment removal. This drain and valve can be connected to the sand bed underdrain system.

B. Drainage Area Stabilization

No runoff should enter the filter's sand bed until the upstream drainage area is completely stabilized and site construction is completed.

C. Watertight Construction

Underground sand filters should always be constructed completely watertight, especially if treating runoff from "hotspots" or over extremely sensitive groundwater areas.

D. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a sand filter. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filters and/or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

As shown in Figures 9.9-1, 9.9-2, and 9.9-3, forebays at the inflow points to sand filters can capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of filter maintenance. A forebay should be sized in accordance with Table 9.9-1 to hold the sediment volume expected between clean-outs.

References

- Claytor, R. and T. Schueler. December 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Ellicott City, MD.
- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 1 0

Standard for Vegetative Filters

Definition

A vegetative filter is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. The vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. It is important to note that all runoff to a vegetated filter strip must both enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's pollutant removal capabilities.

The total suspended solid (TSS) removal rate for vegetative filters will depend upon the vegetated cover in the filter strip. Table 9.10-1 below presents the adopted TSS removal rates for various vegetated covers.

Table 9.10-1: Adopted TSS Removal Rates for Vegetated Filter Strips

Vegetated Cover	Adopted TSS Removal Rate
Turf grass	60 %
Native Grasses, Meadow, and Planted Woods	70 %
Indigenous woods	80 %

For filter strips with multiple vegetated covers, the final TSS removal rate should be based upon a weighted average of the adopted rates shown above in Table 9.10-1. This weighted average removal rate should be based upon the relative flow lengths through each cover type. For example, a 50-foot long vegetated filter strip (measured in the direction of flow) that has turf grass in the upper 25 feet and native grasses in the lower 25 feet would have a TSS removal rate of $(25/50)(60\%) + (25/50)(70\%)$ or 65 percent.

Purpose

A vegetative filter is intended to remove pollutants from runoff flowing through it. Vegetated filter strips can be effective in reducing sediment and other solids and particulates, as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients. The pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake, and microbacterial activity.

Vegetated filter strips with planted or indigenous woods may also create shade along water bodies that lower aquatic temperatures, provide a source of detritus and large woody debris for fish and other aquatic organisms, and provide habitat and corridors for wildlife.

Condition Where Practice Applies

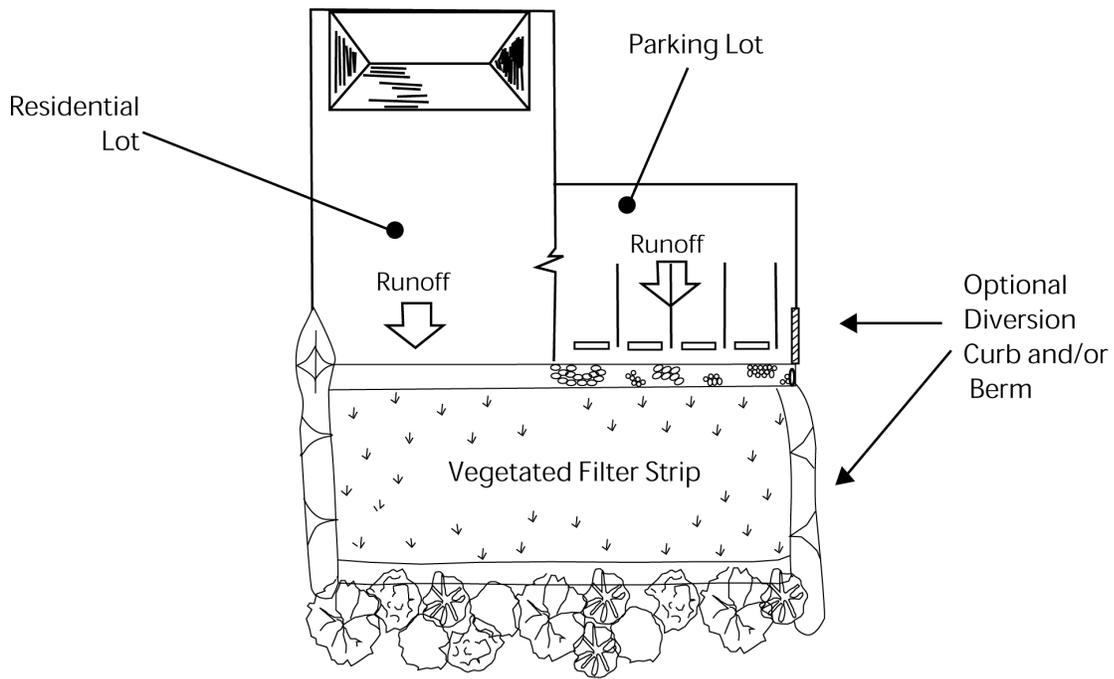
A vegetative filter can be effective only where the runoff entering and flowing through the strip remains as sheet flow and does not concentrate. This sheet flow requirement limits the use of vegetated filter strips in two ways. First, the area used for the filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. Second, since the runoff to a filter strip must enter the strip as sheet flow, the drainage area to the strip must also be uniformly graded and have a relatively horizontal downstream edge where it meets the upstream end of the filter strip. Such drainage areas may include yards, parking lots, and driveways where runoff flows as sheet flow. As a result, an area with irregular grading and other surface features that cause runoff to concentrate could neither be used as a vegetated filter strip nor have its runoff treated by one. For the same reasons, vegetated filter strips are also not intended to treat concentrated discharges from storm sewers, swales, and channels.

As detailed below in *Design Criteria*, additional factors must be considered. First, the vegetation in all filter strips must be dense and remain healthy and, in the case of planted or indigenous woods, have an effective mulch or duff layer. In addition, a vegetated filter strip must have a maintenance plan and be protected by an easement, deed restriction, or other legal measure that guarantees its existence and effectiveness in the future. Depending upon their TSS removal rate, vegetated filter strips can be used separately or in conjunction with other stormwater quality practices to achieve an overall pollutant removal goal.

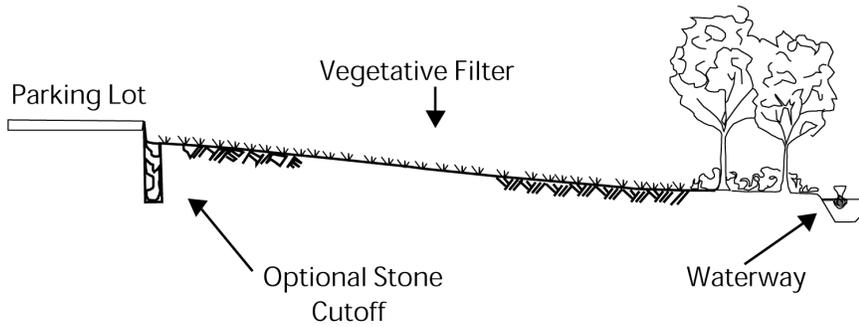
Design Criteria

The primary design parameters for a vegetated filter strip are its slope, type of vegetated cover, and the type of soils within its drainage area. These three parameters are then used to determine the standard filter strip length required to achieve the adopted TSS removal rates shown above in Table 9.10-1. In addition, since runoff from the stormwater quality design storm must enter and continue as sheet flow over this length, the peak runoff rate must be sufficiently low and uniformly distributed to ensure such conditions. This peak runoff rate is achieved by limiting the sheet flow length that runoff will flow before entering the filter strip. This length limitation, in turn, limits the size of the drainage area to the filter strip and, consequently, the peak runoff rate. Details of these and other design parameters are presented below. The components of a typical vegetated filter strip are shown in Figure 9.10-1.

Figure 9.10-1 Vegetative Filter Components



Plan View



Profile View

Source: Adapted from Schueler and Claytor 1996.

A. Drainage Area and Runoff Characteristics

As noted above, runoff from a drainage area may be directed to flow through a filter strip provided it enters the filter strip and continues through it as sheet flow. In addition, the peak rate and maximum depth of runoff entering the filter strip must be low enough to allow the strip's vegetated cover to serve as an effective filter. As such, the maximum drainage area to a vegetated filter strip will be limited to an area 100 feet long for impervious surfaces and 150 feet long for pervious surfaces. These lengths are to be measured in the direction of flow to the upstream edge of the filter strip.

In addition, the interface of the drainage area and the upstream edge of the filter strip must be as horizontal as possible (perpendicular to the flow direction) so that runoff will be evenly distributed along the upstream edge of the strip. As shown in Figure 9.10-1, a stone cutoff trench, recessed curb, or other measure may be used along the filter's upstream edge to help distribute the runoff and dissipate some of its energy as it enters the filter strip.

As noted above, the required strip lengths are based in part upon the type of soils within the filter strip's drainage area. Table 9.10-2 below lists the various types of soils and their associated Hydrologic Soil Groups that will affect the strip's required length. County Soil Surveys and onsite soil investigations can be used to determine these soil types. Where more than one type of soil exists in a drainage area, the soil with the smallest particle size (and, consequently, the longest filter strip length) should be used in the filter strip's design.

B. Filter Strip Cover

As noted above, the vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. The type of vegetation used in the filter strip can be very broad, although the best performance is associated with those with dense growth patterns such as turf-forming grasses and dense forest floor vegetation. All vegetation must be dense and healthy. In addition, planted woods must have a mulch layer with a minimum thickness of 3 inches, while indigenous woods must have at least a 1 inch thick natural duff layer.

Further information and references are presented in *Chapter 7: Landscaping*.

C. Filter Strip Grading

As noted above, the area used for a vegetated filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. As such, indigenous areas such as meadows and woods under consideration as vegetated filter strips should be surveyed and inspected during runoff events to determine runoff flow patterns. Indigenous areas with surface features that obstruct or retard runoff flow, cause ponding, and/or disperse runoff are acceptable, while those with surface features that cause runoff to concentrate are not. It should be noted that such observations must be made with consideration for the proposed volume and peak rate of runoff that the area would receive as a vegetated filter strip.

D. Maximum Filter Strip Slope

In addition to the soils within a vegetated filter strip's drainage area, the soils within the filter strip itself are also important for determining filter strip's maximum allowable slope. Table 9.10-2 below presents maximum filter strip slopes for various vegetated covers and soil types within the filter strip. County Soil Surveys and onsite soil investigations can be used to determine the soil type within a filter strip.

Table 9.10-2: Maximum Filter Strip Slope

Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Grasses, and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8

E. Required Filter Strip Length

To achieve the adopted TSS removal rates shown above in Table 9.10-1, the required filter strip length can be determined from Figures 9.10-2 to 6 below based upon the filter strip’s slope, vegetated cover, and the soil within its drainage area. As shown in the figures, the minimum length for all vegetated filter strips is 25 feet.

**Figure 9.10-2: Vegetated Filter Strip Length
Drainage Area Soil: Sand HSG: A**

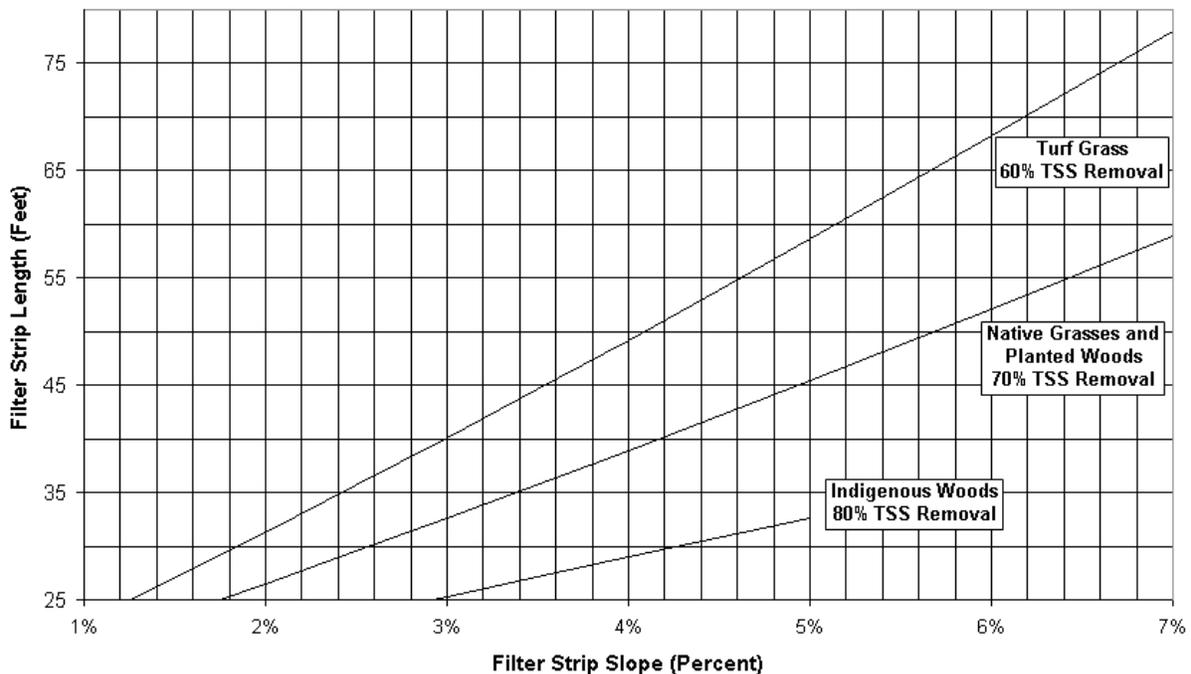


Figure 9.10-3: Vegetated Filter Strip Length
Drainage Area Soil: Sandy Loam HSG: B

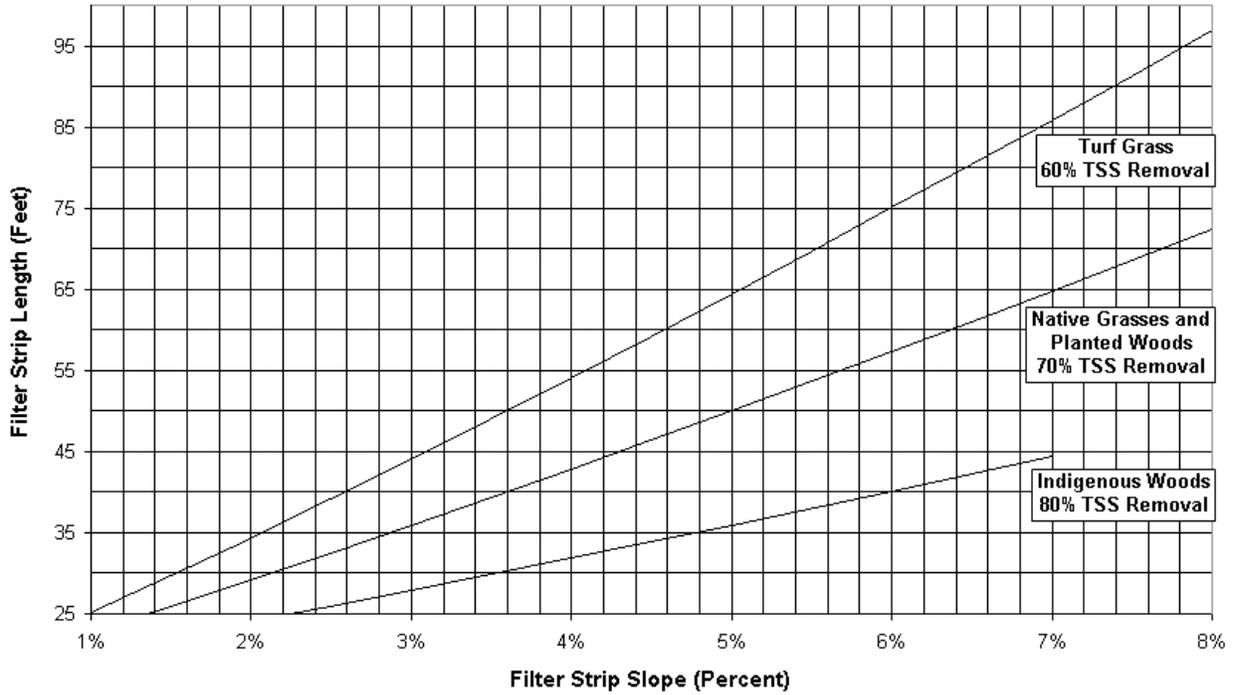


Figure 9.10-4: Vegetated Filter Strip Length
Drainage Area Soil: Loam, Silt Loam HSG: B

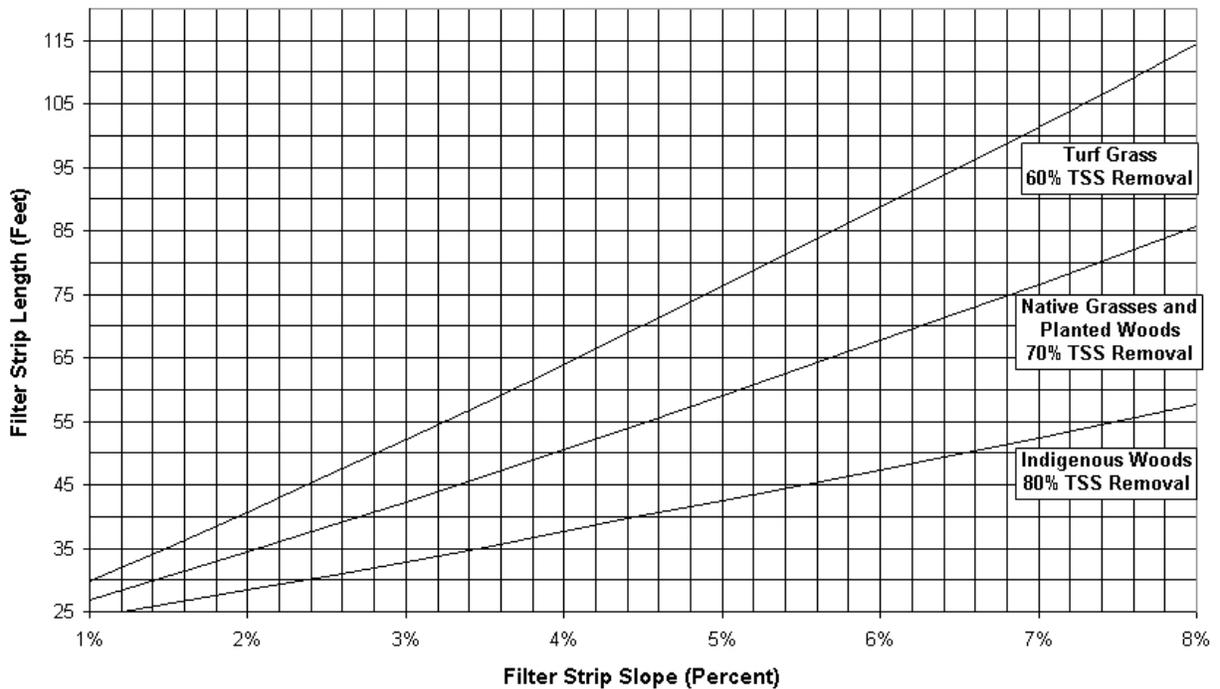


Figure 9.10-5: Vegetated Filter Strip Length
 Drainage Area Soil: Sandy Clay Loam HSG: C

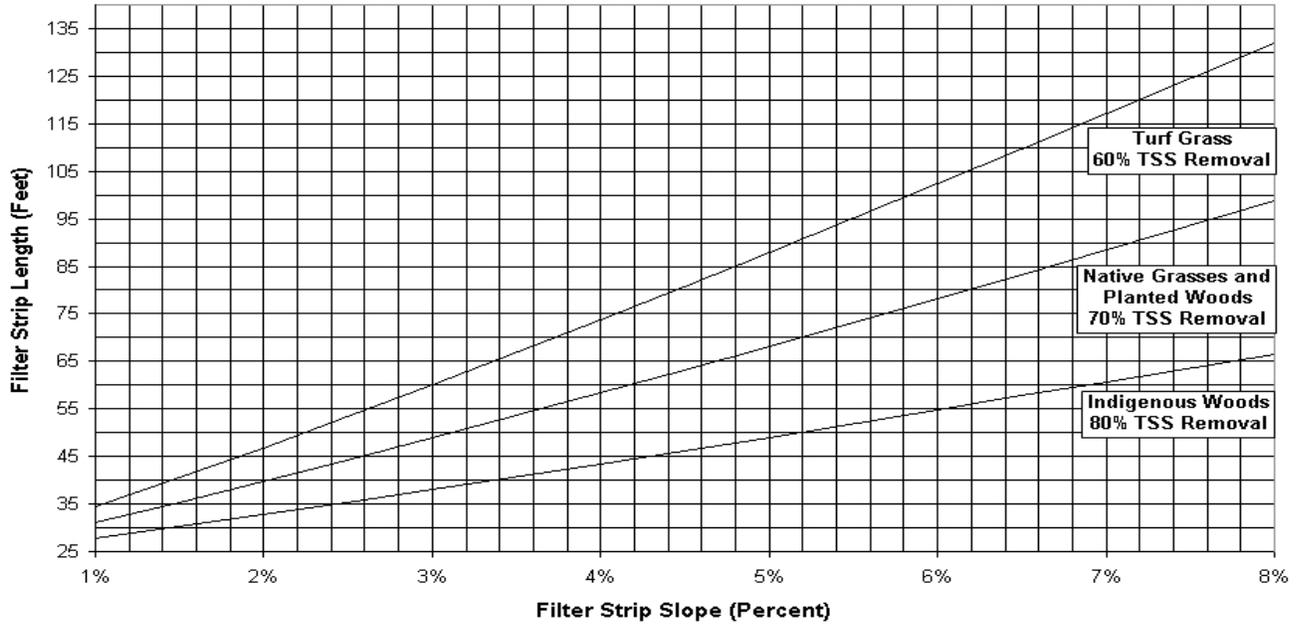


Figure 9.10-6: Vegetated Filter Strip Length
 Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D



Example 9.10-1: Computing Required Vegetated Filter Strip Length

A vegetated filter strip is to be installed at a uniform 5 percent slope to treat the runoff from a drainage area consisting of a paved parking lot and turf grass lawn. Runoff from the parking lot and lawn will enter the filter strip as sheet flow. The maximum sheet flow lengths across the parking lot and lawn do not exceed 100 and 150 feet, respectively. The soil in the drainage area is a silt loam. Compute the required filter strip length if the strip is to be vegetated with turf grass.

1. Determine the Hydrologic Soil Group of the drainage area soil. From Table 9.10-2, a silt loam is in Hydrologic Soil Group B.
2. Determine the maximum slope of the filter strip. Also from Table 9.10-2, the maximum slope of a turf grass filter strip with Hydrologic Soil Group B soils is 8 percent, which is greater than the 5 percent slope of the proposed filter strip.
3. Determine the required length of the filter strip. From Figure 9.10-4 for silt loam soils, the required length of a turf grass filter strip with a 5 percent slope is approximately 76 feet. The resultant TSS removal rate for the turf grass filter strip will be 60 percent.

Maintenance

Effective vegetated filter strip performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Practices* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including vegetated filter strips. Specific maintenance requirements for vegetated filter strips are presented below. These requirements must be included in the filter strip's maintenance plan.

A. General Maintenance

All vegetated filter strip components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding 1 inch of rainfall. Such components may include vegetated areas and stone cutoffs and, in particular, the upstream edge of the filter strip where coarse sediment and/or debris accumulation could cause inflow to concentrate.

Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. The vegetative cover should be maintained at 85 percent. If

vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs.

C. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take for the filter strip to drain the maximum design storm runoff volume and begin to dry. This normal drain time should then be used to evaluate the filter's actual performance. If significant increases or decreases in the normal drain time are observed or if the 72 hour maximum is exceeded, the filter strip's planting soil bed, vegetation, and groundwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the filter strip.

Considerations

A number of factors should be considered when utilizing a vegetated filter strip to treat stormwater runoff. Most importantly, an adequate filter area and length of flow must be provided to achieve the desired treatment. Slopes of less than 5 percent are more effective; steeper slopes require a greater area and length of flow to achieve the same effectiveness. Good surface and subsurface drainage is necessary to ensure satisfactory performance. The designer should also be aware of potential ponding factors during the planning stage. Dry period between flows should be achieved in order to reestablish aerobic soil conditions.

Filter strip vegetation must be fully established before incoming stormwater flow is allowed. At least one full growing season should have elapsed prior to strip functioning as part of the stormwater management system. Further information and references on filter strip vegetation are presented in *Chapter 7*. Species must be appropriate for the region, soil, and shade condition. Mulching is required for both seeded and planted filter strips.

Perhaps the most common, naturally occurring filter strips are those upland vegetative stands associated with floodplains or found adjacent to natural watercourses. In some cases, preservation of these upland areas will allow them to continue to function as filter strips. To help ensure the longevity of these natural areas under altered and perhaps increased pollutant loading, a top dressing of fertilizer and supplemental plantings may be necessary.

References

- Abu-Zreig, M. October 2000. Factors Affecting Sediment Trapping in Vegetated Filter Strips: Simulation Study Using VFSSMOD. *Hydrological Processes*, Volume 15, 1477–1488.
- Abu-Zreig, M., R.P. Rudra, and H.R. Whiteley. 2001. Validation of a Vegetated Filter Strip Model (VFSSMOD). *Hydrological Processes* 15, 729-742.
- Castelle, A.J. and Johnson, A.W. February 2000. Riparian Vegetation Effectiveness – Technical Bulletin No. 799. National Council for Air and Stream Improvement.
- Claytor, R. and T. Schueler. December 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Ellicott City, MD.
- Desbonnet, A., P. Pogue, V. Lee and N. Wolff. July 1994. Vegetated Buffers in the Coastal Zone. Coastal Resources Center. University of Rhode Island.
- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- McCuen, R.H. and S.L. Wong. 1982. The Design of Vegetative Buffer Strips for Runoff and Sediment Control. Maryland Department of Natural Resources.
- Munoz-Carpena, R., J.E. Parsons, and J.W. Gilliam. 1999. Modeling Hydrology and Sediment Transport in Vegetative Filter Strips. *Journal of Hydrology* 214 111-129.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Tollner, E.W., B.J. Barfield, C.T. Hann and T.Y. Kao. 1976. Suspended Sediment Filtration Capacity of Simulated Vegetation. *Transactions of the ASAE*. 10(11). pp. 678-682.
- Walsh, P.M., M.E. Barrett, J.F. Malina and R.J. Charbeneau. October 1997. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. University of Texas at Austin.
- Wenger, S. A. March 1999. Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation. Institute of Ecology. University of Georgia.

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 1 1

Standard for Wet Ponds

Definition

A wet pond is a stormwater facility constructed through filling and/or excavation that provides both permanent and temporary storage of stormwater runoff. It has an outlet structure that creates a permanent pool and detains and attenuates runoff inflows and promotes the settlement of pollutants. A wet pond, also known as a retention basin, can also be designed as a multi-stage facility that also provides extended detention for enhanced stormwater quality design storm treatment and runoff storage and attenuation for stormwater quantity management. The adopted TSS removal rate for wet ponds is 50 to 90 percent depending on the permanent pool storage volume in the pond and, where extended detention is also provided, the duration of detention time provided in the pond.

Purpose

Wet ponds are used to address both the stormwater quantity and quality impacts of land development. A wet pond's permanent pool can retain runoff from the stormwater quality design storm, thereby promoting pollutant removal through sedimentation and biological processing. The permanent pool can also protect deposited sediments from resuspension. Higher stages in the basin can also be used to provide additional stormwater quality treatment through extended detention and/or attenuate the peak rates of runoff from larger storms through the use of multi-stage outlets for flood and erosion control. Wet ponds can also provide aesthetic and recreational benefits as well as water supply for fire protection and/or irrigation.

Conditions Where Practice Applies

Wet ponds require sufficient drainage area and, in turn, dry weather or base flow to maintain the volume and environmental quality of the permanent pool. Therefore, the minimum drainage area to a wet pond must be 20 acres.

Wet ponds should not be located within the limits of natural ponds or wetlands, since they will typically not have the full range of ecological functions as these natural facilities. While providing some habitat and aesthetic values, wet ponds are designed primarily for pollutant removal and erosion and flood control.

It is important to note that a wet pond must be able to maintain its permanent pool level. If the soil at the site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary.

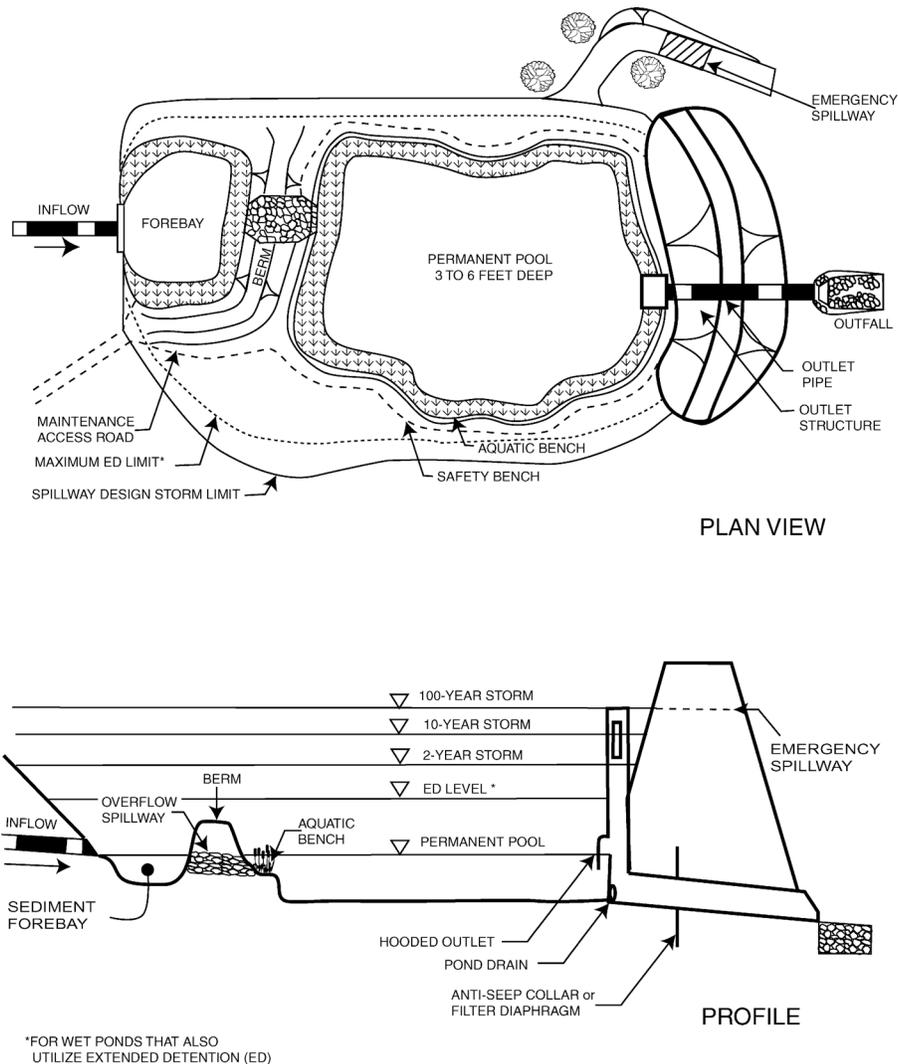
Wet ponds may be limited by the potential for discharge water to be heated in the permanent pool during summer months and should not be used if the receiving waters are ecologically sensitive to temperature change.

Finally, a wet pond must also have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The basic design parameter for a wet pond is the ratio of its permanent pool volume to the volume of runoff entering the pond. This ratio is used to determine the pond's TSS removal rate. This removal rate can be increased if extended detention storage is also provided above the permanent pool level. Details of these and other design parameters are presented below and summarized in Table 9.11-1. The components of a typical wet pond both with and without extended detention are shown in Figure 9.11-1.

Figure 9.11-1: Wet Pond Components



Source: Adapted from Schueler and Claytor 2000.

A. Storage Volumes

Wet ponds should be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. The resultant TSS removal rate for a wet pond will depend on the ratio of its permanent pool volume to the stormwater quality design storm runoff volume. Figure 9.11-2 presents the range of approved TSS removal rates for various permanent pool to runoff volume ratios. As can be seen in the figure, the minimum required permanent pool volume in a wet pond is equal to the stormwater quality design storm runoff volume to the pond. At this 1:1 volume ratio, a wet pond would have a TSS removal rate of 50 percent. This removal rate increases to 80 percent for wet ponds with permanent pool volumes that are three times the stormwater quality design storm runoff volume (i.e., volume ratio of 3:1).

Also shown in Figure 9.11-2 are TSS removal rates in wet ponds that also provide extended detention above the permanent pool water surface. As shown in Figure 9.2-2, a wet pond with a permanent pool to runoff volume ratio of 3:1 that also provides 24 hours of extended detention would have a TSS removal rate of 90 percent. TSS removal rates for other combinations of permanent pool to runoff volume ratios for extended detention times of 12 and 18 hours are also shown in Figure 9.11-2. Definitions and details of extended detention are presented in Section 9.4: Extended Detention Basins.

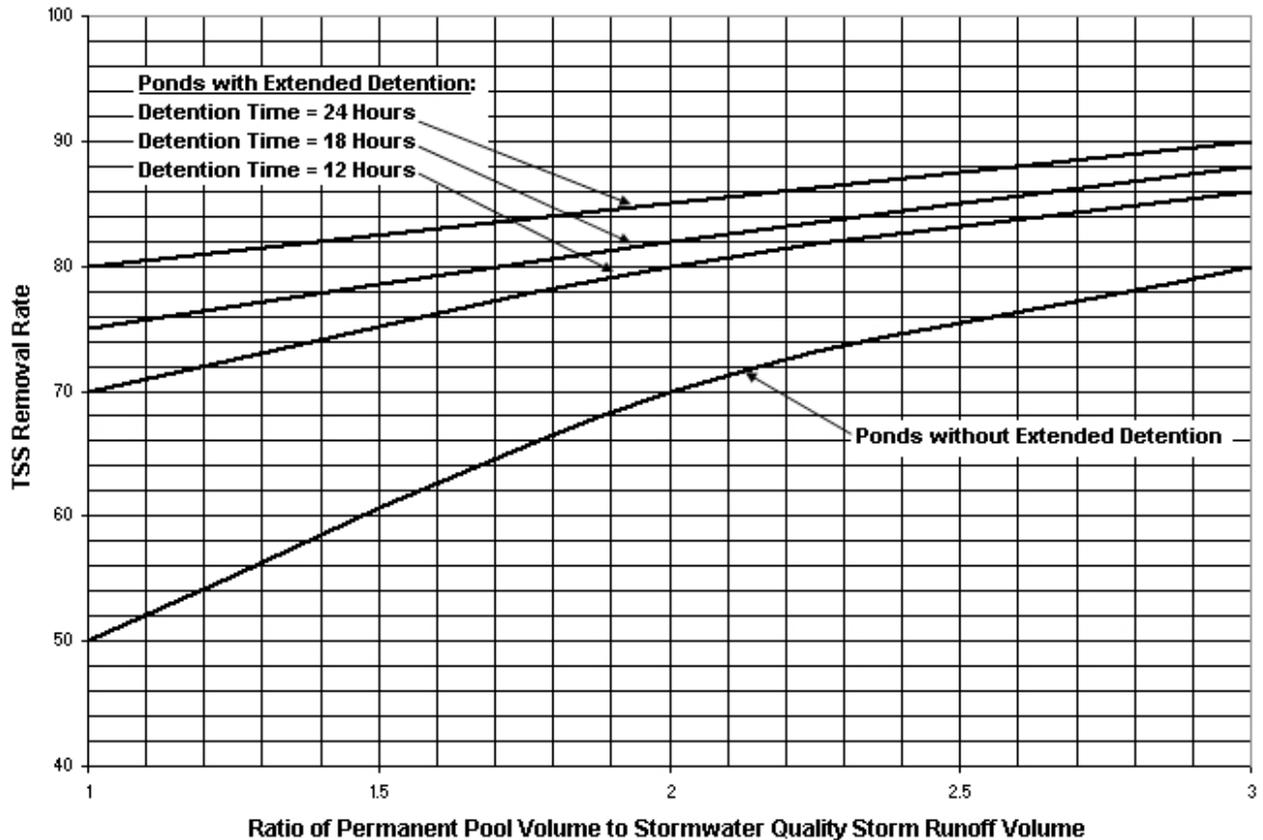
B. Permanent Pool Depth

The depth of a wet pond's permanent pool is an important design parameter. The permanent pool should be shallow enough to avoid thermal stratification and deep enough to minimize algal blooms and resuspension of previously deposited materials by subsequent storms and strong winds. Prevention of thermal stratification will minimize short-circuiting and maintain aerobic bottom waters, thus maximizing pollutant uptake and minimizing the potential release of nutrients to the overlying waters. The mean depth of the permanent pool is obtained by dividing the storage volume by the pool surface area. A mean depth of three to six feet is normally sufficient to maintain a healthy environment within the permanent pool. The outlet structure or riser should be located in a relative deep area to facilitate withdrawal of cold bottom water to help mitigate any downstream thermal impacts. If maintained at the recommended three to six foot depth, the permanent pool can better serve as an aquatic habitat.

C. Permanent Pool Surface Area

The surface area of a wet pond's permanent pool is also an important design parameter as it directly affects the settling rate of particulate solids in the runoff to the pond. The surface area of a permanent pool will depend on site topography, minimum and maximum pool depths, and the desired settling rate. The minimum permanent pool surface area is 0.25 acres.

Figure 9.11-2: TSS Removal Rates for Wet Ponds



D. Drainage Area Size

As noted above, wet ponds require sufficient drainage area and dry weather base flow to function properly. A reliable base flow must be available to maintain the volume and quality of the permanent pool. Therefore, the minimum drainage area to a wet pond is 20 acres. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater inflow is available.

E. Pond Configuration

The length to width ratio of a wet pond should be as large as possible to simulate conditions found in plug flow reaction kinetics. Under ideal plug flow conditions, a plug or pulse of runoff enters a pond and is treated by chemical reactions as well as the physical processes of dispersion and settlement as the pulse travels the length of the wet pond. Therefore, the pond's length to width should be at least 3:1 to maximize these treatment processes. In cases where it is impractical to construct wet ponds with these lengths, internal baffles or berms may be added within the pond to increase the travel length and residence time.

F. Safety Ledges

Safety ledges must be constructed on the slopes of all wet ponds with a permanent pool deeper than three feet. Two ledges must be constructed, each 4 to 6 feet in width. The first or upper ledge must be located between 1 and 1.5 feet above the permanent pool level. The second or lower ledge must be located approximately 2.5 feet below the permanent pool level.

G. Outlet Structure

The riser structure should be equipped with a bottom drain pipe, sized to drain the permanent pool within 40 hours so that sediments may be removed mechanically when necessary. The drain pipe should be controlled by a lockable valve that is readily accessible from the top of the outlet structure. Additional information regarding outlet structures can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

H. Overflows

All wet ponds must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Wet ponds that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards, including safe conveyance of the wet pond's spillway design storm.

I. Tailwater

The hydraulic design of the outlet structure, outlet pipe, and emergency spillway in a wet pond must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the permanent pool level is below the flood hazard area design flood elevation of the receiving stream.

J. Other Components

Information regarding embankments, emergency spillways, bottom and side slopes, trash racks, conduit outlet protection, and vegetative cover can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

Table 9.11-1: Summary of Design Parameters

Design Parameter
Minimum Permanent Pool Volume = Stormwater Quality Design Storm Runoff Volume
Mean Permanent Pool Depth = 3 to 6 Feet
Minimum Permanent Pool Surface Area = 0.25 Acres
Minimum Drainage Area Size = 20 Acres
Maximum Permanent Pool Drain Time = 40 Hours
Recommended Minimum Pool Length to Width Ratio = 3:1

Maintenance

Effective wet pond performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Practices* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including wet ponds. Specific maintenance requirements for wet ponds are presented below. These requirements must be included in the pond's maintenance plan.

A. General Maintenance

All wet pond components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding one inch of rainfall. The primary location for debris and particularly sediment accumulation will be within a wet pond's permanent pool. Additional components may include forebays, inflow points, trash racks, outlet structures, and riprap or gabion aprons.

Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state and federal waste regulations.

Studies have shown that readily visible stormwater management facilities like wet ponds receive more frequent and thorough maintenance than those in less visible, more remote locations. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density and diversity should be performed at least twice annually during both the growing and non-growing season. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to ensure optimum vegetation health must not compromise the intended purpose of the wet pond. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion and deterioration at least annually. All outlet valves are to be inspected and exercised at least four times annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to completely drain the maximum design storm runoff volume and return the pond to its permanent pool level. This normal drain time should then be used to evaluate the pond's actual performance. If significant increases or decreases in the normal drain time are observed, the pond's outlet structure and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements.

Considerations

A. Permanent Pools

The primary component of a wet pond is its permanent pool. To maintain water quality, oxygen levels, control mosquito breeding, and prevent stagnation, an adequate and regular inflow of surface and/or ground water is necessary. Where sufficient oxygen levels and mixing will be difficult to achieve, a fountain or aerator may be included. However, such conditions may be indicative of larger site suitability problems that must be thoroughly investigated before a wet pond is selected for use at a land development site. The potential effects of sediment loading on the permanent pool must also be considered when determining whether a site is suitable for a wet pond. The use of existing lakes and ponds as wet ponds for treatment of stormwater is prohibited.

A well-designed wet pond will accumulate considerable quantities of sediment. The cleanout cycle for a wet pond in a stabilized watershed can vary, with an average cycle of approximately 10 years. Sediment removal at each cycle may cost as much as 20 to 40 percent of the initial construction cost. It should be noted that the exact cleanout cycle and cost will depend on the specific character of the wet pond and its watershed. Therefore, periodic inspections of sediment accumulation in a wet pond are vital to determining how often and how much sediment must be removed. See *Maintenance* above for more information.

In cases where relatively permeable soils are encountered, the risk of seepage losses may be minimized by installing a clay or synthetic liner along the bottom of the pond.

B. Thermal Effects

Thermal effects of the wet pond must be considered since the permanent pool can act as a heat sink between storm events during hot weather. When the water is displaced from the pool, it may be as much as 10 degrees Fahrenheit warmer than the naturally occurring baseflow in the downstream waterway. Runoff to wet ponds from large impervious surfaces can also significantly raise the temperature of runoff during hot weather. The net result of elevated pool temperatures may have an adverse impact on downstream coldwater uses such as trout production.

Therefore, wet pond designers should pay special attention to the potential of thermal effects on downstream water bodies supporting cold water fisheries. Thermal impacts of wet ponds in such areas may be mitigated by:

- Using a deep permanent pool and positioning the outlet pipe to discharge the relatively colder water from near the bottom;
- Planting shade trees on the periphery of the pool to reduce solar warming; and
- Employing a series of pools in sequence rather than a single one.

C. Vegetation

Aquatic vegetation plays an important role in the pollutant removal dynamics of a wet pond. Soluble pollutants, especially nutrients, are removed through biological assimilation by both phytoplankton and macrophytes. Wetland plants can help keep algal proliferation in check by limiting the amount of nutrients available to the phytoplankton. In addition, an organically enriched wetland substrate will provide an ideal environment for bacterial populations to metabolize organic matter and nutrients. Aquatic vegetation may also aid in the regulation of pond water temperature.

Marsh vegetation can also enhance the appearance of the wet pond, stabilize the side-slopes, serve as wildlife habitat, and temporarily conceal unsightly trash and debris. As such, a wet pond may be designed to promote dense growth of appropriate wetland plant species along the banks. A 10 to 15 foot wide wetland vegetation bench starting one foot below the pool surface may be established along the perimeter of the pond. Water tolerant species of vegetative cover for wet pond surfaces should be used. To promote lasting growth, grasses and other vegetative covers should be compatible with prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. An adequate depth of topsoil should be provided below all vegetative covers in uplands. A minimum thickness of six inches is recommended.

D. Designing for Pollutant Removal

Two alternative approaches may be used to design wet pond pollutant removal. The first approach is based on solids settling and assumes that all pollutant removal within the pond occurs due to sedimentation. The Design Criteria section above is based primarily on this approach. The second approach treats the wet pond as a lake with controlled levels of eutrophication to account for the biological and physical/chemical processes that are principal mechanisms for pollutant removal. Both approaches relate the pollutant removal efficiencies to hydraulic residence time.

Design approach should be selected based on the target pollutants as well as site and economic constraints. The controlled eutrophication approach requires longer residence times and larger storage volumes comparable to those of the solids settling approach. However, where the chief concern is to control nutrient levels in waters such as lakes and reservoirs, it is advantageous to use the controlled eutrophication approach. If the major goal is the removal of a broad spectrum of pollutants, especially those adsorbed onto suspended matter (as discussed in *Chapter 4: Stormwater Pollutant Removal Criteria*), it is generally preferable to base the design on the sedimentation approach.

E. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a wet pond. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filters and/or a manufactured treatment device. Information on vegetated filter strips and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

As shown in Figure 9.11-1, forebays at the inflow points to a wet pond can capture coarse sediments, trash and debris, which can simplify and reduce the frequency of pond maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

References

- Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.
- Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.
- Maryland Department of the Environment. 2000. Maryland Stormwater Design Manual – Volume I – Stormwater Management Criteria. Water Management Administration. Baltimore, MD.
- New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.
- New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.
- Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.
- Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R., P.A. Kumble and M. Heraty. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.
- Schueler, T.R. and R.A. Claytor. 2000. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

New Jersey Stormwater Best Management Practices Manual

February 2004

A P P E N D I X A

Low Impact Development Checklist

A checklist for identifying nonstructural stormwater management strategies incorporated into proposed land development

According to the NJDEP Stormwater Management Rules at N.J.A.C. 7:8, the groundwater recharge, stormwater quality, and stormwater quantity standards established by the Rules for major land development projects must be met by incorporating nine specific nonstructural stormwater management strategies into the project's design to the maximum extent practicable.

To accomplish this, the Rules require an applicant seeking land development approval from a regulatory board or agency to identify those nonstructural strategies that have been incorporated into the project's design. In addition, if an applicant contends that it is not feasible to incorporate any of the specific strategies into the project's design, particularly for engineering, environmental, or safety reasons, the Rules further require that the applicant provide a basis for that contention.

This checklist has been prepared to assist applicants, site designers, and regulatory boards and agencies in ensuring that the nonstructural stormwater management requirements of the Rules are met. It provides an applicant with a means to identify both the nonstructural strategies incorporated into the development's design and the specific low impact development BMPs (LID-BMPs) that have been used to do so. It can also help an applicant explain the engineering, environmental, and/or safety reasons that a specific nonstructural strategy could not be incorporated into the development's design.

The checklist can also assist municipalities and other land development review agencies in the development of specific requirements for both nonstructural strategies and LID-BMPs in zoning and/or land use ordinances and regulations. As such, where requirements consistent with the Rules have been adopted, they may supersede this checklist.

Finally, the checklist can be used during a pre-design meeting between an applicant and pertinent review personnel to discuss local nonstructural strategies and LID-BMPs requirements in order to optimize the development's nonstructural stormwater management design.

Since this checklist is intended to promote the use of nonstructural stormwater management strategies and provide guidance in their incorporation in land development projects, municipalities are permitted to revise it as necessary to meet the goals and objectives of their specific stormwater management program and plan within the limits of N.J.A.C. 7:8.

Low Impact Development Checklist

A checklist for identifying nonstructural stormwater management strategies incorporated into proposed land development

Municipality: _____

County: _____ Date: _____

Review board or agency: _____

Proposed land development name: _____

Lot(s): _____ Block(s): _____

Project or application number: _____

Applicant's name: _____

Applicant's address: _____

Telephone: _____ Fax: _____

Email address: _____

Designer's name: _____

Designer's address: _____

Telephone: _____ Fax: _____

Email address: _____

Part 2: Review of Local Stormwater Management Regulations

Title and date of stormwater management regulations used in development design:

Do regulations include nonstructural requirements? Yes: _____ No: _____

If yes, briefly describe: _____

List LID-BMPs prohibited by local regulations: _____

Pre-design meeting held? Yes: _____ Date: _____ No: _____

Meeting held with: _____

Pre-design site walk held? Yes: _____ Date: _____ No: _____

Site walk held with: _____

Other agencies with stormwater review jurisdiction:

Name: _____

Required approval: _____

Name: _____

Required approval: _____

Name: _____

Required approval: _____

Part 3: Nonstructural Strategies and LID-BMPs in Design

3.1 Vegetation and Landscaping

Effective management of both existing and proposed site vegetation can reduce a development's adverse impacts on groundwater recharges and runoff quality and quantity. This section of the checklist helps identify the vegetation and landscaping strategies and nonstructural LID-BMPs that have been incorporated into the proposed development's design to help maintain existing recharge rates and/or minimize or prevent increases in runoff quantity and pollutant loading.

A. Has an inventory of existing site vegetation been performed? Yes: _____ No: _____

If yes, was this inventory a factor in the site's layout and design? Yes: _____ No: _____

B. Does the site design utilize any of the following nonstructural LID-BMPs?

Preservation of natural areas? Yes: _____ No: _____ If yes, specify % of site: _____

Native ground cover? Yes: _____ No: _____ If yes, specify % of site: _____

Vegetated buffers? Yes: _____ No: _____ If yes, specify % of site: _____

C. Do the land development regulations require these nonstructural LID-BMPs?

Preservation of natural areas? Yes: _____ No: _____ If yes, specify % of site: _____

Native ground cover? Yes: _____ No: _____ If yes, specify % of site: _____

Vegetated buffers? Yes: _____ No: _____ If yes, specify % of site: _____

D. If vegetated filter strips or buffers are utilized, specify their functions:

Reduce runoff volume increases through lower runoff coefficient: Yes: _____ No: _____

Reduce runoff pollutant loads through runoff treatment: Yes: _____ No: _____

Maintain groundwater recharge by preserving natural areas: Yes: _____ No: _____

3.2 Minimize Land Disturbance

Minimizing land disturbance is a nonstructural LID-BMP that can be applied during both the development's construction and post-construction phases. This section of the checklist helps identify those land disturbance strategies and nonstructural LID-BMPs that have been incorporated into the proposed development's design to minimize land disturbance and the resultant change in the site's hydrologic character.

A. Have inventories of existing site soils and slopes been performed? Yes: _____ No: _____

If yes, were these inventories factors in the site's layout and design? Yes: _____ No: _____

B. Does the development's design utilize any of the following nonstructural LID-BMPs?

Restrict permanent site disturbance by land owners? Yes: _____ No: _____

If yes, how: _____

Restrict temporary site disturbance during construction? Yes: _____ No: _____

If yes, how: _____

Consider soils and slopes in selecting disturbance limits? Yes: _____ No: _____

If yes, how: _____

C. Specify percentage of site to be cleared: _____ Regraded: _____

D. Specify percentage of cleared areas done so for buildings: _____

For driveways and parking: _____ For roadways: _____

E. What design criteria and/or site changes would be required to reduce the percentages in C and D above?

F. Specify site's hydrologic soil group (HSG) percentages:

HSG A: _____ HSG B: _____ HSG C: _____ HSG D: _____

G. Specify percentage of each HSG that will be permanently disturbed:

HSG A: _____ HSG B: _____ HSG C: _____ HSG D: _____

H. Locating site disturbance within areas with less permeable soils (HSG C and D) and minimizing disturbance within areas with greater permeable soils (HSG A and B) can help maintain groundwater recharge rates and reduce runoff volume increases. In light of the HSG percentages in F and G above, what other practical measures if any can be taken to achieve this?

I. Does the site include Karst topography? Yes: _____ No: _____

If yes, discuss measures taken to limit Karst impacts:

3.3 Impervious Area Management

New impervious surfaces at a development site can have the greatest adverse effect on groundwater recharge and stormwater quality and quantity. This section of the checklist helps identify those nonstructural strategies and LID-BMPs that have been incorporated into a proposed development's design to comprehensively manage the extent and impacts of new impervious surfaces.

A. Specify impervious cover at site: Existing: _____ Proposed: _____

B. Specify maximum site impervious coverage allowed by regulations: _____

C. Compare proposed street cartway widths with those required by regulations:

Type of Street	Proposed Cartway Width (feet)	Required Cartway Width (feet)
Residential access – low intensity		
Residential access – medium intensity		
Residential access – high intensity with parking		
Residential access – high intensity without parking		
Neighborhood		
Minor collector – low intensity without parking		
Minor collector – with one parking lane		
Minor collector – with two parking lanes		
Minor collector – without parking		
Major collector		

D. Compare proposed parking space dimensions with those required by regulations:

Proposed: _____ Regulations: _____

E. Compare proposed number of parking spaces with those required by regulations:

Proposed: _____ Regulations: _____

F. Specify percentage of total site impervious cover created by buildings:

By driveways and parking: _____ By roadways: _____

G. What design criteria and/or site changes would be required to reduce the percentages in F above?

H. Specify percentage of total impervious area that will be unconnected:

Total site: _____ Buildings: _____ Driveways and parking: _____ Roads: _____

I. Specify percentage of total impervious area that will be porous:

Total site: _____ Buildings: _____ Driveways and parking: _____ Roads: _____

J. Specify percentage of total building roof area that will be vegetated: _____

K. Specify percentage of total parking area located beneath buildings: _____

L. Specify percentage of total parking located within multi-level parking deck: _____

3.4 Time of Concentration Modifications

Decreasing a site's time of concentration (Tc) can lead directly to increased site runoff rates which, in turn, can create new and/or aggravate existing erosion and flooding problems downstream. This section of the checklist helps identify those nonstructural strategies and LID-BMPs that have been incorporated into the proposed development's design to effectively minimize such Tc decreases.

When reviewing Tc modification strategies, it is important to remember that a drainage area's Tc should reflect the general conditions throughout the area. As a result, Tc modifications must generally be applied throughout a drainage area, not just along a specific Tc route.

A. Specify percentage of site's total stormwater conveyance system length that will be:

Storm sewer: _____ Vegetated swale: _____ Natural channel: _____

Stormwater management facility: _____ Other: _____

Note: the total length of the stormwater conveyance system should be measured from the site's downstream property line to the downstream limit of sheet flow at the system's headwaters.

B. What design criteria and/or site changes would be required to reduce the storm sewer percentages and increase the vegetated swale and natural channel percentages in A above?

C. In conveyance system subareas that have overland or sheet flow over impervious surfaces or turf grass, what practical and effective site changes can be made to:

Decrease overland flow slope: _____

Increase overland flow roughness: _____

3.5 Preventative Source Controls

The most effective way to address water quality concerns is by pollution prevention. This section of the checklist helps identify those nonstructural strategies and LID-BMPs that have been incorporated into the proposed development's design to reduce the exposure of pollutants to prevent their release into the stormwater runoff.

A. Trash Receptacles

Specify the number of trash receptacles provided: _____

Specify the spacing between the trash receptacles: _____

Compare trash receptacles proposed with those required by regulations:

Proposed: _____ Regulations: _____

B. Pet Waste Stations

Specify the number of pet waste stations provided: _____

Specify the spacing between the pet waste stations: _____

Compare pet waste stations proposed with those required by regulations:

Proposed: _____ Regulations: _____

C. Inlets, Trash Racks, and Other Devices that Prevent Discharge of Large Trash and Debris

Specify percentage of total inlets that comply with the NJPDES storm drain inlet criteria: _____

D. Maintenance

Specify the frequency of the following maintenance activities:

Street sweeping: Proposed: _____ Regulations: _____

Litter collection: Proposed: _____ Regulations: _____

Identify other stormwater management measures on the site that prevent discharge of large trash and debris:

E. Prevention and Containment of Spills

Identify locations where pollutants are located on the site, and the features that prevent these pollutants from being exposed to stormwater runoff:

Pollutant: _____ Location: _____

Feature utilized to prevent pollutant exposure, harmful accumulation, or contain spills:

Pollutant: _____ Location: _____

Feature utilized to prevent pollutant exposure, harmful accumulation, or contain spills:

Pollutant: _____ Location: _____

Feature utilized to prevent pollutant exposure, harmful accumulation, or contain spills:

Pollutant: _____ Location: _____

Feature utilized to prevent pollutant exposure, harmful accumulation, or contain spills:

Pollutant: _____ Location: _____

Part 4: Compliance with Nonstructural Requirements of NJDEP Stormwater Management Rules

1. Based upon the checklist responses above, indicate which nonstructural strategies have been incorporated into the proposed development's design in accordance with N.J.A.C. 7:8-5.3(b):

No.	Nonstructural Strategy	Yes	No
1.	Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss.		
2.	Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces.		
3.	Maximize the protection of natural drainage features and vegetation.		
4.	Minimize the decrease in the pre-construction time of concentration.		
5.	Minimize land disturbance including clearing and grading.		
6.	Minimize soil compaction.		
7.	Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers, and pesticides.		
8.	Provide vegetated open-channel conveyance systems discharge into and through stable vegetated areas.		
9.	Provide preventative source controls.		

2. For those strategies that have not been incorporated into the proposed development's design, provide engineering, environmental, and/or safety reasons. Attached additional pages as necessary.

New Jersey Stormwater Best Management Practices Manual

February 2004

A P P E N D I X B

Municipal Regulations Checklist

A checklist for incorporating nonstructural stormwater management strategies into local regulations

As part of the requirements for municipal stormwater management plans in the Stormwater Management Rules at N.J.A.C. 7:8-4, municipalities are required to evaluate the municipal master plan, and land use and zoning ordinances to determine what adjustments need to be made to allow the implementation of nonstructural stormwater management techniques, also called low impact development techniques, which are presented in *Chapter 2: Low Impact Development Techniques*. *Chapter 3: Regional and Municipal Stormwater Management Plans* provides information on the development of municipal stormwater management plans, including the evaluation of the master plan, and land use and zoning ordinances. This checklist was prepared to assist municipalities in identifying the specific ordinances that should be evaluated, and the types of changes to be incorporated to address the requirements of the Stormwater Management Rules.

Part 1: Vegetation and Landscaping

Effective management of both existing and proposed site vegetation can reduce a development's adverse impacts on groundwater recharge and stormwater runoff quality and quantity.

A. Preservation of Natural Areas

Municipal regulations should include requirements to preserve existing vegetated areas, minimize turf grass lawn areas, and use native vegetation.

- Yes No Are applicants required to provide a layout of the existing vegetated areas, and a description of the conditions in those areas?
- Yes No Does the municipality have maximum as well as minimum yard sizing ordinances?
- Yes No Are residents restricted from enlarging existing turf lawn areas?
- Yes No Do the ordinances provide incentives for the use of vegetation as filters for stormwater runoff?
- Yes No Do the ordinances require a specific percentage of permanently preserved open space as part of the evaluation of cluster development?

B. Tree Protection Ordinances

Municipalities often have a tree ordinance to minimize the removal of trees and to replace trees that are removed. However, while tree ordinances protect the number of trees, they do not typically address the associated leaf litter or smaller vegetation that provides additional water quality and quantity benefits. Municipalities should consider enhancing tree ordinances to a forest ordinance that would also maintain the benefits of a forested area.

- Yes No Does the municipality have a tree protection ordinance?
- Yes No Can the municipality include a forest protection ordinance?
- Yes No If forested areas are present at development sites, is there a required percentage of the stand to be preserved?

C. Landscaping Island and Screening Ordinances

Municipalities often have ordinances that require landscaping islands for parking areas. The landscaping islands can provide ideal opportunities for the filtration and disconnection of runoff, or the placement of small LID-BMPs. Screening ordinances limit the view of adjoining properties, parking areas, or loading areas. Low maintenance vegetation can be required in islands and areas used for screening to provide stormwater quality, groundwater recharge, or stormwater quantity benefits.

- Yes No Do the ordinances require landscaping islands in parking lots, or between the roadway and the sidewalk? Can the ordinance be adjusted to require vegetation that is more beneficial for stormwater quality, groundwater recharge, or stormwater quantity, but that does not interfere with driver vision at the intersections?
- Yes No Is the use of bioretention islands and other stormwater practices within landscaped areas or setbacks allowed?
- Yes No Do the ordinances require screening from adjoining properties? Can the screening criteria require the use of vegetation to the maximum extent practicable before the use of walls or berms?

D. Riparian Buffers

Municipalities may have existing buffer and/or floodplain ordinances that require the protection of vegetation adjacent to streams. Municipalities should consult existing regulations adopted by the Department to ensure that riparian buffer or floodplain ordinances reflect the requirements of the Department within these areas. The municipality should consider conservation restrictions and allowable maintenance to ensure the preservation of these areas.

- Yes No Is there a stream buffer or floodplain ordinance in the community?
- Yes No Is the ordinance consistent with existing state regulatory requirements?
- Yes No Does the ordinance require a conservation easement, or other permanent restrictions on buffer areas?
- Yes No Does the ordinance identify or limit when stormwater outfall structures can cross the buffer?
- Yes No Does the ordinance give detailed information on the type of maintenance and/or activities that is allowed in the buffer?

Part 2: Minimizing Land Disturbance

The minimization of disturbance can be used at different phases of a development project. The goal is to limit clearing, grading, and other disturbance associated with development to protect existing features that provide stormwater benefits. Zoning ordinances typically limit the amount of impervious surfaces on building lots, but do not limit the amount of area that can be disturbed during construction. This strategy helps preserve the site's existing hydrologic character, as well as limiting the occurrence of soil compaction.

A. Limits of Disturbance

Designing with the terrain, or site fingerprinting, requires an assessment of the characteristics of the site and the selection of areas for development that would minimize the impact. This can be incorporated into the requirements for existing site conditions and the environmental impact statement. Limits of disturbance should be incorporated into construction plans reviewed and approved by the municipality. Setbacks should be evaluated to determine whether they can be reduced. The following maximum setbacks are recommended for low impact development designs:

- front yard – 20 feet;
- rear yard – 25 feet; and
- side yard – 8 feet.

Yes No As part of the depiction of existing conditions, are environmentally critical and environmentally constrained areas identified? (Environmentally critical areas are areas or features with significant environmental value, such as steep slopes, stream corridors, natural heritage priority sites, and habitats of threatened and endangered species. Environmentally constrained areas are those with development restrictions, such as wetlands, floodplains, and sites of endangered species.)

Yes No Can any of the existing setbacks be reduced?

Yes No Are there maximum turf grass or impervious cover limits in any of the setbacks?

Yes No Do the ordinances inhibit or prohibit the clearcutting of the project site as part of the construction?

Yes No Is the traffic of heavy construction vehicles limited to specific areas, such as areas of proposed roadway? Are these areas required to be identified on the plans and marked in the field?

Yes No Do the ordinances require the identification of specific areas that provide significant hydrologic functions, such as existing surface storage areas, forested areas, riparian corridors, and areas with high groundwater recharge capabilities?

Yes No Does the municipality require an as-built inspection before issuing a certificate of occupancy? If so, does the inspection include identification of compacted areas, if they exist within the site?

Yes No Does the municipality require the restoration to compacted areas in accordance with the Soil Erosion and Sediment Control Standards?

B. Open Space and Cluster Development

Open space areas are restricted land that may be set aside for conservation, recreation, or agricultural use, and are often associated with cluster development requirements. Since open space can have a variety of uses, the municipality should evaluate its open space ordinances to determine whether amendments are necessary to provide improved stormwater benefits.

- Yes No Are open space or cluster development designs allowed in the municipality?
- Yes No Are flexible site design incentives available for developers that utilize open space or cluster design options?
- Yes No Are there limitations on the allowable disturbance of existing vegetated areas in open space?
- Yes No Are the requirements to re-establish vegetation in disturbed areas dedicated for open space?
- Yes No Is there a maximum allowable impervious cover in open space areas?

Part 3: Impervious Area Management

The amount of impervious area, and its relationship to adjacent vegetated areas, can significantly change the amount of runoff that needs to be addressed by BMPs. Most of a site's impervious surfaces are typically located in the streets, sidewalks, driveway, and parking areas. These areas are further hampered by requirements for continuous curbing that prevent discharge from impervious surfaces into adjacent vegetated areas.

A. Streets and Driveways

Street widths of 18 to 22 feet are recommended for low impact development designs in low density residential developments. Minimum driveway widths of 9 and 18 feet for one lane and two lanes, respectively, are also recommended. The minimum widths of all streets and driveways should be evaluated to demonstrate that the proposed width is the narrowest possible consistent with safety and traffic concerns and requirements. Municipalities should evaluate which traffic calming features, such as circles, rotaries, medians, and islands, can be vegetated or landscaped. Cul-de-sacs can also be evaluated to reduce the radius area, or to provide a landscape island in the center.

- Yes No Are the street widths the minimum necessary for traffic density, emergency vehicle movement, and roadside parking?
- Yes No Are street features, such as circles, rotaries, or landscaped islands allowed to or required to receive runoff?
- Yes No Are curb cuts or flush curbs with curb stops an allowable alternative to raised curbs?
- Yes No Can the minimum cul-de-sac radius be reduced or is a landscaped island required in the center of the cul-de-sac?
- Yes No Are alternative turn-arounds such as "hammerheads" allowed on short streets in low density residential developments?
- Yes No Can the minimum driveway width be reduced?
- Yes No Are shared driveways permitted in residential developments?

B. Parking Areas and Sidewalks

A mix of uses at a development site can allow for shared parking areas, reducing the total parking area. Municipalities require minimum parking areas, but seldom limit the total number of parking spaces. Table 1 shows recommendations for minimum parking space ratios for low impact design:

Table 1: Low Impact Development Parking Space Ratios

Use	Parking Ratio per 1000 sq. ft. of Gross Floor Area
Professional office building	Less than 3.0
Shopping centers	Less than 4.5

- Yes No Can the parking ratios be reduced?
- Yes No Are the parking requirements set as maximum or median rather than minimum requirements?
- Yes No Is the use of shared parking arrangements allowed to reduce the parking area?
- Yes No Are model shared parking agreements provided?
- Yes No Does the presence of mass transit allow for reduced parking ratios?
- Yes No Is a minimum stall width of 9 feet allowed?
- Yes No Is a minimum stall length of 18 feet allowed?
- Yes No Can the stall lengths be reduced to allow vehicle overhang into a vegetated area?
- Yes No Do ordinances allow for permeable material to be used in overflow parking areas?
- Yes No Do ordinances allow for multi-level parking?
- Yes No Are there incentives to provide parking that reduces impervious cover, rather than providing only surface parking lots?

Sidewalks can be made of pervious material or disconnected from the drainage system to allow runoff to re-infiltrate into the adjacent pervious areas.

- Yes No Do ordinances allow for sidewalks constructed with pervious material?
- Yes No Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)?

C. Unconnected Impervious Areas

Disconnection of impervious areas can occur in both low density development and high density commercial development, provided sufficient vegetated area is available to accept dispersed stormwater flows. Areas for disconnection include parking lot or cul-de-sac islands, lawn areas, and other vegetated areas.

- Yes No Are developers required to disconnect impervious surfaces to promote pollutant removal and groundwater recharge?
- Yes No Do ordinances allow the reduction of the runoff volume when runoff from impervious areas are re-infiltrated into vegetated areas?
- Yes No Do ordinances allow flush curb and/or curb cuts to allow for runoff to discharge into adjacent vegetated areas as sheet flow?

Part 4: Vegetated Open Channels

The use of vegetated channels, rather than the standard concrete curb and gutter configuration, can decrease flow velocity, and allow for stormwater filtration and re-infiltration. One design option is for vegetated channels that convey smaller storm events, such as the water quality design storm, and provide an overflow into a storm sewer system for larger storm events.

- Yes No Do ordinances allow or require vegetated open channel conveyance instead of the standard curb and gutter designs?
- Yes No Are there established design criteria for vegetated channels?

New Jersey Stormwater Best Management Practices Manual

February 2004

A P P E N D I X C

Sample Municipal Stormwater Management Plan

This is a sample of a municipal stormwater management plan. It was prepared to assist municipalities in developing the municipal stormwater management plans required by the new Stormwater Phase II Permitting Regulations and the Stormwater Management Rules. The plan has all of the required elements outlined in the Stormwater Management Rules at N.J.A.C. 7:8-4.2. The plan also includes additional recommended elements to enable municipalities to better manage the impact of stormwater on the receiving waters of the state from new and existing development. *Throughout the document, italicized text is provided to assist municipalities in the preparation of their own plan.*

Please note that portions of this plan are fictional and intended only as a model to assist municipalities in the development of the stormwater management plan. It is anticipated that municipalities will provide more detail and information than what is presented in this plan.

Note: Figures can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Table of Contents

Introduction.....	3
Goals	3
Stormwater Discussion	4
Background	5
Design and Performance Standards	11
Plan Consistency	11
Nonstructural Stormwater Management Strategies.....	12
Land Use/Build-Out Analysis	16
Mitigation Plans	24

List of Tables

Table C-1: Sample Build-Out Calculations for Two HUC14s.....	22
Table C-2: Pollutant Loads by Land Cover	22
Table C-3: Nonpoint Source Loads at Build-Out for Two Example HUC14s.....	23

List of Figures

Figure C-1: Groundwater Recharge in the Hydrologic Cycle.....	4
Figure C-2: Township and Its Waterways	6
Figure C-3: Township Boundary on USGS Quadrangles	7
Figure C-4: Groundwater Recharge Areas in the Township.....	9
Figure C-5: Wellhead Protection Areas in the Township	10
Figure C-6: Township's Existing Land Use.....	17
Figure C-7: Hydrologic Units (HUC14s) Within the Township.....	18
Figure C-8: Zoning Districts Within the Township	20
Figure C-9: Wetlands and Water Land Uses within the Township – Constrained Land.....	21

Introduction

Every plan should include an introduction to identify why the plan is being prepared and a summary of the contents of the plan. Here is sample language.

This Municipal Stormwater Management Plan (MSWMP) documents the strategy for the ABC Township (“the Township”) to address stormwater-related impacts. The creation of this plan is required by N.J.A.C. 7:14A-25 Municipal Stormwater Regulations. This plan contains all of the required elements described in N.J.A.C. 7:8 Stormwater Management Rules. The plan addresses groundwater recharge, stormwater quantity, and stormwater quality impacts by incorporating stormwater design and performance standards for new major development, defined as projects that disturb one or more acre of land. These standards are intended to minimize the adverse impact of stormwater runoff on water quality and water quantity and the loss of groundwater recharge that provides baseflow in receiving water bodies. The plan describes long-term operation and maintenance measures for existing and future stormwater facilities.

A “build-out” analysis has been included in this plan based upon existing zoning and land available for development. The plan also addresses the review and update of existing ordinances, the Township Master Plan, and other planning documents to allow for project designs that include low impact development techniques. The final component of this plan is a mitigation strategy for when a variance or exemption of the design and performance standards is sought. As part of the mitigation section of the stormwater plan, specific stormwater management measures are identified to lessen the impact of existing development.

Goals

Although each municipal plan may have different or more specific goals, listed below are the minimum set of goals that should be included in all municipal stormwater management plans.

The goals of this MSWMP are to:

- reduce flood damage, including damage to life and property;
- minimize, to the extent practical, any increase in stormwater runoff from any new development;
- reduce soil erosion from any development or construction project;
- assure the adequacy of existing and proposed culverts and bridges, and other in-stream structures;
- maintain groundwater recharge;
- prevent, to the greatest extent feasible, an increase in nonpoint pollution;
- maintain the integrity of stream channels for their biological functions, as well as for drainage;
- minimize pollutants in stormwater runoff from new and existing development to restore, enhance, and maintain the chemical, physical, and biological integrity of the waters of the state, to protect public health, to safeguard fish and aquatic life and scenic and ecological values, and to enhance the domestic, municipal, recreational, industrial, and other uses of water; and
- protect public safety through the proper design and operation of stormwater basins.

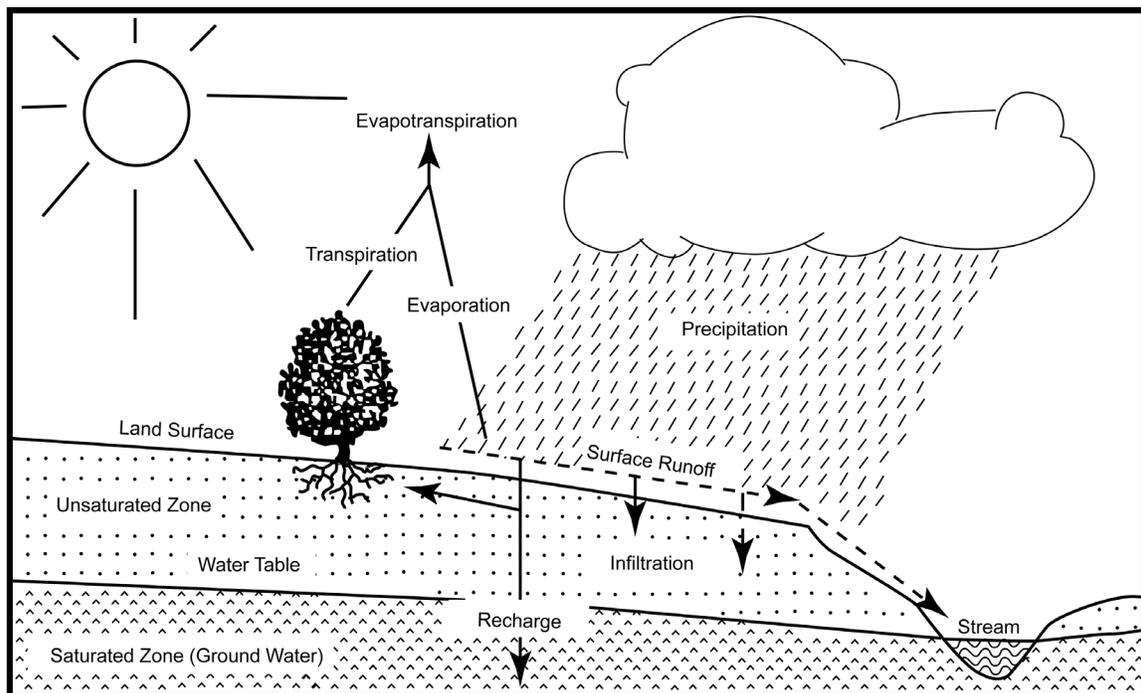
To achieve these goals, this plan outlines specific stormwater design and performance standards for new development. Additionally, the plan proposes stormwater management controls to address impacts from existing development. Preventative and corrective maintenance strategies are included in the plan to ensure long-term effectiveness of stormwater management facilities. The plan also outlines safety standards for stormwater infrastructure to be implemented to protect public safety.

Stormwater Discussion

Some of the readers of the plan may have limited knowledge of stormwater related issues. A brief description of the hydrologic cycle and how development affects the cycle may be useful to the reader. Sample language is provided below.

Land development can dramatically alter the hydrologic cycle (See Figure C-1) of a site and, ultimately, an entire watershed. Prior to development, native vegetation can either directly intercept precipitation or draw that portion that has infiltrated into the ground and return it to the atmosphere through evapotranspiration. Development can remove this beneficial vegetation and replace it with lawn or impervious cover, reducing the site's evapotranspiration and infiltration rates. Clearing and grading a site can remove depressions that store rainfall. Construction activities may also compact the soil and diminish its infiltration ability, resulting in increased volumes and rates of stormwater runoff from the site. Impervious areas that are connected to each other through gutters, channels, and storm sewers can transport runoff more quickly than natural areas. This shortening of the transport or travel time quickens the rainfall-runoff response of the drainage area, causing flow in downstream waterways to peak faster and higher than natural conditions. These increases can create new and aggravate existing downstream flooding and erosion problems and increase the quantity of sediment in the channel. Filtration of runoff and removal of pollutants by surface and channel vegetation is eliminated by storm sewers that discharge runoff directly into a stream. Increases in impervious area can also decrease opportunities for infiltration which, in turn, reduces stream base flow and groundwater recharge. Reduced base flows and increased peak flows produce greater fluctuations between normal and storm flow rates, which can increase channel erosion. Reduced base flows can also negatively impact the hydrology of adjacent wetlands and the health of biological communities that depend on base flows. Finally, erosion and sedimentation can destroy habitat from which some species cannot adapt.

Figure C-1: Groundwater Recharge in the Hydrologic Cycle



Source: New Jersey Geological Survey Report GSR-32.

In addition to increases in runoff peaks, volumes, and loss of groundwater recharge, land development often results in the accumulation of pollutants on the land surface that runoff can mobilize and transport to streams. New impervious surfaces and cleared areas created by development can accumulate a variety of pollutants from the atmosphere, fertilizers, animal wastes, and leakage and wear from vehicles. Pollutants can include metals, suspended solids, hydrocarbons, pathogens, and nutrients.

In addition to increased pollutant loading, land development can adversely affect water quality and stream biota in more subtle ways. For example, stormwater falling on impervious surfaces or stored in detention or retention basins can become heated and raise the temperature of the downstream waterway, adversely affecting cold water fish species such as trout. Development can remove trees along stream banks that normally provide shading, stabilization, and leaf litter that falls into streams and becomes food for the aquatic community.

Background

The plan should include background information on the municipality to help the reader understand its characteristics – size in square miles, population, population changes, waterways, and health of these waterways. For example, is the municipality a rural community rapidly becoming developed or is it an older established community where land use is fairly stable? Is the health of the waterways in the municipality impaired? Are there flooding concerns in the municipality? Also, maps should be included to help the reader visualize the municipality and its physical features.

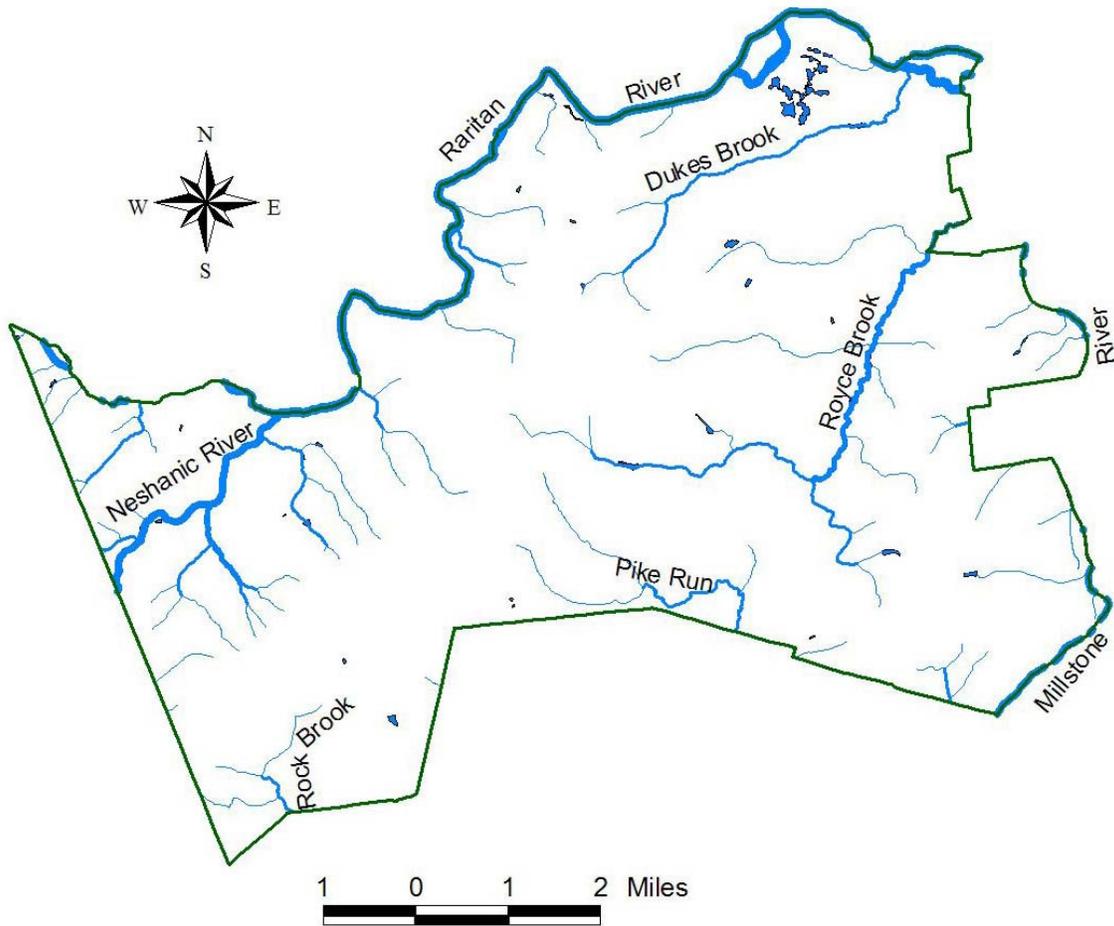
A township was selected for this sample plan so that the mapping and municipal characteristics can be presented along with information as to where to obtain these data. Due to the sample nature of this plan, this section does not present a comprehensive background of the municipality and its stormwater-related issues.

The Township encompasses 55 square mile area in Somerset County, New Jersey. In recent years, the Township has been under significant development pressure. The population of the Township has increased from 19,061 in 1980, to 28,808 in 1990, to 36,634 in 2000. This population increase has resulted in considerable demand for new development; changes in the landscape have most likely increased stormwater runoff volumes and pollutant loads to the waterways of the municipality. Figure C-2 illustrates the waterways in the Township. Figure C-3 depicts the Township boundary on the USGS quadrangle maps.

Each municipality should have population statistics. This information is available from the New Jersey Department of Labor at www.wnjp.in.net/OneStopCareerCenter/LaborMarketInformation/lmi25/index.html. Mapping required for a municipal plan is fairly simple, but requires Geographic Information System (GIS) software. Mapping information is available at <http://www.nj.gov/dep/gis/lists.html> as well as a link to a free version of GIS software, ArcExplorer. Many local watershed associations and environmental commissions have GIS and can help create maps for an MSWMP. Rutgers University Center for Remote Sensing and Spatial Analysis can also assist in preparing these maps. Detailed direction on how to create these maps is provided at <http://rwqp.rutgers.edu/univ/nj/>.

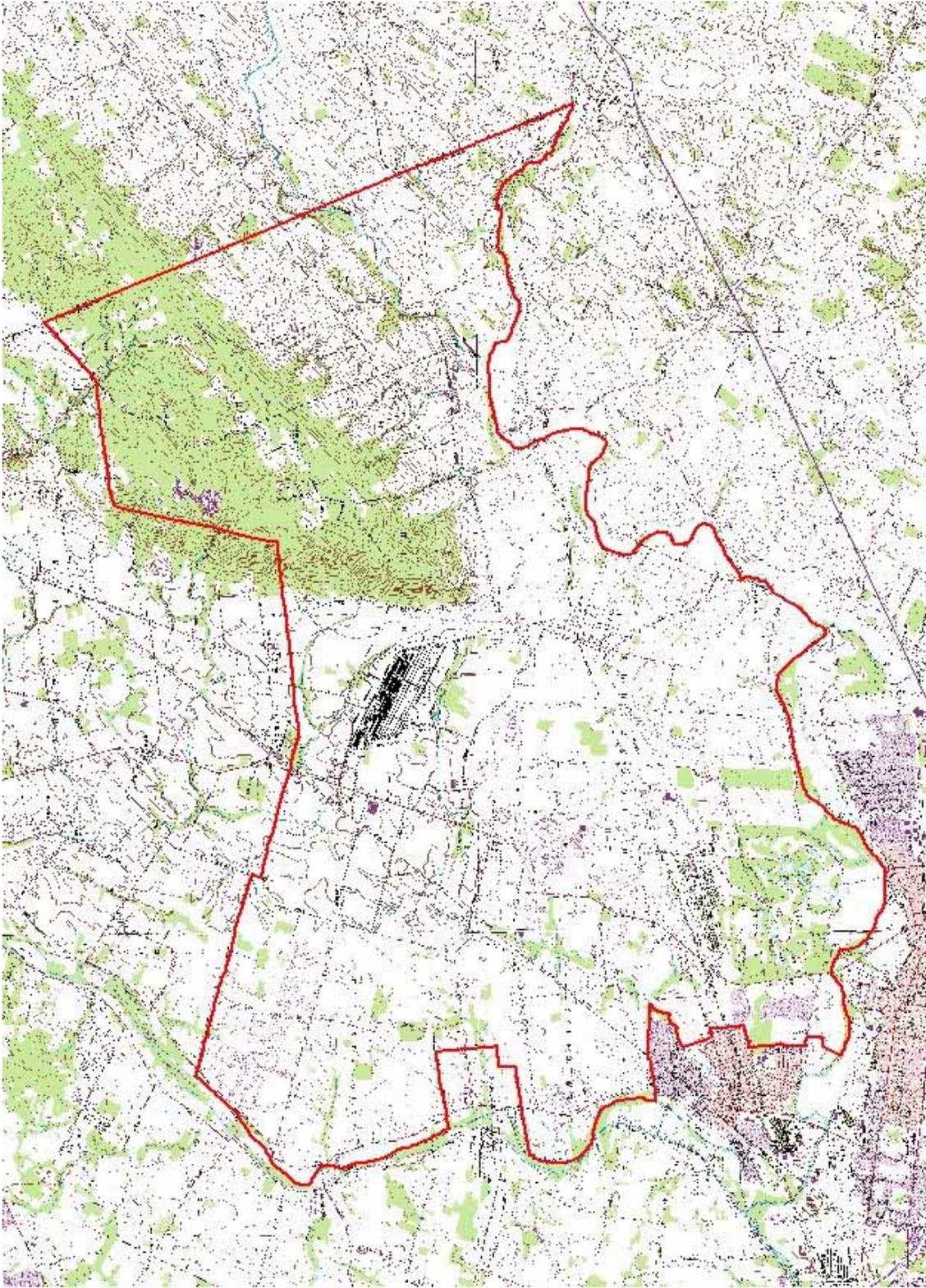
The New Jersey Department of Environmental Protection (NJDEP) has established an Ambient Biomonitoring Network (AMNET) to document the health of the state's waterways. There are over 800 AMNET sites throughout the state of New Jersey. These sites are sampled for benthic macroinvertebrates by NJDEP on a five-year cycle. Streams are classified as non-impaired, moderately impaired, or severely impaired based on the AMNET data. The data is used to generate a New Jersey Impairment Score (NJIS), which is based on a number of biometrics related to benthic macroinvertebrate community dynamics. The two major rivers that border the Township to the north and east, the Raritan River and the Millstone River,

Figure C-2: Township and Its Waterways



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Figure C-3: Township Boundary on USGS Quadrangles



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

respectively, are both moderately impaired. The five tributaries that flow through the Township to these major rivers are also moderately impaired based on AMNET data. In addition to the AMNET data, the NJDEP and other regulatory agencies collect water quality chemical data on the streams in the state. These data show that the instream total phosphorus concentrations and fecal coliform concentrations of the Raritan River and Millstone River frequently exceed the state's criteria. This means that these rivers are impaired waterways and the NJDEP is required to develop a Total Maximum Daily Load (TMDL) for these pollutants for each waterway.

A TMDL is the amount of a pollutant that can be accepted by a waterbody without causing an exceedance of water quality standards or interfering with the ability to use a waterbody for one or more of its designated uses. The allowable load is allocated to the various sources of the pollutant, such as stormwater and wastewater discharges, which require an NJPDES permit to discharge, and nonpoint source, which includes stormwater runoff from agricultural areas and residential areas, along with a margin of safety. Provisions may also be made for future sources in the form of reserve capacity. An implementation plan is developed to identify how the various sources will be reduced to the designated allocations. Implementation strategies may include improved stormwater treatment plants, adoption of ordinances, reforestation of stream corridors, retrofitting stormwater systems, and other BMPs.

The New Jersey Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)) (Integrated List) is required by the federal Clean Water Act to be prepared biennially and is a valuable source of water quality information. This combined report presents the extent to which New Jersey waters are attaining water quality standards, and identifies waters that are impaired. Sublist 5 of the Integrated List constitutes the list of waters impaired or threatened by pollutants, for which one or more TMDLs are needed.

The integrated list is available from the NJDEP website at www.nj.gov/dep/wmm/sgwqt/wat/index.html. Specific data on biological monitoring (AMNET data) is available from the NJDEP web site at www.state.nj.us/dep/wmm/bfbm. Additional data can be found on the United States Geological Survey (USGS) site at www.water.usgs.gov.

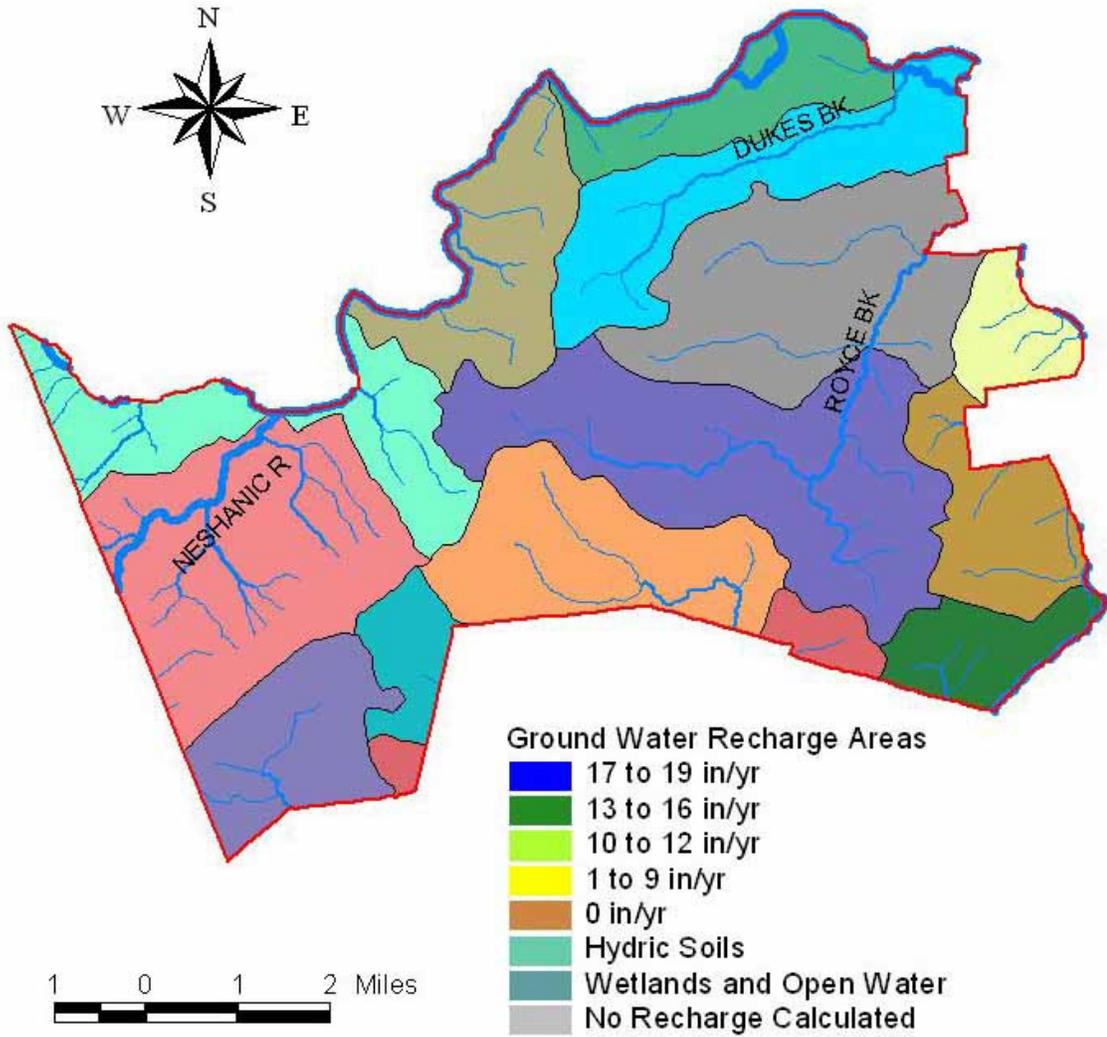
In addition to water quality problems, the Township has exhibited severe water quantity problems including flooding, stream bank erosion, and diminished base flow in its streams. Many of the culverts associated with road crossings in the Township are undersized. During severe storm events, these undersized culverts do not have adequate capacity, thereby causing a backwater effect and flooding upstream.

The municipality should list specific areas that are affected by stormwater quantity problems and the extent. For example, if in a storm event in 2001, considered equivalent to a 20-year design storm, specific areas reached particular elevations, that should be included.

These culverts were designed for much different hydrologic conditions (i.e., less impervious area) than presently exist in the Township. As the imperviousness increased in the Township, the peak and volumes of stream flows also increased. The increased amount of water resulted in stream bank erosion, which resulted in unstable areas at roadway/bridge crossings, and degraded stream habitats. The high imperviousness of the Township has significantly decreased groundwater recharge, decreasing base flows in streams during dry weather periods. Lower base flows can have a negative impact on instream habitat during the summer months. A map of the groundwater recharge areas are shown in Figure C-4. Wellhead protection areas, also required as part of the MSWMP, are shown in Figure C-5.

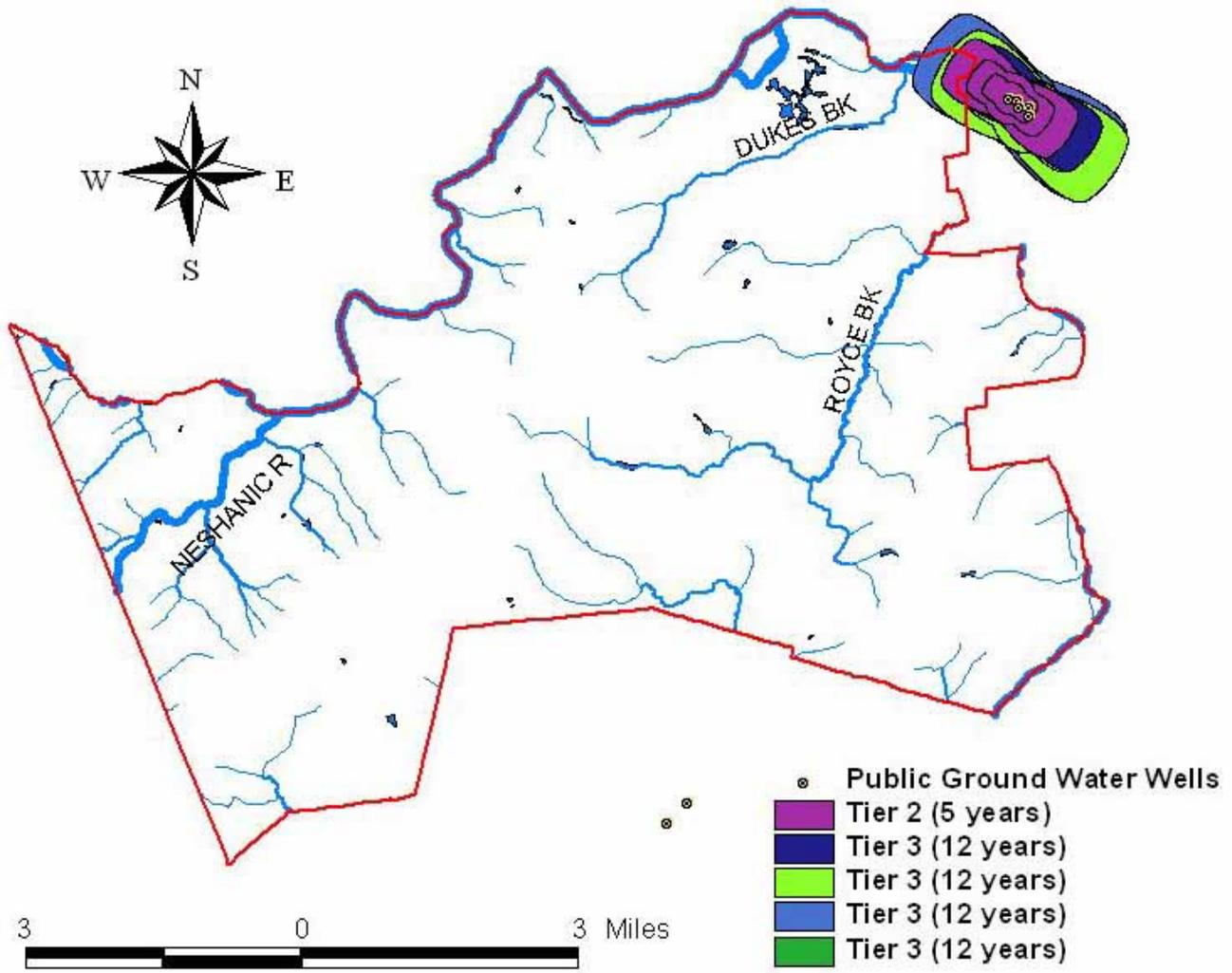
The Township may want to adopt specific ordinances to protect wellhead protection areas to minimize the infiltration of pollutants into aquifers.

Figure C-4: Groundwater Recharge Areas in the Township



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Figure C-5: Wellhead Protection Areas in the Township



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Design and Performance Standards

Municipal stormwater management plans must describe how the plan incorporates the design and performance standards in N.J.A.C. 7:8-5 or alternative design and performance standards that were adopted as a part of a regional stormwater management plan or water quality management plan. The design and performance standards should be incorporated into the municipality's stormwater management ordinance to be consistent with this requirement. A sample ordinance is provided in Appendix D: Model Stormwater Control Ordinance for Municipalities to assist in the incorporation of these design and performance standards into municipal plans. This section should clearly state that the municipality will adopt ordinances consistent with the design and performance standards at N.J.A.C. 7:8-5, ordinances to address maintenance consistent with N.J.A.C. 7:8-5.8, and ordinances to address safety consistent with N.J.A.C. 7:8-6. It should also indicate steps the municipality will take to ensure compliance with these standards.

The Township will adopt the design and performance standards for stormwater management measures as presented in N.J.A.C. 7:8-5 to minimize the adverse impact of stormwater runoff on water quality and water quantity and loss of groundwater recharge in receiving water bodies. The design and performance standards include the language for maintenance of stormwater management measures consistent with the stormwater management rules at N.J.A.C. 7:8-5.8 Maintenance Requirements, and language for safety standards consistent with N.J.A.C. 7:8-6 Safety Standards for Stormwater Management Basins. The ordinances will be submitted to the county for review and approval within [24 months of the effective date of the Stormwater Management Rules.]

During construction, Township inspectors will observe the construction of the project to ensure that the stormwater management measures are constructed and function as designed.

The simplest method to address the need to incorporate design and performance standards is to adopt the language in the Stormwater Management Rules and model ordinance. However, the municipality may adjust these standards. For example, certain municipalities have designated entities required to assume maintenance responsibility. In some cases, the municipality may choose to assume this responsibility. The municipality may choose to revise land use and zoning ordinances to prescribe how nonstructural stormwater management measures must be addressed. Additional discussion on the relationship of nonstructural stormwater management measures and ordinances are provided in Chapter 2: Low Impact Development Techniques, Chapter 3: Regional and Municipal Stormwater Management Plans, and Appendix B: Municipal Regulations Checklist.

Plan Consistency

The MSWMP must be coordinated with the appropriate Soil Conservation District and any other stormwater management plan, such as an adopted regional stormwater management plan. A short paragraph as given below is sufficient to comply with this requirement unless there is a TMDL for any of the waterways within the municipality. If a TMDL is in place and requires reductions in nonpoint sources within the municipalities, the TMDL requirements should be incorporated into this municipal stormwater management plan. For example, if a TMDL completed for fecal coliform identified the need for a goose management plan to control the impact from the resident geese at a local park, the goose management plan should be incorporated into this municipal stormwater management plan. Another example is that a TMDL may have identified over-fertilization of residential lawns as a source of nutrients to the impaired waterway and recommended development of a no-phosphorus ordinance for a particular section of the Township unless soil testing indicates a lack of sufficient phosphorus in the soil. This ordinance should be incorporated into this municipal stormwater management plan.

The Township is not within a Regional Stormwater Management Planning Area and no TMDLs have been developed for waters within the Township; therefore this plan does not need to be consistent with any regional stormwater management plans (RSWMPs) nor any TMDLs. If any RSWMPs or TMDLs are developed in the future, this Municipal Stormwater Management Plan will be updated to be consistent.

The Municipal Stormwater Management Plan is consistent with the Residential Site Improvement Standards (RSIS) at N.J.A.C. 5:21. The municipality will utilize the most current update of the RSIS in the

stormwater management review of residential areas. This Municipal Stormwater Management Plan will be updated to be consistent with any future updates to the RSIS.

The Township's Stormwater Management Ordinance requires all new development and redevelopment plans to comply with New Jersey's Soil Erosion and Sediment Control Standards. During construction, Township inspectors will observe on-site soil erosion and sediment control measures and report any inconsistencies to the local Soil Conservation District.

Nonstructural Stormwater Management Strategies

In addition to the design and performance standards for nonstructural strategies discussed above, the municipal stormwater management plan must be evaluated to determine how the municipal plan and ordinances should be amended to implement the principles of nonstructural stormwater management. Municipalities are required to evaluate the municipal master plan, and land use and zoning ordinances to determine what adjustments need to be made to allow the implementation of nonstructural stormwater management techniques, also called low impact development techniques, which are presented in Chapter 2: Low Impact Development Techniques. Additional discussion on the relationship of nonstructural stormwater management measures and ordinances is provided in Chapter 3: Regional and Municipal Stormwater Management Plans.

To address this requirement, municipal ordinances and plans must be reviewed to determine where changes can be made to incorporate nonstructural stormwater management strategies. Appendix B: Municipal Regulations Checklist has been provided to assist municipalities.

An example of the changes identified in ordinances is given below. (Note: This is not an exhaustive list of every ordinance that should be evaluated, but presents some examples.) Since many municipal codes are similar in much of the state, the recommendations provided here may prove useful in modifying individual municipal codes. When submitting the plan and ordinances to the county for review and a copy to the Department, all revised ordinances, master plans, and maps must be attached, along with an adoption schedule.

The Township has reviewed the master plan and ordinances, and has provided a list of the sections in the Township land use and zoning ordinances that are to be modified to incorporate nonstructural stormwater management strategies. These are the ordinances identified for revision. Once the ordinance texts are completed, they will be submitted to the county review agency for review and approval within [24 months of the effective date of the Stormwater Management Rules]. A copy will be sent to the Department of Environmental Protection at the time of submission.

Chapter 77 of the Township Code, entitled Development Regulations, was reviewed with regard to incorporating nonstructural stormwater management strategies. Several changes were made to Article VI of this Chapter, entitled "Design and Performance Standards" to incorporate these strategies.

Section 77-39: Buffers requires buffer areas along all lot and street lines separating residential uses from arterial and collector streets, separating a nonresidential use from either a residential use or residential zoning district line, and along all street lines where loading and storage areas can be seen from the street. The landscape requirements for these buffer areas in the existing section do not recommend the use of native vegetation. The language of this section was amended to require the use of native vegetation, which requires less fertilization and watering than non-native species. Additionally, language was included to allow buffer areas to be used for stormwater management by disconnecting impervious surfaces and treating runoff from these impervious surfaces. This section currently requires the preservation of natural wood tracts and limits land disturbance for new construction.

Section 77-41: Cluster Development provides for a cluster development option to preserve land for public and agricultural purposes, to prevent development on environmentally sensitive areas, and to aid in reducing the cost of providing streets, utilities and services in residential developments. This cluster

option is an excellent tool for reducing impervious roads and driveways. The option allows for smaller lots with smaller front and side yard setbacks than traditional development options. It also minimizes the disturbance of large tracts of land, which is a key nonstructural stormwater management strategy. The cluster option is being amended to require that [insert percentage here] of the total tract be preserved as common open space for residential area. The cluster option does require that 25 percent of the green or common area be landscaped with trees and/or shrubs. This language was amended to promote the use of native vegetation, which requires less fertilization and watering than non-native ornamental plants. Although the cluster option requires public concrete sidewalks to be installed along all streets, the option requires paths in open space to be mulched or stone to decrease the impervious area.

Section 77-43: Curbs and Gutters requires that concrete curb and gutter, concrete curb, or Belgian block curb be installed along every street within and fronting on a development. This section was amended to allow for curb cuts or flush curbs with curb stops to allow vegetated swales to be used for stormwater conveyance and to allow the disconnection of impervious areas.

Section 77-44: Drainage, Watercourses and Flood Hazard Areas requires that all streets be provided with inlets and pipes where the same are necessary for proper drainage. This section was amended to encourage the used of natural vegetated swales in lieu of inlets and pipes.

Section 77-45: Driveways and Accessways describes the procedure for construction of any new driveway or accessway to any street. This section was amended to allow the use of pervious paving materials to minimize stormwater runoff and promote groundwater recharge.

Section 77-60: Natural Features requires that natural features, such as trees, brooks, swamps, hilltops, and views, be preserved whenever possible, and that care be taken to preserve selected trees to enhance soil stability and landscaped treatment of the area. This section was amended to expand trees to forested areas, to ensure that leaf litter and other beneficial aspects of the forest are maintained in addition to the trees.

Section 77-62: Nonconforming Uses, Structures or Lots requires a variance for existing single family homes proposing additions that exceed the maximum percent impervious. The homeowner must mitigate the impact of the additional impervious surfaces unless the stormwater management plan for the development provided for these increases in impervious surfaces. This mitigation effort must address water quality, flooding, and groundwater recharge as described in Chapter 135. A detailed description of how to develop a mitigation plan is present in the Township Code.

Section 77-63: Off-site and Off-tract Improvements describes essential off-site and off-tract improvements. Language was added to this section to require that any off-site and off-tract stormwater management and drainage improvements must conform to the “Design and Performance Standards” described in this plan and provided in Chapter 135 of the Township Code.

Section 77-64: Off-street Parking and Loading details off-street parking and loading requirements. All parking lots with more than 10 spaces and all loading areas are required to have concrete or Belgian block curbing around the perimeter of the parking and loading areas. This section also requires that concrete or Belgian block curbing be installed around all landscaped areas within the parking lot or loading areas. This section was amended to allow for flush curb with curb stop, or curbing with curb cuts to encourage developers to allow for the discharge of impervious areas into landscaped areas for stormwater management. Also, language was added to allow for use of natural vegetated swales for the

water quality design storm, with overflow for larger storm events into storm sewers. This section also provides guidance on minimum parking space requirements. These requirements are based on the number of dwelling units and/or gross floor area. The section allows a developer to demonstrate that fewer spaces would be required, provided area is set aside for additional spaces if necessary. This section was amended to allow pervious paving to be used in areas to provide overflow parking, vertical parking structures, smaller parking stalls, and shared parking.

Sections 77-66: Performance Standards provide pollution source control. It prohibits materials or wastes to be deposited upon a lot in such form or manner that they can be transferred off the lot, directly or indirectly, by natural forces such as precipitation, evaporation or wind. It also requires that all materials and wastes that might create a pollutant or a hazard be enclosed in appropriate containers.

Section 77-73: Shade Trees requires a minimum of three shade trees per lot to be planted in the front yard. In addition to Section 77-73, the Township has a Tree Preservation Ordinance (Sections 77-160 to 77-165) that restricts and otherwise controls the removal of mature trees throughout the Township. This ordinance recognizes that the preservation of mature trees and forested areas is a key strategy in the management of environmental resources, particularly watershed management, air quality, and ambient heating and cooling. These sections set out a “critical footprint area” that extends 20 feet beyond the driveway and building footprint where clearing of trees cannot occur. This complies with minimizing land disturbance, which is a nonstructural stormwater management strategy. These sections were amended to require the identification of forested areas, and that *[insert percentage here]* of forested areas be protected from disturbance.

Section 77-74: Sidewalks describe sidewalk requirements for the Township. Although sidewalks are not required along all streets, the Township can require them in areas where the probable volume of pedestrian traffic, the development’s location in relation to other populated areas and high vehicular traffic, pedestrian access to bus stops, schools, parks, and other public places, and the general type of improvement intended indicate the advisability of providing a pedestrianway. Sidewalks are to be a minimum of four feet wide and constructed of concrete. Language was added to this section to require developers to design sidewalks to discharge stormwater to neighboring lawns where feasible to disconnect these impervious surfaces, or use permeable paving materials where appropriate.

Section 77-77: Soil Erosion and Sediment Control addresses soil erosion and sediment control by referencing Chapter 128, the Township’s Soil Erosion and Sediment Control Ordinance. This ordinance requires developers to comply with the New Jersey Soil Erosion and Sediment Control Standards and outlines some general design principles, including: whenever possible, retain and protect natural vegetation; minimize and retain water runoff to facilitate groundwater recharge; and, install diversions, sediment basins, and similar required structures prior to any on-site grading or disturbance.

Section 77-79 Stormwater Runoff addresses stormwater runoff by referencing Chapter 135, the Township’s Surface Water Management Ordinance, which was updated to include all requirements outlined in N.J.A.C. 7:8-5. These changes were presented earlier in this document.

Section 77-82: Streets describes the requirements for streets in the Township. The Township has several street classifications, ranging from “Arterial,” which has a minimum right-of-way of 80 feet, to “Secondary Local,” which has a minimum right-of-way of 50 feet. Street paving widths are a function of the number of units served, whether a street is curbed, whether on-street parking is permitted, whether the interior streets serve lots of two acres or larger, and whether on-site topographical constraints allow design flexibility. Depending on these factors, paving width for secondary local streets has a range from 20 to 32 feet. This section was amended to encourage developers to limit on-street parking to allow for narrower paved widths. This section also required that cul-de-sacs have a minimum radius of 50 feet. Language was added to this section to reduce the minimum radius of cul-de-sac designs. Cul-de-sacs with landscaped islands have a minimum radius of [insert radius here], cul-de-sacs with flush curbs have a minimum radius of [insert radius here], with a [insert width here] reinforced shoulder to accommodate larger equipment and emergency vehicles.

Several changes were made to Article VII of the Township Code entitled “Zoning Districts and Standards.” The Township has 11 types of residential districts. Each district has a maximum percent impervious surface allocation, ranging from 5 percent for the MZ District, which has a minimum lot size of five acres for detached single-family homes, to 40 percent for the AM and RCA Districts, which have a minimum lot size of 7,000 square feet for cluster single-family homes. The Township has 12 types of non-residential districts. Each of these districts has a maximum percent impervious surface allocation, ranging from 30 percent for the HOO District to 60 percent for the I-1 District. Although each zone has a maximum allowable percent impervious surface, the Township Code was amended to remind developers that satisfying the percent impervious requirements does not relieve them of responsibility for complying with the Design and Performance Standards for Stormwater Management Measures contained in Chapter 135 – Surface Water Runoff. The Township is evaluating the maximum allowable impervious cover for each zone to determine whether a reduction in impervious cover is appropriate. The Township is also evaluating a maximum percent of disturbance for each zone, for those areas identified as natural features in Section 77-60. Also, if a developer is given a variance to exceed the maximum allowable percent imperviousness, the developer must mitigate the impact of the additional impervious surfaces. This mitigation effort must address water quality, flooding, and groundwater recharge as described in Chapter 135. A detailed description of how to develop a mitigation plan is included in this Municipal Stormwater Management Plan.

Land Use/Build-Out Analysis

If a municipality can document that it has a combined total of less than one square mile of vacant or agricultural lands, the municipality is not required to complete the following build-out analysis. Otherwise, a build-out analysis must be conducted assuming full development under existing zoning for each HUC14 drainage area in the municipality. To satisfy the minimum requirements, the result of the build-out analysis is acreage of impervious surfaces by HUC14 and associated nonpoint loadings attributed to the build-out of the municipality. Although not required by the regulations, a quantitative analysis of the impact of build-out can be calculated, including population and number of school-age children, housing units and housing density, traffic, tax revenues, demands on schools, water supply, sewage, electrical production, and police force. Additional information on the build-out is provided in Chapter 3.

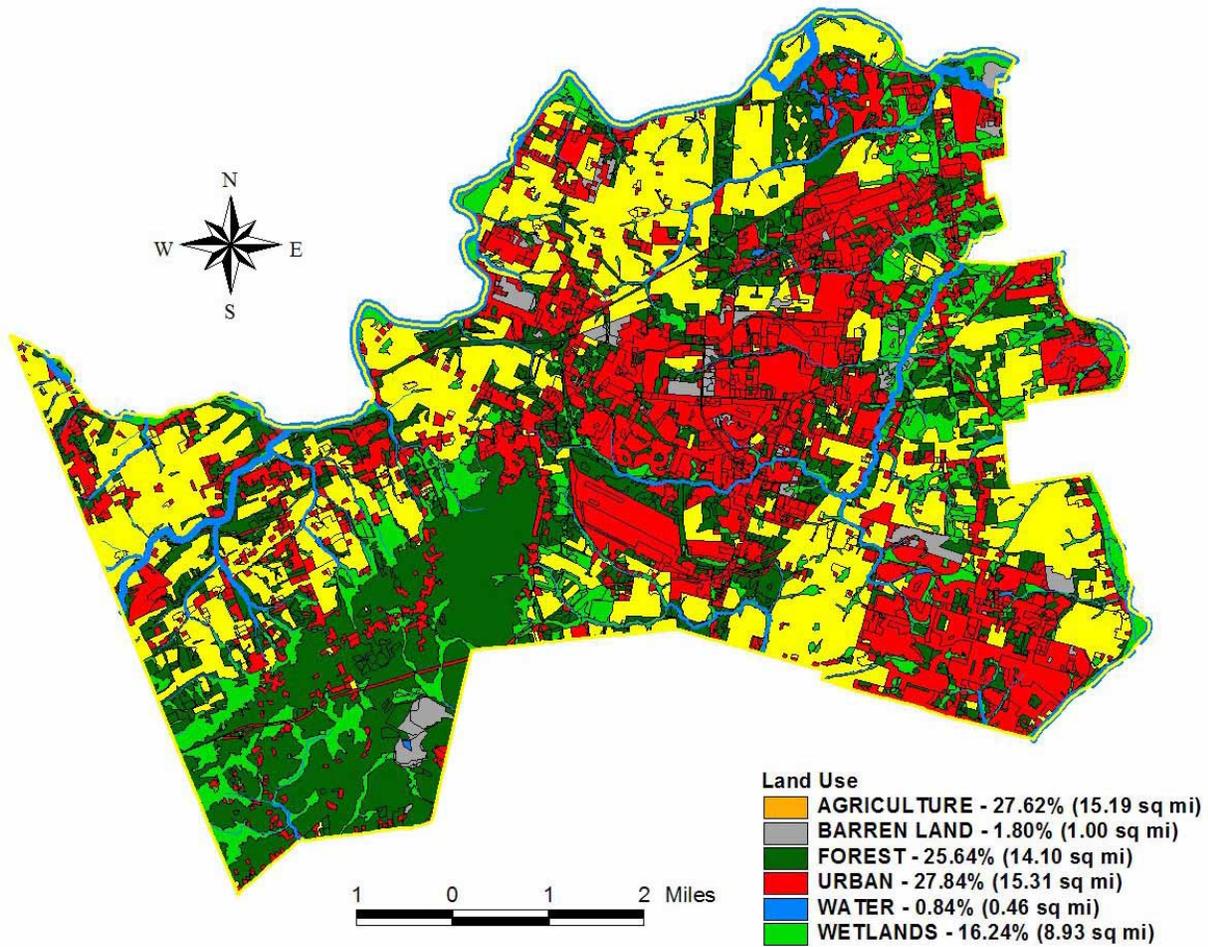
There are four steps to preparing a build-out analysis that satisfies the requirements for the municipal stormwater management plan:

- 1. Determine the total land area within each of the HUC14s of the municipality.*
- 2. Determine the area of constrained lands within each HUC14 of the municipality.*
- 3. Determine the land available for development by simply subtracting the constrained lands from the total land area for each HUC14. In essence, the land available for development is the agricultural, forest and/or barren lands available within each HUC14. Existing residential, commercial, and industrial areas are also eligible for redevelopment and should be considered as land available for development.*
- 4. For each HUC14, complete a build-out analysis by using the municipal zoning map and applicable ordinances to determine the acreage of new development. Once the build-out acreage of each land use is determined for each HUC14, nonpoint source loadings can be determined for the build-out scenario. Shown below are examples of build-out analyses for two HUC14s located in the municipality.*

A detailed land use analysis for the Township was conducted. Figure C-6 illustrates the existing land use in the Township based on 1995/97 GIS information from NJDEP. Figure C-7 illustrates the HUC14s within the Township. The Township zoning map is shown in Figure C-8. Figure C-9 illustrates the constrained lands within the Township. (*Note: For this sample plan, every constrained land was not mapped.*) The build-out calculations for impervious cover are shown in Table C-1. As expected when developing agricultural and forest lands, the build-out of these two HUC14s will result in a significant increase in impervious surfaces.

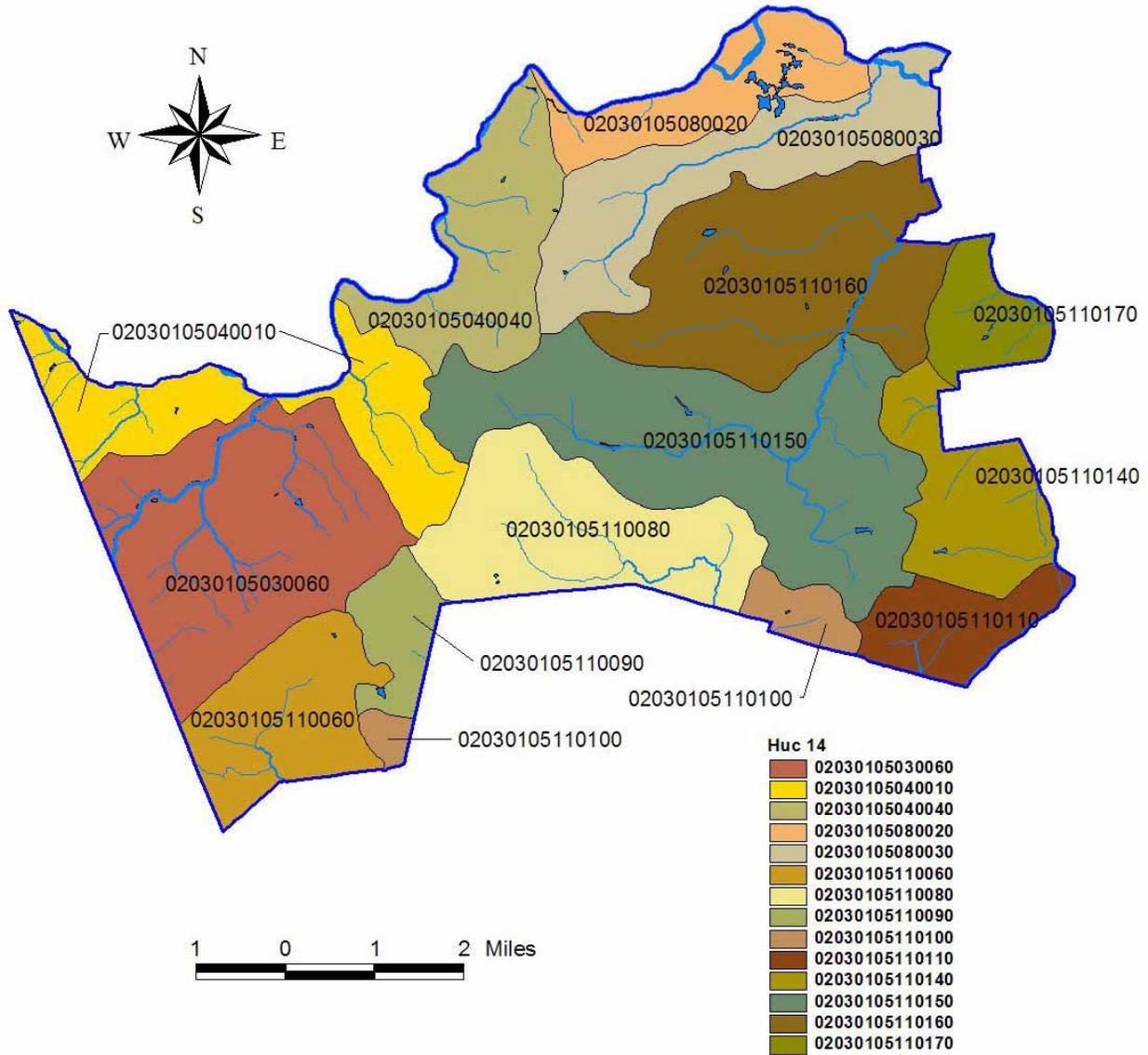
Table C-2 presents the pollutant loading coefficients by land cover. The pollutant loads at full build-out are presented in Table C-3.

Figure C-6: Township's Existing Land Use



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Figure C-7: Hydrologic Units (HUC14s) Within the Township

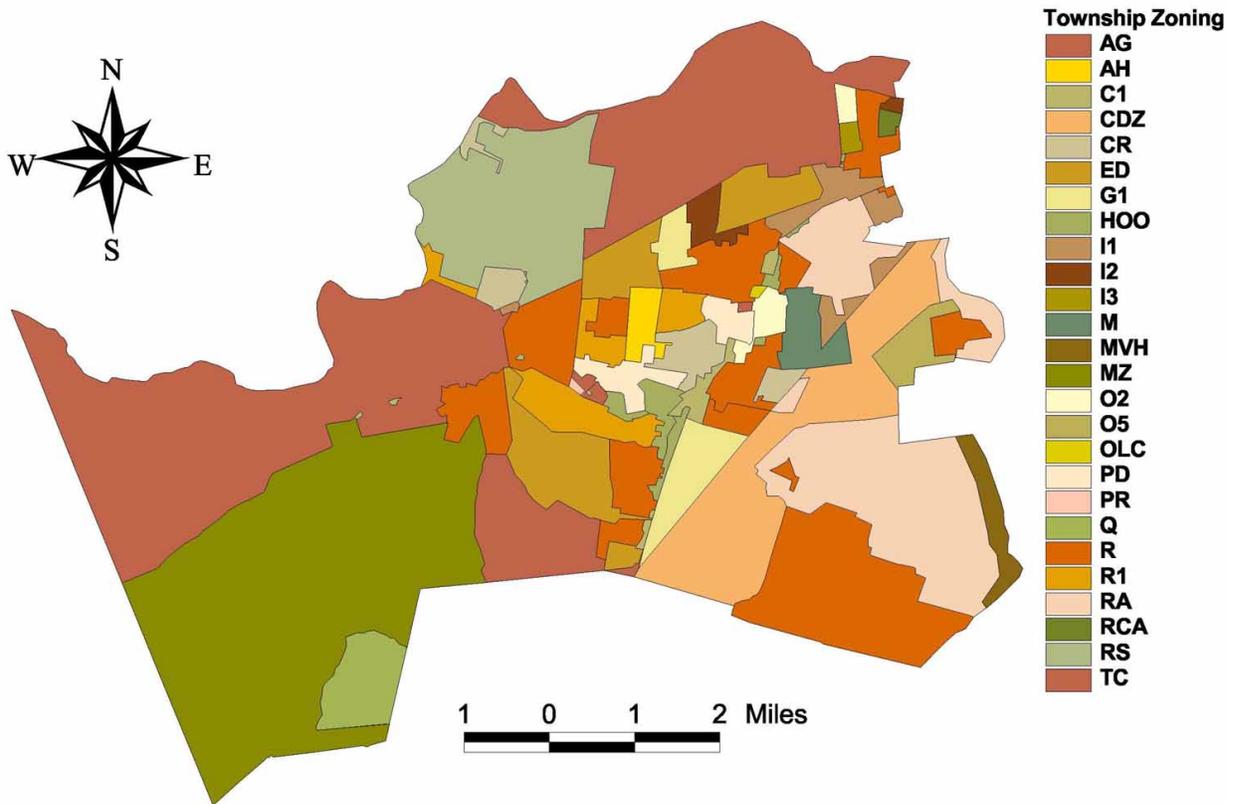


This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

It is important to note that, although the pollutant loads for agricultural lands are higher than those for low density residential for the parameters in Table C-2, converting agricultural lands to residential typically results in an increase in pollutant loads for metals and petroleum hydrocarbons. It is recommended that each municipality calculate build-out pollutant loads for each. Also, total suspended solids loads due to stormwater runoff may decrease due to the conversion of agricultural lands to low density residential, but the percentage of impervious surfaces increases dramatically. If, due to the increase of impervious surfaces, increases in stormwater runoff flows are not managed properly, these high flows will increase streambank erosion, thereby increasing sediment loads to the receiving waters.

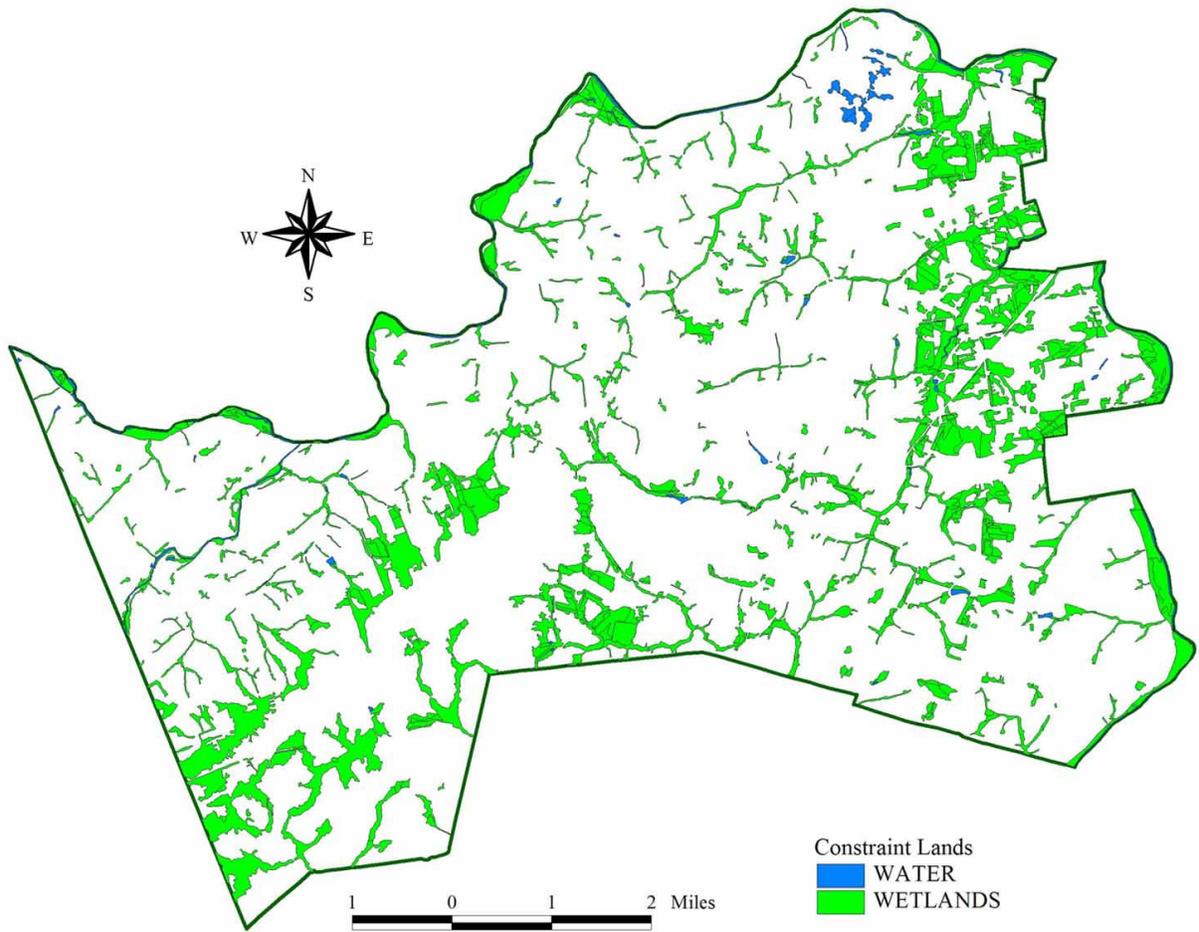
There are a number of resources available for assistance with preparing the build-out analysis, including the Association of New Jersey Environmental Commissions (ANJEC), the Stony Brook-Millstone Watershed Association, Rutgers University's Center for Remote Sensing and Spatial Analysis, the Nonpoint Education of Municipal Officials (NEMO), and USEPA (Green Communities: How to do a Build-Out Analysis at www.epa.gov/greenkit/build-out.htm). The mapping and querying ability of GIS software such as ESRI's ArcView is essential for preparing a build-out analysis in a cost-effective manner.

Figure C-8: Zoning Districts Within the Township



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Figure C-9: Wetlands and Water Land Uses Within the Township – Constrained Land



This figure can be viewed in color in the PDF version of this appendix available at <http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm>

Table C-1: Sample Build-Out Calculations for Two HUC14s

HUC14 and Zone	Total Area (acres)	Existing Impervious (%)	Existing Impervious (acres)	Wetlands/ Water Area (acres)	Developable Area (acres)	Allowable Impervious (%)	Build-Out Impervious (acres)
02030105110060							
Mountain (MZ)	2,009.84	1.08%	21.68	485.84	1,524.00	5%	76.20
Quarry (Q)	765.52	0.02%	0.18	32.46	733.06	5%	36.65
TOTALS	2,775.36	0.8%	21.86	518.30	2,257.06	5%	112.85
020301050040010							
Agriculture (AG)	2,206.32	2.94%	64.92	327.38	1,878.94	5%	93.95
Neighborhood Shopping Center District (C1)	402.70	1.85%	7.47	7.05	395.65	65%	257.17
Mountain (MZ)	663.23	2.88%	19.12	134.88	528.35	5%	26.42
TOTALS	3,272.25	2.8%	91.51	469.31	2,802.94	13%	377.54

Note: The Mountain, Quarry, and Agricultural Zoning District allow for rural residential development on five acre lots with a maximum percent impervious of 5 percent.

Table C-2: Pollutant Loads by Land Cover

Land Cover	Total Phosphorus Load (lbs/acre/year)	Total Nitrogen Load (lbs/acre/year)	Total Suspended Solids Load (lbs/acre/yr)
High, Medium Density Residential	1.4	15	140
Low Density, Rural Residential	0.6	5	100
Commercial	2.1	22	200
Industrial	1.5	16	200
Urban, Mixed Urban, Other Urban	1.0	10	120
Agricultural	1.3	10	300
Forest, Water, Wetlands	0.1	3	40
Barrenland/Transitional Area	0.5	5	60

Source: NJDEP Stormwater BMP Manual 2004.

Table C-3: Nonpoint Source Loads at Build-Out for Two Example HUC14s

HUC14 and Zone	Build-Out Zoning	Developable Area (acres)	TP (lbs/acre/yr)	TP (lbs/yr)	TN (lbs/acre/yr)	TN (lbs/yr)	TSS (lbs/acre/yr)	TSS (lbs/yr)
02030105110060								
Mountain (MZ)	Rural Residential	1,524	0.60	963	5	7,685	100	153,267
Quarry (Q)	Rural Residential	733	0.60	443	5	3,666	100	73,313
TOTALS		2,257		1,406		11,351		226,580
020301050040010								
Agriculture (AG)	Rural Residential	1,879	0.60	1,160	5	9,589	100	190,491
Neighborhood Shopping Center District (C1)	Commercial	396	2.10	832	22	8,727	200	79,429
Mountain (MZ)	Rural Residential	528	0.60	331	5	2,699	100	53,600
TOTALS		2,803		2,323		21,015		323,520

Mitigation Plans

A mitigation plan is required to grant a variance or exemption from the design and performance standards of a municipal stormwater management plan. The mitigation requirements should offer a hierarchy of options that clearly offset the effect on groundwater recharge, stormwater quantity control, and/or stormwater quality control that was created by granting the variance or exemption. The following fictional example is one of the means a municipality can select for a mitigation plan.

This mitigation plan is provided for a proposed development that is granted a variance or exemption from the stormwater management design and performance standards. Presented is a hierarchy of options.

Mitigation Project Criteria

1. The mitigation project must be implemented in the same drainage area as the proposed development. The project must provide additional groundwater recharge benefits, or protection from stormwater runoff quality and quantity from previously developed property that does not currently meet the design and performance standards outlined in the Municipal Stormwater Management Plan. The developer must ensure the long-term maintenance of the project, including the maintenance requirements under Chapters 8 and 9 of the NJDEP Stormwater BMP Manual.

a. The applicant can select one of the following projects listed to compensate for the deficit from the performance standards resulting from the proposed project. More detailed information on the projects can be obtained from the Township Engineer. Listed below are specific projects that can be used to address the mitigation requirement.

Groundwater Recharge

- Retrofit the L.B. Middle School site and detention basin to provide an additional 300,000 cf of average annual groundwater recharge.
- Replace the existing deteriorated 20,000 sf overflow impervious parking lot at Children's Memorial Soccer Complex with permeable paving to provide 150,000 cf of additional average annual groundwater recharge.

Water Quality

- Retrofit the existing stormwater management facility at Matisse Elementary School to provide the removal of 80 percent of total suspended solids from the parking lot runoff.
- Retrofit the existing parking area at the West Side Municipal Complex to provide the removal of 80 percent of total suspended solids. Due to site constraints, the retrofit BMP must be installed underground and cannot reduce the existing number of parking spaces.

Water Quantity

- Install stormwater management measures in the open space in the Woodlot Development to reduce the peak flow from the upstream development on the receiving stream by 20 cfs, 35 cfs, and 100 cfs for the 2, 10, and 100-year storms respectively.

2. If a suitable site cannot be located in the same drainage area as the proposed development, as discussed in Option 1, the mitigation project may provide mitigation that is not equivalent to the impacts for which the variance or exemption is sought, but that addresses the same issue. For example, if a variance is given because the 80 percent TSS requirement is not met, the selected project may address water quality impacts due to a fecal impairment. Listed below are specific projects that can be used to address the mitigation option.

Water Quality

- Re-establish a vegetative buffer (minimum 50 foot wide) along 1,500 linear feet of the shoreline at Sunshine Pond as a goose control measure and to filter stormwater runoff from the high goose traffic areas.
- Provide goose management measures, including public education at Central Park.

Options 1 and 2 would be available only if the MSWMP includes a list of environmental enhancement projects that provide groundwater recharge, control flooding, or control nonpoint source pollution. These are fictitious projects for the purposes of providing examples for this plan. Although only a brief description of each project is presented here, it is important for the municipality to have sufficient information on each project, including size of the project, permit requirements, land ownership, and estimated project costs (i.e., permitting fees, engineering costs, construction costs, and maintenance costs).

The municipality may allow a developer to provide funding or partial funding to the municipality for an environmental enhancement project that has been identified in a Municipal Stormwater Management Plan, or towards the development of a Regional Stormwater Management Plan. The funding must be equal to or greater than the cost to implement the mitigation outlined above, including costs associated with purchasing the property or easement for mitigation, and the cost associated with the long-term maintenance requirements of the mitigation measure.

New Jersey Stormwater Best Management Practices Manual

April 2004

A P P E N D I X D

Model Stormwater Control Ordinance for Municipalities

Important note: *This sample ordinance is provided to assist municipalities in the development of municipal stormwater control ordinances and the incorporation of design and performance standards into municipal stormwater management plans. It is provided for information purposes only. It is important that current regulations are carefully reviewed before any portion of this draft ordinance is adopted.*

This model ordinance does not include a section on fees. The Department expects that the review of development applications under this ordinance would be an integral part of the municipal review of subdivisions and site plans. As a result, the costs to municipalities of reviewing development applications under this ordinance can be defrayed by fees charged for review of subdivisions and site plans under N.J.S.A. 40:55D-8.b.

Notes are provided in italics throughout this model stormwater control ordinance, and are not intended to be adopted as part of the ordinance.

*An editable Word version of this model ordinance is available at:
http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_D.doc*

Section 1: Scope and Purpose

A. Policy Statement

Flood control, groundwater recharge, and pollutant reduction through nonstructural or low impact techniques shall be explored before relying on structural BMPs. Structural BMPs should be integrated with nonstructural stormwater management strategies and proper maintenance plans. Nonstructural strategies include both environmentally sensitive site design and source controls that prevent pollutants from being placed on the site or from being exposed to stormwater. Source control plans should be developed based upon physical site conditions and the origin, nature, and the anticipated quantity or amount of potential pollutants. Multiple stormwater management BMPs may be necessary to achieve the established performance standards for water quality, quantity, and groundwater recharge.

Note: Municipalities are encouraged to participate in the development of regional stormwater management plans, and to adopt and implement ordinances for specific drainage area performance standards that address local stormwater management and environmental characteristics.

B. Purpose

It is the purpose of this ordinance to establish minimum stormwater management requirements and controls for “major development,” as defined in Section 2.

C. Applicability

1. This ordinance shall be applicable to all site plans and subdivisions for the following major developments that require preliminary or final site plan or subdivision review:

- a. Non-residential major developments; and
- b. Aspects of residential major developments that are not pre-empted by the Residential Site Improvement Standards at N.J.A.C. 5:21.

2. This ordinance shall also be applicable to all major developments undertaken by [insert name of municipality].

D. Compatibility with Other Permit and Ordinance Requirements

Development approvals issued for subdivisions and site plans pursuant to this ordinance are to be considered an integral part of development approvals under the subdivision and site plan review process and do not relieve the applicant of the responsibility to secure required permits or approvals for activities regulated by any other applicable code, rule, act, or ordinance. In their interpretation and application, the provisions of this ordinance shall be held to be the minimum requirements for the promotion of the public health, safety, and general welfare. This ordinance is not intended to interfere with, abrogate, or annul any other ordinances, rule or regulation, statute, or other provision of law except that, where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, the more restrictive provisions or higher standards shall control.

Section 2: Definitions

Unless specifically defined below, words or phrases used in this ordinance shall be interpreted so as to give them the meaning they have in common usage and to give this ordinance its most reasonable application. The definitions below are the same as or based on the corresponding definitions in the Stormwater Management Rules at N.J.A.C. 7:8-1.2.

“CAFRA Planning Map” means the geographic depiction of the boundaries for Coastal Planning Areas, CAFRA Centers, CAFRA Cores and CAFRA Nodes pursuant to N.J.A.C. 7:7E-5B.3.

“CAFRA Centers, Cores or Nodes” means those areas within boundaries accepted by the Department pursuant to N.J.A.C. 7:8E-5B.

“Compaction” means the increase in soil bulk density.

“Core” means a pedestrian-oriented area of commercial and civic uses serving the surrounding municipality, generally including housing and access to public transportation.

“County review agency” means an agency designated by the County Board of Chosen Freeholders to review municipal stormwater management plans and implementing ordinance(s). The county review agency may either be:

A county planning agency; or

A county water resource association created under N.J.S.A 58:16A-55.5, if the ordinance or resolution delegates authority to approve, conditionally approve, or disapprove municipal stormwater management plans and implementing ordinances.

“Department” means the New Jersey Department of Environmental Protection.

“Designated Center” means a State Development and Redevelopment Plan Center as designated by the State Planning Commission such as urban, regional, town, village, or hamlet.

“Design engineer” means a person professionally qualified and duly licensed in New Jersey to perform engineering services that may include, but not necessarily be limited to, development of project requirements, creation and development of project design and preparation of drawings and specifications.

“Development” means the division of a parcel of land into two or more parcels, the construction, reconstruction, conversion, structural alteration, relocation or enlargement of any building or structure, any mining excavation or landfill, and any use or change in the use of any building or other structure, or land or extension of use of land, by any person, for which permission is required under the Municipal Land Use Law , N.J.S.A. 40:55D-1 et seq. In the case of development of agricultural lands, development means: any activity that requires a State permit; any activity reviewed by the County Agricultural Board (CAB) and the State Agricultural Development Committee (SADC), and municipal review of any activity not exempted by the Right to Farm Act , N.J.S.A 4:1C-1 et seq.

“Drainage area” means a geographic area within which stormwater, sediments, or dissolved materials drain to a particular receiving waterbody or to a particular point along a receiving waterbody.

“Environmentally critical areas” means an area or feature which is of significant environmental value, including but not limited to: stream corridors; natural heritage priority sites; habitat of endangered or threatened species; large areas of contiguous open space or upland forest; steep slopes; and well head protection and groundwater recharge areas. Habitats of endangered or threatened species are identified

using the Department's Landscape Project as approved by the Department's Endangered and Nongame Species Program.

"Empowerment Neighborhood" means a neighborhood designated by the Urban Coordinating Council "in consultation and conjunction with" the New Jersey Redevelopment Authority pursuant to N.J.S.A. 55:19-69.

"Erosion" means the detachment and movement of soil or rock fragments by water, wind, ice or gravity.

"Impervious surface" means a surface that has been covered with a layer of material so that it is highly resistant to infiltration by water.

"Infiltration" is the process by which water seeps into the soil from precipitation.

"Major development" means any "development" that provides for ultimately disturbing one or more acres of land. Disturbance for the purpose of this rule is the placement of impervious surface or exposure and/or movement of soil or bedrock or clearing, cutting, or removing of vegetation.

"Municipality" means any city, borough, town, township, or village.

"Node" means an area designated by the State Planning Commission concentrating facilities and activities which are not organized in a compact form.

"Nutrient" means a chemical element or compound, such as nitrogen or phosphorus, which is essential to and promotes the development of organisms.

"Person" means any individual, corporation, company, partnership, firm, association, [*insert name of municipality*], or political subdivision of this State subject to municipal jurisdiction pursuant to the Municipal Land Use Law , N.J.S.A. 40:55D-1 et seq.

"Pollutant" means any dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, refuse, oil, grease, sewage sludge, munitions, chemical wastes, biological materials, medical wastes, radioactive substance (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.), thermal waste, wrecked or discarded equipment, rock, sand, cellar dirt, industrial, municipal, agricultural, and construction waste or runoff, or other residue discharged directly or indirectly to the land, ground waters or surface waters of the State, or to a domestic treatment works. "Pollutant" includes both hazardous and nonhazardous pollutants.

"Recharge" means the amount of water from precipitation that infiltrates into the ground and is not evapotranspired.

"Sediment" means solid material, mineral or organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water or gravity as a product of erosion.

"Site" means the lot or lots upon which a major development is to occur or has occurred.

"Soil" means all unconsolidated mineral and organic material of any origin.

"State Development and Redevelopment Plan Metropolitan Planning Area (PA1)" means an area delineated on the State Plan Policy Map and adopted by the State Planning Commission that is intended to be the focus for much of the state's future redevelopment and revitalization efforts.

"State Plan Policy Map" is defined as the geographic application of the State Development and Redevelopment Plan's goals and statewide policies, and the official map of these goals and policies.

“Stormwater” means water resulting from precipitation (including rain and snow) that runs off the land’s surface, is transmitted to the subsurface, or is captured by separate storm sewers or other sewage or drainage facilities, or conveyed by snow removal equipment.

“Stormwater runoff” means water flow on the surface of the ground or in storm sewers, resulting from precipitation.

“Stormwater management basin” means an excavation or embankment and related areas designed to retain stormwater runoff. A stormwater management basin may either be normally dry (that is, a detention basin or infiltration basin), retain water in a permanent pool (a retention basin), or be planted mainly with wetland vegetation (most constructed stormwater wetlands).

“Stormwater management measure” means any structural or nonstructural strategy, practice, technology, process, program, or other method intended to control or reduce stormwater runoff and associated pollutants, or to induce or control the infiltration or groundwater recharge of stormwater or to eliminate illicit or illegal non-stormwater discharges into stormwater conveyances.

“Tidal Flood Hazard Area” means a flood hazard area, which may be influenced by stormwater runoff from inland areas, but which is primarily caused by the Atlantic Ocean.

“Urban Coordinating Council Empowerment Neighborhood” means a neighborhood given priority access to State resources through the New Jersey Redevelopment Authority.

“Urban Enterprise Zones” means a zone designated by the New Jersey Enterprise Zone Authority pursuant to the New Jersey Urban Enterprise Zones Act, N.J.S.A. 52:27H-60 et. seq.

“Urban Redevelopment Area” is defined as previously developed portions of areas:

- (1) Delineated on the State Plan Policy Map (SPPM) as the Metropolitan Planning Area (PA1), Designated Centers, Cores or Nodes;
- (2) Designated as CAFRA Centers, Cores or Nodes;
- (3) Designated as Urban Enterprise Zones; and
- (4) Designated as Urban Coordinating Council Empowerment Neighborhoods.

“Waters of the State” means the ocean and its estuaries, all springs, streams, wetlands, and bodies of surface or ground water, whether natural or artificial, within the boundaries of the State of New Jersey or subject to its jurisdiction.

“Wetlands” or “wetland” means an area that is inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

Section 3: General Standards

A. Design and Performance Standards for Stormwater Management Measures

1. Stormwater management measures for major development shall be developed to meet the erosion control, groundwater recharge, stormwater runoff quantity, and stormwater runoff quality standards in Section 4. To the maximum extent practicable, these standards shall be met by incorporating nonstructural stormwater management strategies into the design. If these strategies alone are not sufficient to meet these standards, structural stormwater management measures necessary to meet these standards shall be incorporated into the design.
2. The standards in this ordinance apply only to new major development and are intended to minimize the impact of stormwater runoff on water quality and water quantity in receiving water bodies and maintain groundwater recharge. The standards do not apply to new major development to the extent that alternative design and performance standards are applicable under a regional stormwater management plan or Water Quality Management Plan adopted in accordance with Department rules.

Note: Alternative standards shall provide at least as much protection from stormwater-related loss of groundwater recharge, stormwater quantity and water quality impacts of major development projects as would be provided under the standards in N.J.A.C. 7:8-5.

Section 4: Stormwater Management Requirements for Major Development

- A. The development shall incorporate a maintenance plan for the stormwater management measures incorporated into the design of a major development in accordance with Section 10.
- B. Stormwater management measures shall avoid adverse impacts of concentrated flow on habitat for threatened and endangered species as documented in the Department' Landscape Project or Natural Heritage Database established under N.J.S.A. 13:1B-15.147 through 15.150, particularly *Helonias bullata* (swamp pink) and/or *Clemmys muhlenbergi* (bog turtle).
- C. The following linear development projects are exempt from the groundwater recharge, stormwater runoff quantity, and stormwater runoff quality requirements of Sections 4.F and 4.G:
 1. The construction of an underground utility line provided that the disturbed areas are revegetated upon completion;
 2. The construction of an aboveground utility line provided that the existing conditions are maintained to the maximum extent practicable; and
 3. The construction of a public pedestrian access, such as a sidewalk or trail with a maximum width of 14 feet, provided that the access is made of permeable material.
- D. A waiver from strict compliance from the groundwater recharge, stormwater runoff quantity, and stormwater runoff quality requirements of Sections 4.F and 4.G may be obtained for the enlargement of an existing public roadway or railroad; or the construction or enlargement of a public pedestrian access, provided that the following conditions are met:

1. The applicant demonstrates that there is a public need for the project that cannot be accomplished by any other means;
2. The applicant demonstrates through an alternatives analysis, that through the use of nonstructural and structural stormwater management strategies and measures, the option selected complies with the requirements of Sections 4.F and 4.G to the maximum extent practicable;
3. The applicant demonstrates that, in order to meet the requirements of Sections 4.F and 4.G, existing structures currently in use, such as homes and buildings, would need to be condemned; and
4. The applicant demonstrates that it does not own or have other rights to areas, including the potential to obtain through condemnation lands not falling under D.3 above within the upstream drainage area of the receiving stream, that would provide additional opportunities to mitigate the requirements of Sections 4.F and 4.G that were not achievable on-site.

E. Nonstructural Stormwater Management Strategies

1. To the maximum extent practicable, the standards in Sections 4.F and 4.G shall be met by incorporating nonstructural stormwater management strategies set forth at Section 4.E into the design. The applicant shall identify the nonstructural measures incorporated into the design of the project. If the applicant contends that it is not feasible for engineering, environmental, or safety reasons to incorporate any nonstructural stormwater management measures identified in Paragraph 2 below into the design of a particular project, the applicant shall identify the strategy considered and provide a basis for the contention.
2. Nonstructural stormwater management strategies incorporated into site design shall:
 - a. Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss;
 - b. Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces;
 - c. Maximize the protection of natural drainage features and vegetation;
 - d. Minimize the decrease in the "time of concentration" from pre-construction to post construction. "Time of concentration" is defined as the time it takes for runoff to travel from the hydraulically most distant point of the watershed to the point of interest within a watershed;
 - e. Minimize land disturbance including clearing and grading;
 - f. Minimize soil compaction;
 - g. Provide low-maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers and pesticides;
 - h. Provide vegetated open-channel conveyance systems discharging into and through stable vegetated areas;
 - i. Provide other source controls to prevent or minimize the use or exposure of pollutants at the site, in order to prevent or minimize the release of those pollutants into stormwater runoff. Such source controls include, but are not limited to:

- (1) Site design features that help to prevent accumulation of trash and debris in drainage systems, including features that satisfy Section 4.E.3. below;
 - (2) Site design features that help to prevent discharge of trash and debris from drainage systems;
 - (3) Site design features that help to prevent and/or contain spills or other harmful accumulations of pollutants at industrial or commercial developments; and
 - (4) When establishing vegetation after land disturbance, applying fertilizer in accordance with the requirements established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq., and implementing rules.
3. Site design features identified under Section 4.E.2.i.(2) above shall comply with the following standard to control passage of solid and floatable materials through storm drain inlets. For purposes of this paragraph, "solid and floatable materials" means sediment, debris, trash, and other floating, suspended, or settleable solids. For exemptions to this standard see Section 4.E.3.c below.
- a. Design engineers shall use either of the following grates whenever they use a grate in pavement or another ground surface to collect stormwater from that surface into a storm drain or surface water body under that grate:
 - (1) The New Jersey Department of Transportation (NJDOT) bicycle safe grate, which is described in Chapter 2.4 of the NJDOT Bicycle Compatible Roadways and Bikeways Planning and Design Guidelines (April 1996); or
 - (2) A different grate, if each individual clear space in that grate has an area of no more than seven (7.0) square inches, or is no greater than 0.5 inches across the smallest dimension.

Examples of grates subject to this standard include grates in grate inlets, the grate portion (non-curb-opening portion) of combination inlets, grates on storm sewer manholes, ditch grates, trench grates, and grates of spacer bars in slotted drains. Examples of ground surfaces include surfaces of roads (including bridges), driveways, parking areas, bikeways, plazas, sidewalks, lawns, fields, open channels, and stormwater basin floors.

- b. Whenever design engineers use a curb-opening inlet, the clear space in that curb opening (or each individual clear space, if the curb opening has two or more clear spaces) shall have an area of no more than seven (7.0) square inches, or be no greater than two (2.0) inches across the smallest dimension.
- c. This standard does not apply:
 - (1) Where the review agency determines that this standard would cause inadequate hydraulic performance that could not practicably be overcome by using additional or larger storm drain inlets that meet these standards;
 - (2) Where flows from the water quality design storm as specified in Section 4.G.1 are conveyed through any device (e.g., end of pipe netting facility, manufactured treatment device, or a catch basin hood) that is designed, at a minimum, to prevent delivery of all solid and floatable materials that could not pass through one of the following:
 - (a) A rectangular space four and five-eighths inches long and one and one-half inches wide (this option does not apply for outfall netting facilities); or

- (b) A bar screen having a bar spacing of 0.5 inches.
 - (3) Where flows are conveyed through a trash rack that has parallel bars with one-inch (1") spacing between the bars, to the elevation of the water quality design storm as specified in Section 4.G.1; or
 - (4) Where the New Jersey Department of Environmental Protection determines, pursuant to the New Jersey Register of Historic Places Rules at N.J.A.C. 7:4-7.2(c), that action to meet this standard is an undertaking that constitutes an encroachment or will damage or destroy the New Jersey Register listed historic property.
4. Any land area used as a nonstructural stormwater management measure to meet the performance standards in Sections 4.F and 4.G shall be dedicated to a government agency, subjected to a conservation restriction filed with the appropriate County Clerk's office, or subject to an approved equivalent restriction that ensures that measure or an equivalent stormwater management measure approved by the reviewing agency is maintained in perpetuity.
5. Guidance for nonstructural stormwater management strategies is available in the New Jersey Stormwater Best Management Practices Manual. The BMP Manual may be obtained from the address identified in Section 7, or found on the Department's website at www.njstormwater.org.

F. Erosion Control, Groundwater Recharge and Runoff Quantity Standards

1. This subsection contains minimum design and performance standards to control erosion, encourage and control infiltration and groundwater recharge, and control stormwater runoff quantity impacts of major development.
- a. The minimum design and performance standards for erosion control are those established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq. and implementing rules.
 - b. The minimum design and performance standards for groundwater recharge are as follows:
 - (1) The design engineer shall, using the assumptions and factors for stormwater runoff and groundwater recharge calculations at Section 5, either:
 - (a) Demonstrate through hydrologic and hydraulic analysis that the site and its stormwater management measures maintain 100 percent of the average annual pre-construction groundwater recharge volume for the site; or
 - (b) Demonstrate through hydrologic and hydraulic analysis that the increase of stormwater runoff volume from pre-construction to post-construction for the 2-year storm is infiltrated.
 - (2) This groundwater recharge requirement does not apply to projects within the "urban redevelopment area," or to projects subject to (3) below.
 - (3) The following types of stormwater shall not be recharged:
 - (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 applied, areas where pesticides 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; areas where recharge would be inconsistent with Department approved remedial action work plan or landfill closure plan and areas with high risks for spills of toxic materials, such as gas stations and vehicle maintenance facilities; and

- (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 groundwater. 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.
 - (4) The design engineer shall assess the hydraulic impact on the groundwater table and design the site so as to avoid adverse hydraulic impacts. Potential adverse hydraulic impacts include, but are not limited to, exacerbating a naturally or seasonally high water table so as to cause surficial ponding, flooding of basements, or interference with the proper operation of subsurface sewage disposal systems and other subsurface structures in the vicinity or downgradient of the groundwater recharge area.
- c. In order to control stormwater runoff quantity impacts, the design engineer shall, using the assumptions and factors for stormwater runoff calculations at Section 5, complete one of the following:
- (1) Demonstrate through hydrologic and hydraulic analysis that for stormwater leaving the site, post-construction runoff hydrographs for the two, 10, and 100-year storm events do not exceed, at any point in time, the pre-construction runoff hydrographs for the same storm events;
 - (2) Demonstrate through hydrologic and hydraulic analysis that there is no increase, as compared to the pre-construction condition, in the peak runoff rates of stormwater leaving the site for the two, 10, and 100-year storm events and that the increased volume or change in timing of stormwater runoff will not increase flood damage at or downstream of the site. This analysis shall include the analysis of impacts of existing land uses and projected land uses assuming full development under existing zoning and land use ordinances in the drainage area;
 - (3) Design stormwater management measures so that the post-construction peak runoff rates for the 2, 10 and 100 year storm events are 50, 75 and 80 percent, respectively, of the pre-construction peak runoff rates. The percentages apply only to the post-construction stormwater runoff that is attributable to the portion of the site on which the proposed development or project is to be constructed. The percentages shall not be applied to post-construction stormwater runoff into tidal flood hazard areas if the increased volume of stormwater runoff will not increase flood damages below the point of discharge; or
 - (4) In tidal flood hazard areas, stormwater runoff quantity analysis in accordance with (1), (2) and (3) above shall only be applied if the increased volume of stormwater runoff could increase flood damages below the point of discharge.

2. Any application for a new agricultural development that meets the definition of major development at Section 2 shall be submitted to the appropriate Soil Conservation District for review and approval in accordance with the requirements of this section and any applicable Soil Conservation District guidelines for stormwater runoff quantity and erosion control. For the purposes of this section, “agricultural development” means land uses normally associated with the production of food, fiber and livestock for sale. Such uses do not include the development of land for the processing or sale of food and the manufacturing of agriculturally related products.

G. Stormwater Runoff Quality Standards

1. Stormwater management measures shall be designed to reduce the post-construction load of total suspended solids (TSS) in stormwater runoff by 80 percent of the anticipated load from the developed site, expressed as an annual average. Stormwater management measures shall only be required for water quality control if an additional 1/4 acre of impervious surface is being proposed on a development site. The requirement to reduce TSS does not apply to any stormwater runoff in a discharge regulated under a numeric effluent limitation for TSS imposed under the New Jersey Pollution Discharge Elimination System (NJPDES) rules, N.J.A.C. 7:14A, or in a discharge specifically exempt under a NJPDES permit from this requirement. The water quality design storm is 1.25 inches of rainfall in two hours. Water quality calculations shall take into account the distribution of rain from the water quality design storm, as reflected in Table 1. The calculation of the volume of runoff may take into account the implementation of non-structural and structural stormwater management measures.

Table 1: Water Quality Design Storm Distribution			
Time (Minutes)	Cumulative Rainfall (Inches)	Time (Minutes)	Cumulative Rainfall (Inches)
0	0.0000	65	0.8917
5	0.0083	70	0.9917
10	0.0166	75	1.0500
15	0.0250	80	1.0840
20	0.0500	85	1.1170
25	0.0750	90	1.1500
30	0.1000	95	1.1750
35	0.1330	100	1.2000
40	0.1660	105	1.2250
45	0.2000	110	1.2334
50	0.2583	115	1.2417
55	0.3583	120	1.2500
60	0.6250		

2. For purposes of TSS reduction calculations, Table 2 below presents the presumed removal rates for certain BMPs designed in accordance with the New Jersey Stormwater Best Management Practices Manual. The BMP Manual may be obtained from the address identified in Section 7, or found on the Department’s website at www.njstormwater.org. The BMP Manual and other sources of technical guidance are listed in Section 7. TSS reduction shall be calculated based on the removal rates for the BMPs in Table 2 below. Alternative removal rates and methods of calculating removal rates may be used if the design engineer provides documentation demonstrating the capability of these alternative rates and methods to the review agency. A copy of any approved alternative rate or method of calculating the removal rate shall be provided to the Department at the following address: Division of Watershed Management, New Jersey Department of Environmental Protection, PO Box 418 Trenton, New Jersey, 08625-0418.
3. If more than one BMP in series is necessary to achieve the required 80 percent TSS reduction for a site, the applicant shall utilize the following formula to calculate TSS reduction:

$$R = A + B - (AXB)/100$$

Where

R = total TSS percent load removal from application of both BMPs, and

A = the TSS percent removal rate applicable to the first BMP

B = the TSS percent removal rate applicable to the second BMP

Table 2: TSS Removal Rates for BMPs	
Best Management Practice	TSS Percent Removal Rate
Bioretention Systems	90
Constructed Stormwater Wetland	90
Extended Detention Basin	40-60
Infiltration Structure	80
Manufactured Treatment Device	See Section 6.C
Sand Filter	80
Vegetative Filter Strip	60-80
Wet Pond	50-90

4. If there is more than one onsite drainage area, the 80 percent TSS removal rate shall apply to each drainage area, unless the runoff from the subareas converge on site in which case the removal rate can be demonstrated through a calculation using a weighted average.
5. Stormwater management measures shall also be designed to reduce, to the maximum extent feasible, the post-construction nutrient load of the anticipated load from the developed site in stormwater runoff generated from the water quality design storm. In achieving reduction of nutrients to the maximum extent feasible, the design of the site shall include nonstructural strategies and structural

measures that optimize nutrient removal while still achieving the performance standards in Sections 4.F and 4.G.

6. Additional information and examples are contained in the New Jersey Stormwater Best Management Practices Manual, which may be obtained from the address identified in Section 7.
7. In accordance with the definition of FW1 at N.J.A.C. 7:9B-1.4, stormwater management measures shall be designed to prevent any increase in stormwater runoff to waters classified as FW1.
8. Special water resource protection areas shall be established along all waters designated Category One at N.J.A.C. 7:9B, and perennial or intermittent streams that drain into or upstream of the Category One waters as shown on the USGS Quadrangle Maps or in the County Soil Surveys, within the associated HUC14 drainage area. These areas shall be established for the protection of water quality, aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, and exceptional fisheries significance of those established Category One waters. These areas shall be designated and protected as follows:
 - a. The applicant shall preserve and maintain a special water resource protection area in accordance with one of the following:
 - (1) A 300-foot special water resource protection area shall be provided on each side of the waterway, measured perpendicular to the waterway from the top of the bank outwards or from the centerline of the waterway where the bank is not defined, consisting of existing vegetation or vegetation allowed to follow natural succession is provided. (2) Encroachment within the designated special water resource protection area under Subsection (1) above shall only be allowed where previous development or disturbance has occurred (for example, active agricultural use, parking area or maintained lawn area). The encroachment shall only be allowed where applicant demonstrates that the functional value and overall condition of the special water resource protection area will be maintained to the maximum extent practicable. In no case shall the remaining special water resource protection area be reduced to less than 150 feet as measured perpendicular to the top of bank of the waterway or centerline of the waterway where the bank is undefined. All encroachments proposed under this subparagraph shall be subject to review and approval by the Department.
 - b. All stormwater shall be discharged outside of and flow through the special water resource protection area and shall comply with the Standard for Off-Site Stability in the "Standards For Soil Erosion and Sediment Control in New Jersey," established under the Soil Erosion and Sediment Control Act , N.J.S.A. 4:24-39 et seq.
 - c. If stormwater discharged outside of and flowing through the special water resource protection area cannot comply with the Standard For Off-Site Stability in the "Standards for Soil Erosion and Sediment Control in New Jersey," established under the Soil Erosion and Sediment Control Act , N.J.S.A. 4:24-39 et seq., then the stabilization measures in accordance with the requirements of the above standards may be placed within the special water resource protection area, provided that:
 - (1) Stabilization measures shall not be placed within 150 feet of the Category One waterway;
 - (2) Stormwater associated with discharges allowed by this section shall achieve a 95 percent TSS post-construction removal rate;
 - (3) Temperature shall be addressed to ensure no impact on the receiving waterway;

- (4) The encroachment shall only be allowed where the applicant demonstrates that the functional value and overall condition of the special water resource protection area will be maintained to the maximum extent practicable;
 - (5) A conceptual project design meeting shall be held with the appropriate Department staff and Soil Conservation District staff to identify necessary stabilization measures; and
 - (6) All encroachments proposed under this section shall be subject to review and approval by the Department.
- d. A stream corridor protection plan may be developed by a regional stormwater management planning committee as an element of a regional stormwater management plan, or by a municipality through an adopted municipal stormwater management plan. If a stream corridor protection plan for a waterway subject to Section 4.G(8) has been approved by the Department of Environmental Protection, then the provisions of the plan shall be the applicable special water resource protection area requirements for that waterway. A stream corridor protection plan for a waterway subject to G.8 shall maintain or enhance the current functional value and overall condition of the special water resource protection area as defined in G.8.a.(1) above. In no case shall a stream corridor protection plan allow the reduction of the Special Water Resource Protection Area to less than 150 feet as measured perpendicular to the waterway subject to this subsection.
- e. Paragraph G.8 does not apply to the construction of one individual single family dwelling that is not part of a larger development on a lot receiving preliminary or final subdivision approval on or before February 2, 2004 , provided that the construction begins on or before February 2, 2009.

Section 5: Calculation of Stormwater Runoff and Groundwater Recharge

A. Stormwater runoff shall be calculated in accordance with the following:

1. The design engineer shall calculate runoff using one of the following methods:
 - a. The USDA Natural Resources Conservation Service (NRCS) methodology, including the NRCS Runoff Equation and Dimensionless Unit Hydrograph, as described in the NRCS National Engineering Handbook Section 4 – Hydrology and Technical Release 55 – Urban Hydrology for Small Watersheds; or
 - b. The Rational Method for peak flow and the Modified Rational Method for hydrograph computations.
2. For the purpose of calculating runoff coefficients and groundwater recharge, there is a presumption that the pre-construction condition of a site or portion thereof is a wooded land use with good hydrologic condition. The term “runoff coefficient” applies to both the NRCS methodology at Section 5.A.1.a and the Rational and Modified Rational Methods at Section 5.A.1.b. A runoff coefficient or a groundwater recharge land cover for an existing condition may be used on all or a portion of the site if the design engineer verifies that the hydrologic condition has existed on the site or portion of the site for at least five years without interruption prior to the time of application. If more than one land cover have existed on the site during the five years immediately prior to the time of application, the land cover with the lowest runoff potential shall be used for the computations. In addition, there is the presumption that the site is in good hydrologic condition (if the land use type is pasture, lawn, or park), with good cover (if the land use type is woods), or with good hydrologic condition and conservation treatment (if the land use type is cultivation).

3. In computing pre-construction stormwater runoff, the design engineer shall account for all significant land features and structures, such as ponds, wetlands, depressions, hedgerows, or culverts, that may reduce pre-construction stormwater runoff rates and volumes.
 4. In computing stormwater runoff from all design storms, the design engineer shall consider the relative stormwater runoff rates and/or volumes of pervious and impervious surfaces separately to accurately compute the rates and volume of stormwater runoff from the site. To calculate runoff from unconnected impervious cover, urban impervious area modifications as described in the NRCS Technical Release 55 – Urban Hydrology for Small Watersheds and other methods may be employed.
 5. If the invert of the outlet structure of a stormwater management measure is below the flood hazard design flood elevation as defined at N.J.A.C. 7:13, the design engineer shall take into account the effects of tailwater in the design of structural stormwater management measures.
- B. Groundwater recharge may be calculated in accordance with the following:
1. The New Jersey Geological Survey Report GSR-32 A Method for Evaluating Ground-Water Recharge Areas in New Jersey, incorporated herein by reference as amended and supplemented. Information regarding the methodology is available from the New Jersey Stormwater Best Management Practices Manual; at <http://www.state.nj.us/dep/njgs/>; or at New Jersey Geological Survey, 29 Arctic Parkway, P.O. Box 427 Trenton, New Jersey 08625-0427; (609) 984-6587.

Section 6: Standards for Structural Stormwater Management Measures

- A. Standards for structural stormwater management measures are as follows:
1. Structural stormwater management measures shall be designed to take into account the existing site conditions, including, for example, environmentally critical areas, wetlands; flood-prone areas; slopes; depth to seasonal high water table; soil type, permeability and texture; drainage area and drainage patterns; and the presence of solution-prone carbonate rocks (limestone).
 2. Structural stormwater management measures shall be designed to minimize maintenance, facilitate maintenance and repairs, and ensure proper functioning. Trash racks shall be installed at the intake to the outlet structure as appropriate, and shall have parallel bars with one-inch (1") spacing between the bars to the elevation of the water quality design storm. For elevations higher than the water quality design storm, the parallel bars at the outlet structure shall be spaced no greater than one-third (1/3) the width of the diameter of the orifice or one-third (1/3) the width of the weir, with a minimum spacing between bars of one-inch and a maximum spacing between bars of six inches. In addition, the design of trash racks must comply with the requirements of Section 8.D.
 3. Structural stormwater management measures shall be designed, constructed, and installed to be strong, durable, and corrosion resistant. Measures that are consistent with the relevant portions of the Residential Site Improvement Standards at N.J.A.C. 5:21-7.3, 7.4, and 7.5 shall be deemed to meet this requirement.
 4. At the intake to the outlet from the stormwater management basin, the orifice size shall be a minimum of two and one-half inches in diameter.
 5. Stormwater management basins shall be designed to meet the minimum safety standards for stormwater management basins at Section 8.

- B. Stormwater management measure guidelines are available in the New Jersey Stormwater Best Management Practices Manual. Other stormwater management measures may be utilized provided the design engineer demonstrates that the proposed measure and its design will accomplish the required water quantity, groundwater recharge and water quality design and performance standards established by Section 4 of this ordinance.
- C. Manufactured treatment devices may be used to meet the requirements of Section 4 of this ordinance, provided the pollutant removal rates are verified by the New Jersey Corporation for Advanced Technology and certified by the Department.

Section 7: Sources for Technical Guidance

- A. Technical guidance for stormwater management measures can be found in the documents listed at 1 and 2 below, which are available from Maps and Publications, New Jersey Department of Environmental Protection, 428 East State Street, P.O. Box 420, Trenton, New Jersey, 08625; telephone (609) 777-1038.
1. Guidelines for stormwater management measures are contained in the New Jersey Stormwater Best Management Practices Manual, as amended. Information is provided on stormwater management measures such as: bioretention systems, constructed stormwater wetlands, dry wells, extended detention basins, infiltration structures, manufactured treatment devices, pervious paving, sand filters, vegetative filter strips, and wet ponds.
 2. The New Jersey Department of Environmental Protection Stormwater Management Facilities Maintenance Manual, as amended.
- B. Additional technical guidance for stormwater management measures can be obtained from the following:
1. The "Standards for Soil Erosion and Sediment Control in New Jersey" promulgated by the State Soil Conservation Committee and incorporated into N.J.A.C. 2:90. Copies of these standards may be obtained by contacting the State Soil Conservation Committee or any of the Soil Conservation Districts listed in N.J.A.C. 2:90-1.3(a)4. The location, address, and telephone number of each Soil Conservation District may be obtained from the State Soil Conservation Committee, P.O. Box 330, Trenton, New Jersey 08625; (609) 292-5540;
 2. The Rutgers Cooperative Extension Service, 732-932-9306; and
 3. The Soil Conservation Districts listed in N.J.A.C. 2:90-1.3(a)4. The location, address, and telephone number of each Soil Conservation District may be obtained from the State Soil Conservation Committee, P.O. Box 330, Trenton, New Jersey, 08625, (609) 292-5540.

Section 8: Safety Standards for Stormwater Management Basins

A. This section sets forth requirements to protect public safety through the proper design and operation of stormwater management basins. This section applies to any new stormwater management basin.

Note: The provisions of this section are not intended to preempt more stringent municipal or county safety requirements for new or existing stormwater management basins. Municipal and county stormwater management plans and ordinances may, pursuant to their authority, require existing stormwater management basins to be retrofitted to meet one or more of the safety standards in Sections 8.B.1, 8.B.2, and 8.B.3 for trash racks, overflow grates, and escape provisions at outlet structures.

B. Requirements for Trash Racks, Overflow Grates and Escape Provisions

1. A trash rack is a device designed to catch trash and debris and prevent the clogging of outlet structures. Trash racks shall be installed at the intake to the outlet from the stormwater management basin to ensure proper functioning of the basin outlets in accordance with the following:
 - a. The trash rack shall have parallel bars, with no greater than six inch spacing between the bars.
 - b. The trash rack shall be designed so as not to adversely affect the hydraulic performance of the outlet pipe or structure.
 - c. The average velocity of flow through a clean trash rack is not to exceed 2.5 feet per second under the full range of stage and discharge. Velocity is to be computed on the basis of the net area of opening through the rack.
 - d. The trash rack shall be constructed and installed to be rigid, durable, and corrosion resistant, and shall be designed to withstand a perpendicular live loading of 300 lbs/ft sq.
2. An overflow grate is designed to prevent obstruction of the overflow structure. If an outlet structure has an overflow grate, such grate shall meet the following requirements:
 - a. The overflow grate shall be secured to the outlet structure but removable for emergencies and maintenance.
 - b. The overflow grate spacing shall be no less than two inches across the smallest dimension.
 - c. The overflow grate shall be constructed and installed to be rigid, durable, and corrosion resistant, and shall be designed to withstand a perpendicular live loading of 300 lbs./ft sq.
3. For purposes of this paragraph 3, escape provisions means the permanent installation of ladders, steps, rungs, or other features that provide easily accessible means of egress from stormwater management basins. Stormwater management basins shall include escape provisions as follows:
 - a. If a stormwater management basin has an outlet structure, escape provisions shall be incorporated in or on the structure. With the prior approval of the reviewing agency identified in Section 8.C a free-standing outlet structure may be exempted from this requirement.
 - b. Safety ledges shall be constructed on the slopes of all new stormwater management basins having a permanent pool of water deeper than two and one-half feet. Such safety ledges shall be comprised of two steps. Each step shall be four to six feet in width. One step shall be located approximately two and one-half feet below the permanent water surface, and the second step shall be located one to

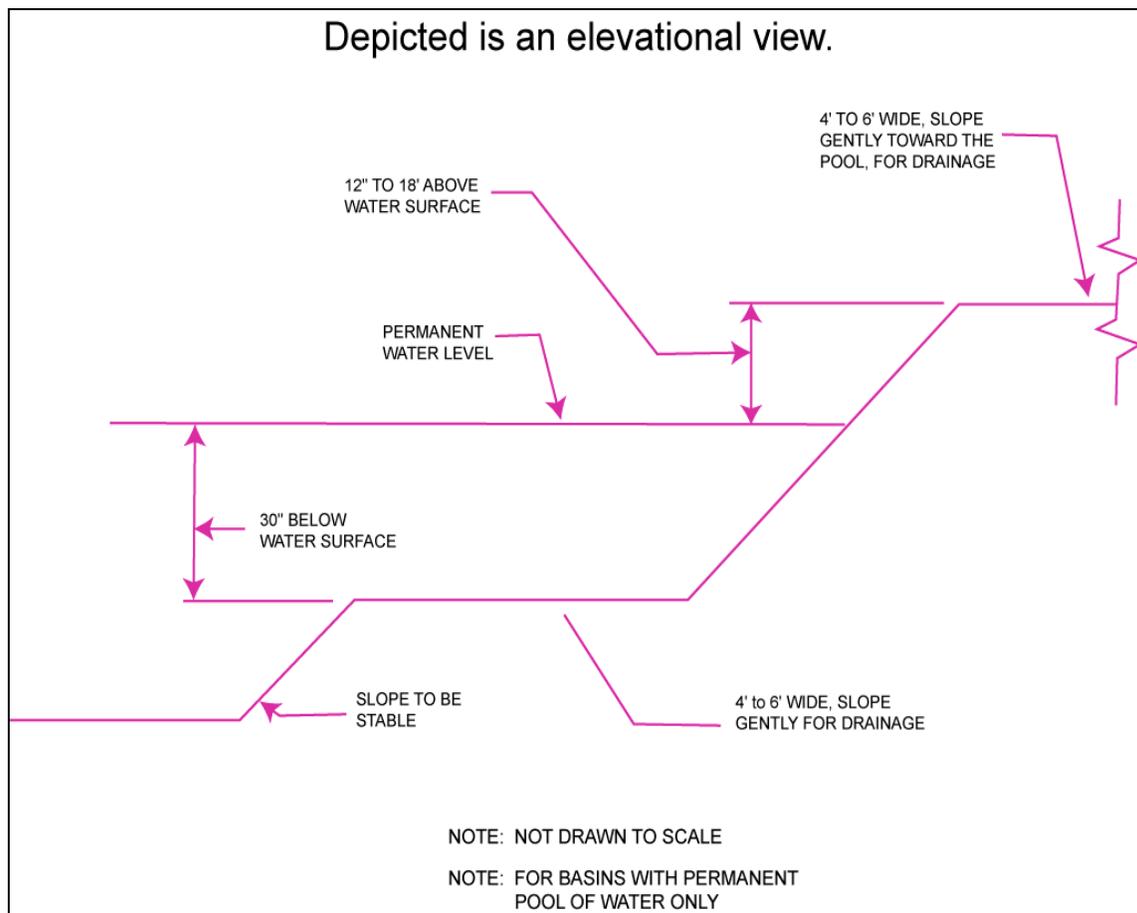
one and one-half feet above the permanent water surface. See Section 8.D for an illustration of safety ledges in a stormwater management basin.

c. In new stormwater management basins, the maximum interior slope for an earthen dam, embankment, or berm shall not be steeper than 3 horizontal to 1 vertical.

C. Variance or Exemption from Safety Standards

1. A variance or exemption from the safety standards for stormwater management basins may be granted only upon a written finding by the appropriate reviewing agency (municipality, county or Department) that the variance or exemption will not constitute a threat to public safety.

D. Illustration of Safety Ledges in a New Stormwater Management Basin



Section 9: Requirements for a Site Development Stormwater Plan

A. Submission of Site Development Stormwater Plan

1. Whenever an applicant seeks municipal approval of a development subject to this ordinance, the applicant shall submit all of the required components of the Checklist for the Site Development Stormwater Plan at Section 9.C below as part of the submission of the applicant's application for subdivision or site plan approval.
2. The applicant shall demonstrate that the project meets the standards set forth in this ordinance.
3. The applicant shall submit [*specify number*] copies of the materials listed in the checklist for site development stormwater plans in accordance with Section 9.C of this ordinance.

B. Site Development Stormwater Plan Approval

The applicant's Site Development project shall be reviewed as a part of the subdivision or site plan review process by the municipal board or official from which municipal approval is sought. That municipal board or official shall consult the engineer retained by the Planning and/or Zoning Board (as appropriate) to determine if all of the checklist requirements have been satisfied and to determine if the project meets the standards set forth in this ordinance.

C. Checklist Requirements

The following information shall be required:

1. Topographic Base Map

The reviewing engineer may require upstream tributary drainage system information as necessary. It is recommended that the topographic base map of the site be submitted which extends a minimum of 200 feet beyond the limits of the proposed development, at a scale of 1"=200' or greater, showing 2-foot contour intervals. The map as appropriate may indicate the following: existing surface water drainage, shorelines, steep slopes, soils, erodible soils, perennial or intermittent streams that drain into or upstream of the Category One waters, wetlands and flood plains along with their appropriate buffer strips, marshlands and other wetlands, pervious or vegetative surfaces, existing man-made structures, roads, bearing and distances of property lines, and significant natural and manmade features not otherwise shown.

2. Environmental Site Analysis

A written and graphic description of the natural and man-made features of the site and its environs. This description should include a discussion of soil conditions, slopes, wetlands, waterways and vegetation on the site. Particular attention should be given to unique, unusual, or environmentally sensitive features and to those that provide particular opportunities or constraints for development.

3. Project Description and Site Plan(s)

A map (or maps) at the scale of the topographical base map indicating the location of existing and proposed buildings, roads, parking areas, utilities, structural facilities for stormwater management and sediment control, and other permanent structures. The map(s) shall also clearly show areas where alterations occur in the natural terrain and cover, including lawns and other landscaping, and seasonal

high ground water elevations. A written description of the site plan and justification of proposed changes in natural conditions may also be provided.

4. Land Use Planning and Source Control Plan

This plan shall provide a demonstration of how the goals and standards of Sections 3 through 6 are being met. The focus of this plan shall be to describe how the site is being developed to meet the objective of controlling groundwater recharge, stormwater quality and stormwater quantity problems at the source by land management and source controls whenever possible.

5. Stormwater Management Facilities Map

The following information, illustrated on a map of the same scale as the topographic base map, shall be included:

- a. Total area to be paved or built upon, proposed surface contours, land area to be occupied by the stormwater management facilities and the type of vegetation thereon, and details of the proposed plan to control and dispose of stormwater.
- b. Details of all stormwater management facility designs, during and after construction, including discharge provisions, discharge capacity for each outlet at different levels of detention and emergency spillway provisions with maximum discharge capacity of each spillway.

6. Calculations

- a. Comprehensive hydrologic and hydraulic design calculations for the pre-development and post-development conditions for the design storms specified in Section 4 of this ordinance.
- b. When the proposed stormwater management control measures (e.g., infiltration basins) depends on the hydrologic properties of soils, then a soils report shall be submitted. The soils report shall be based on onsite boring logs or soil pit profiles. The number and location of required soil borings or soil pits shall be determined based on what is needed to determine the suitability and distribution of soils present at the location of the control measure.

7. Maintenance and Repair Plan

The design and planning of the stormwater management facility shall meet the maintenance requirements of Section 10.

8. Waiver from Submission Requirements

The municipal official or board reviewing an application under this ordinance may, in consultation with the municipal engineer, waive submission of any of the requirements in Sections 9.C.1 through 9.C.6 of this ordinance when it can be demonstrated that the information requested is impossible to obtain or it would create a hardship on the applicant to obtain and its absence will not materially affect the review process.

Section 10: Maintenance and Repair

A. Applicability

1. Projects subject to review as in Section 1.C of this ordinance shall comply with the requirements of Sections 10.B and 10.C.

B. General Maintenance

1. The design engineer shall prepare a maintenance plan for the stormwater management measures incorporated into the design of a major development.
2. The maintenance plan shall contain specific preventative maintenance tasks and schedules; cost estimates, including estimated cost of sediment, debris, or trash removal; and the name, address, and telephone number of the person or persons responsible for preventative and corrective maintenance (including replacement). Maintenance guidelines for stormwater management measures are available in the New Jersey Stormwater Best Management Practices Manual. If the maintenance plan identifies a person other than the developer (for example, a public agency or homeowners' association) as having the responsibility for maintenance, the plan shall include documentation of such person's agreement to assume this responsibility, or of the developer's obligation to dedicate a stormwater management facility to such person under an applicable ordinance or regulation.
3. Responsibility for maintenance shall not be assigned or transferred to the owner or tenant of an individual property in a residential development or project, unless such owner or tenant owns or leases the entire residential development or project.
4. If the person responsible for maintenance identified under Section 10.B.2 above is not a public agency, the maintenance plan and any future revisions based on Section 10.B.7 below shall be recorded upon the deed of record for each property on which the maintenance described in the maintenance plan must be undertaken.
5. Preventative and corrective maintenance shall be performed to maintain the function of the stormwater management measure, including repairs or replacement to the structure; removal of sediment, debris, or trash; restoration of eroded areas; snow and ice removal; fence repair or replacement; restoration of vegetation; and repair or replacement of nonvegetated linings.
6. The person responsible for maintenance identified under Section 10.B.2 above shall maintain a detailed log of all preventative and corrective maintenance for the structural stormwater management measures incorporated into the design of the development, including a record of all inspections and copies of all maintenance-related work orders.
7. The person responsible for maintenance identified under Section 10.B.2 above shall evaluate the effectiveness of the maintenance plan at least once per year and adjust the plan and the deed as needed.
8. The person responsible for maintenance identified under Section 10.B.2 above shall retain and make available, upon request by any public entity with administrative, health, environmental, or safety authority over the site, the maintenance plan and the documentation required by Sections 10.B.6 and 10.B.7 above.

9. The requirements of Sections 10.B.3 and 10.B.4 do not apply to stormwater management facilities that are dedicated to and accepted by the municipality or another governmental agency.

(Note: It may be appropriate to delete requirements in the maintenance and repair plan that are not applicable if the ordinance requires the facility to be dedicated to the municipality. If the municipality does not want to take this responsibility, the ordinance should require the posting of a two year maintenance guarantee in accordance with N.J.S.A. 40:55D-53. Guidelines for developing a maintenance and inspection program are provided in the New Jersey Stormwater Best Management Practices Manual and the NJDEP Ocean County Demonstration Study, Stormwater Management Facilities Maintenance Manual, dated June 1989 available from the NJDEP, Watershed Management Program.)

10. In the event that the stormwater management facility becomes a danger to public safety or public health, or if it is in need of maintenance or repair, the municipality shall so notify the responsible person in writing. Upon receipt of that notice, the responsible person shall have fourteen (14) days to effect maintenance and repair of the facility in a manner that is approved by the municipal engineer or his designee. The municipality, in its discretion, may extend the time allowed for effecting maintenance and repair for good cause. If the responsible person fails or refuses to perform such maintenance and repair, the municipality or County may immediately proceed to do so and shall bill the cost thereof to the responsible person.

- B. Nothing in this section shall preclude the municipality in which the major development is located from requiring the posting of a performance or maintenance guarantee in accordance with N.J.S.A. 40:55D-53.

Section 11: Penalties

Any person who erects, constructs, alters, repairs, converts, maintains, or uses any building, structure or land in violation of this ordinance shall be subject to the following penalties: *[Municipality to specify]*.

Section 12: Effective Date

This ordinance shall take effect immediately upon the approval by the county review agency, or sixty (60) days from the receipt of the ordinance by the county review agency if the county review agency should fail to act.

Section 13: Severability

If the provisions of any section, subsection, paragraph, subdivision, or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any section, subsection, paragraph, subdivision, or clause of this ordinance.