



**2000 MARYLAND  
STORMWATER DESIGN MANUAL  
VOLUMES I & II**

**PREPARED BY:**



ELLICOTT CITY, MARYLAND

**AND THE**



**MARYLAND DEPARTMENT OF THE ENVIRONMENT**

**WATER MANAGEMENT ADMINISTRATION**

2500 BROENING HIGHWAY • BALTIMORE MARYLAND 21224

(410) 631-3543 1-800-633-6101 <http://www.mde.state.md.us>





# Table of Contents

## Maryland Stormwater Design Manual

---

### VOLUME ONE

---

	Page
List of Tables .....	<i>i</i>
List of Figures .....	<i>ii</i>
Preface .....	<i>iv</i>

#### **Chapter 1: Introduction to the Manual**

1.0	Purpose of Manual .....	1.1
1.1	Why Stormwater Matters: Impact of Runoff on Maryland Watersheds .....	1.3
	1.1.1 Declining Water Quality .....	1.5
	1.1.2 Diminishing Groundwater Recharge and Quality .....	1.7
	1.1.3 Degradation of Stream Channels .....	1.8
	1.1.4 Increased Overbank Flooding.....	1.10
	1.1.5 Floodplain Expansion .....	1.11
1.2	General Performance Standards for Stormwater Management in Maryland.....	1.13
1.3	How to Use the Manual.....	1.16
	1.3.1 Volume One.....	1.16
	1.3.2 Volume Two (Appendices) .....	1.17
1.4	Revising the Manual.....	1.19
1.5	What's New .....	1.19
1.6	Symbols and Acronyms .....	1.21

#### **Chapter 2: Unified Stormwater Sizing Criteria**

2.0	Unified Stormwater Sizing Criteria .....	2.1
2.1	Water Quality Volume (WQ <sub>v</sub> ) .....	2.2
2.2	Recharge Volume Requirements (Re <sub>v</sub> ) .....	2.5
2.3	Channel Protection Storage Volume Requirements (Cp <sub>v</sub> ).....	2.8
2.4	Overbank Flood Protection Volume Requirements (Qp <sub>2</sub> or Qp <sub>10</sub> ) .....	2.12
2.5	Extreme Flood Volume (Q <sub>f</sub> ).....	2.13
2.6	Design Examples: Computing Stormwater Storage Requirements .....	2.14

2.7	Acceptable Urban BMP Options .....	2.37
2.7.1	Urban BMP Groups .....	2.37
2.7.2	Structural BMPs that do not fully meet the WQ <sub>v</sub> Requirement .....	2.39
2.8	Designation of Stormwater Hotspots .....	2.41

### Chapter 3: Performance Criteria for Urban BMP Design

3.0	Performance Criteria for Urban BMP Design .....	3.1
3.1	Stormwater Ponds.....	3.2
3.1.1	Pond Feasibility Criteria.....	3.8
3.1.2	Pond Conveyance Criteria.....	3.9
3.1.3	Pond Pretreatment Criteria.....	3.10
3.1.4	Pond Treatment Criteria .....	3.10
3.1.5	Pond Landscaping Criteria .....	3.11
3.1.6	Pond Maintenance Criteria .....	3.12
3.2	Stormwater Wetlands.....	3.16
3.2.1	Wetland Feasibility Criteria.....	3.21
3.2.2	Wetland Conveyance Criteria.....	3.21
3.2.3	Wetland Pretreatment Criteria .....	3.21
3.2.4	Wetland Treatment Criteria .....	3.21
3.2.5	Wetland Landscaping Criteria .....	3.22
3.2.6	Wetland Maintenance Criteria .....	3.24
3.3	Stormwater Infiltration .....	3.25
3.3.1	Infiltration Feasibility Criteria .....	3.28
3.3.2	Infiltration Conveyance Criteria.....	3.28
3.3.3	Infiltration Pretreatment Criteria .....	3.29
3.3.4	Infiltration Treatment Criteria .....	3.30
3.3.5	Infiltration Landscaping Criteria .....	3.30
3.3.6	Infiltration Maintenance Criteria .....	3.30
3.4	Stormwater Filtering Systems.....	3.31
3.4.1	Filtering Feasibility Criteria .....	3.38
3.4.2	Filtering Conveyance Criteria .....	3.38
3.4.3	Filtering Pretreatment Criteria.....	3.38
3.4.4	Filtering Treatment Criteria.....	3.39
3.4.5	Filtering Landscaping Criteria.....	3.40
3.4.6	Filtering Maintenance Criteria.....	3.41
3.5	Open Channel Systems.....	3.42
3.5.1	Open Channel Feasibility Criteria .....	3.45
3.5.2	Open Channel Conveyance Criteria .....	3.45
3.5.3	Open Channel Pretreatment Criteria.....	3.45

3.5.4	Open Channel Treatment Criteria .....	3.46
3.5.5	Open Channel Landscaping Criteria .....	3.46
3.5.6	Open Channel Maintenance Criteria .....	3.46

#### **Chapter 4: A Guide to BMP Selection and Location in the State of Maryland**

4.0	Selecting the Best BMP at a Site .....	4.1
4.1	Watershed Factors .....	4.3
4.2	Terrain Factors .....	4.6
4.3	Stormwater Treatment Suitability .....	4.8
4.4	Physical Feasibility Factors .....	4.10
4.5	Community and Environmental Factors .....	4.12
4.6	Checklist: Location/Permitting Factors .....	4.14

#### **Chapter 5: Stormwater Credits for Innovative Site Planning**

5.0	Stormwater Credits .....	5.1
5.1	Credit 1. Natural Area Conservation Credit .....	5.3
5.2	Credit 2. Disconnection of Rooftop Runoff Credit .....	5.6
5.3	Credit 3. Disconnection of Non Rooftop Runoff Credit .....	5.9
5.4	Credit 4. Sheetflow to Buffer Credit .....	5.11
5.5	Credit 5. Grass Channel Credit .....	5.14
5.6	Credit 6. Environmentally Sensitive Development Credit .....	5.17
5.7	Dealing With Multiple Credits .....	5.19
5.8	Other Strategies to Reduce Impervious Cover .....	5.19

<b>Glossary .....</b>	<b>G.1</b>
-----------------------	------------

<b>References .....</b>	<b>R.1</b>
-------------------------	------------

---

**VOLUME TWO: APPENDICES**


---

**Appendix A: Landscaping Guidance for Stormwater BMPs**

A.1	General Landscaping Guidance for All Stormwater BMPs .....	A.2
A.2	Specific Landscaping Criteria for BMP Groups .....	A.4
	A.2.1 Ponds and Wetlands .....	A.4
	A.2.2 Infiltration and Filter Systems .....	A.12
	A.2.3 Bioretention .....	A.12
	A.2.4 Open Channels .....	A.18
	A.2.5 Filter Strips and Stream Buffer .....	A.18
A.3	Plant Selection for Stormwater Facilities .....	A.19
	A.3.1 Hardiness Zones .....	A.19
	A.3.2 Physiographic Provinces .....	A.21
	A.3.3 Hydrologic Zones .....	A.25
	A.3.3 Other Considerations in Stormwater BMP Landscaping .....	A.26
A.4	Stormwater Plant List .....	A.27
A.5	References .....	A.49

**Appendix B: BMP Construction Specifications**

B.1	NRCS-MD Code No 378 Pond Standards/ Specifications .....	B.1
	B.1.1 Supplemental Pond and Wetland Stormwater Specifications .....	B.1.1.1
	B.1.2 MDE Dam Safety Small Pond Review Criteria .....	B.1.2.1
B.2	Construction Specifications for Infiltration Practices .....	B.2.1
B.3	Construction Specifications for Bioretention, Sand Filters, and Open Channels ....	B.3.1

**Appendix C: Step-by-Step Design Examples**

C.1	Shallow Wetland Design Example .....	C.1.1
C.2	Design Example 2 – Water Quality BMPs .....	C.2.1
	C.2.1 Design Criteria .....	C.2.2
	C.2.2 Preliminary Design .....	C.2.2
	C.2.3 BMP Design Option 1 .....	C.2.8
	C-2.3.1 Perimeter Sand Filter (F-3) .....	C.2.8
	C-2.3.2 Pocket Sand Filter (F-5) .....	C.2.12
	C.2.4 BMP Design Option 2 .....	C.2.16
	C.2.4.1 Bioretention System (F-6) .....	C.2.17
	C.2.4.2 Infiltration Trench (I-1) .....	C.2.18

C.2.5 BMP Design Option 3.....	C.2.21
C.2.5.1 Dry Swale (O-1).....	C.2.21

#### **Appendix D: Assorted Design Tools**

D.1 Testing Requirements for Infiltration, Bioretention, and Sand Filter Subsoils.....	D.1.1
D.2 Geotechnical Methods for Karst Feasibility Testing.....	D.2.1
D.3 Short Cut Method for a Wetland Drawdown Assessment.....	D.3.1
D.4 Stormwater Criteria for the Maryland Critical Area IDA Zone.....	D.4.1
D.5 Documentation of BMP Ability to Meet the 80% TSS Removal Requirement.....	D.5.1
D.6 Industrial Stormwater NPDES Permit Requirements.....	D.6.1
D.7 MDE/WMA Overview of the NPDES Stormwater Program.....	D.7.1
D.8 Miscellaneous Details for Compliance with Performance Criteria.....	D.8.1
D.9 MD Stream Use Designations.....	D.9.1
D.10 Method for Computing Peak Discharge for Water Quality Storm.....	D.10.1
D.11 Method for Computing the Channel Protection Storage Volume (Cp <sub>v</sub> ).....	D.11.1
D.12 Critical Erosive Velocity for Grass and Soil.....	D.12.1
D.13 Method for Designing Infiltration Structures.....	D.13.1
D.14 Eastern Shore (Delmarva) Dimensionless Hydrograph.....	D.14.1
D.15 Miscellaneous MD SHA Design Charts for Determining Pipe Inlet Control.....	D.15.1

# LIST OF TABLES

---

No.	Title	Page
1.1	Typical Pollutant Concentrations Found in Urban Stormwater .....	1.6
1.2	NRCS Estimates of Annual Recharge Rates, Based on Soil Type.....	1.7
1.3	Symbols and Acronyms .....	1.21
2.1	Summary of the Statewide Stormwater Criteria .....	2.1
2.2	Rainfall Depths Associated with the 1,2,10, and 100 Year 24-hour Storm Events ..	2.11
2.3	Summary of General Storage Requirements for Reker Meadows .....	2.19
2.4	Summary of General Design Information for Claytor Community Center.....	2.25
2.5	Summary of General Storage Requirements for Pensyl Pointe .....	2.34
2.6	Classification of Stormwater Hotspots .....	2.42
4.1	BMP Selection Matrix No. 1: Watershed Factors.....	4.5
4.2	BMP Selection Matrix No. 2: Terrain Factors .....	4.7
4.3	BMP Selection Matrix No. 3: Stormwater Treatment Suitability .....	4.9
4.4	BMP Selection Matrix No. 4: Physical Feasibility.....	4.11
4.5	BMP Selection Matrix No. 5: Community and Environmental Factors.....	4.13
4.6	Location and Permitting Factors Checklist .....	4.15
5.1	Summary of Stormwater Credits .....	5.2
5.2	Rooftop Disconnection “Drywell” Compensation .....	5.7



# LIST OF FIGURES

---

No.	Title	Page
1.1	Water Balance at a Developed and Undeveloped Site .....	1.3
1.2	Relationship between Impervious Cover and the Volumetric Runoff Coefficient .....	1.4
1.3	Decline in Stream Flow Due to Diminished Groundwater Recharge .....	1.8
1.4	Increased Frequency of Flows Greater than the Critical Discharge Rate in a Stream Channel After Development.....	1.9
1.5	Change in Hydrograph Following Development .....	1.11
1.6	Change in Floodplain Elevations .....	1.12
2.1	Location of the Eastern and Western Rainfall Zones in Maryland .....	2.3
2.2	Relationship between Impervious Cover and the Water Quality Volume .....	2.3
2.3	Relationship between $Re_v$ and Site Impervious Cover .....	2.6
2.4	Regions of Maryland Not Subject to the Channel Protection Requirement ( $Cp_v$ ).....	2.8
2.5	Example of Conventional Stormwater Detention Pond.....	2.9
2.6	Reker Meadows .....	2.15
2.7	Reker Meadows: Pre Developed Conditions .....	2.20
2.8	Reker Meadows: Developed Conditions .....	2.21
2.9	Claytor Community Center.....	2.22
2.10	Claytor Community Center: Pre Developed Conditions .....	2.26
2.11	Claytor Community Center: Developed Conditions .....	2.27
2.12	Pensyl Pointe .....	2.29
2.13	Pensyl Pointe: Drainage Area 1-Post Developed Conditions.....	2.35
2.14	Pensyl Pointe: Drainage Area 2-Post Developed Conditions .....	2.36
3.1	Example of "Micropool" Extended Detention Pond .....	3.3
3.2	Example of Wet Pond .....	3.4
3.3	Example of Wet Extended Detention Pond .....	3.5
3.4	Example of Multiple Pond System.....	3.6
3.5	Example of Pocket Pond.....	3.7
3.6	Example of Shallow Wetland .....	3.17
3.7	Example of Extended Detention Shallow Wetland .....	3.18
3.8	Example of Pond/Wetland System.....	3.19
3.9	Example of Pocket Wetland.....	3.20
3.10	Example of Infiltration Trench .....	3.26
3.11	Example of Infiltration Basin .....	3.27
3.12	Example of Surface Sand Filter .....	3.32

<b>No.</b>	<b>Title</b>	<b>Page</b>
3.13	Example of Underground Sand Filter .....	3.33
3.14	Example of Perimeter Sand Filter.....	3.34
3.15	Example of Organic Filter.....	3.35
3.16	Example of Pocket Sand Filter .....	3.36
3.17	Example of Bioretention .....	3.37
3.18	Example of Dry Swale .....	3.43
3.19	Example of Wet Swale .....	3.44
4.1	Map of Maryland Showing Key Terrain Factors .....	4.6
5.1	Schematic of Dry Well.....	5.7
5.2	Example of Sheetflow to Buffer Credit .....	5.12
5.3	Example of Grass Channel .....	5.15

# MARYLAND STORMWATER DESIGN MANUAL

## VOLUMES I AND II



### Preface

Stormwater management has evolved dramatically in Maryland since it became the first state to adopt stormwater quality regulations some fifteen years ago. Much has been learned about what works in the field and what does not. The goal for this project is to compile this hard-won knowledge and experience into a single comprehensive design manual that is truly useful to engineers and plan reviewers who design and construct stormwater practices.

We would like to acknowledge the many people who helped us get to this point. In particular, we are grateful to the staff at the Water Management Administration of the Maryland Department of Environment who played an active role in getting the manual to this point. In particular, the patience and support of Stewart Comstock (Project Manager), Ken Pensyl, Brian Clevenger and James Tracy is gratefully acknowledged. In addition, the assistance of other MDE staff was most helpful.

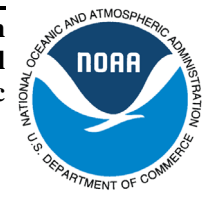
The manual could never have been produced without the talents, experience and hard work of our project team partners, Environmental Quality Resources, Inc. (EQR), and Loiederman Associates, Inc (LAI). In particular, we would like to acknowledge the great contributions of Timothy Schueler, Richard Scafidi, and Joanne Reker of EQR, and Karen Carpenter, Michael Wagner, Josie Greenberg, and Cliff Deward of LAI.

Thanks are also extended to the members of the Stormwater Management Regulations Committee (SMRC), whose insightful comments and local perspective in reviewing earlier drafts were most helpful in improving the manual. SMRC members who graciously gave their time and advice included: David Bourdon (Prince George's Soil Conservation District), Richard Brush (Montgomery County), Michael Clar (Engineering Technology Associates), Andrew Daneker (Howard County Bureau of Highways), Neal Fitzpatrick (Audubon Naturalist Society), John Galli (Metropolitan Washington Council of Governments), James Gracie (Brightwater, Inc.), Terrence McGee (Washington County), John Mickley (Washington County Soil Conservation District), Joseph Necker (The Rouse Company), Steven Oder (Cavalier Development), Daniel O'Leary (Parsons Brinkerhoff, Inc), John Redden (Wicomico County), James Slater (Carroll County), Susan Straus (City of Rockville), William Street (Chesapeake Bay Foundation), Raja Veeramachaneni (Maryland State Highway Administration) and Tom Vidmar (Baltimore County).

The authors would also like to acknowledge Tom Devilbiss (Carroll County), John Redden (Wicomico County), and Terrence McGee (Washington County) for their help in providing their perspectives on stormwater management in unique terrain areas of the State.



**A publication of the Maryland Department of the Environment in cooperation with the Maryland Department of Natural Resources Coastal Zone Management Program pursuant to National Oceanic and Atmospheric Administration Award No. NA67OZ0302.**



Special thanks are extended to Hye Yeong Kwon of the Center for Watershed Protection (CWP) for her heroic efforts to assemble and knit together the many pieces of the manual into a final product. Chris Swann and Deborah Caraco also provided valuable input and review.

This manual was prepared for the Water Management Administration under a cooperative agreement between that agency and the Maryland Department of Natural Resources pursuant to National Oceanic and Atmospheric Administration Grant No. NA67OZ0302. Reference to any particular commercial products and trade names in this manual does not in any way constitute an endorsement by the State.

Thomas Schueler

Richard Claytor

Center for Watershed Protection