Delaware Ground-Water Recharge Design Manual

"Supplement 1 to the Source Water Protection Guidance Manual for the Local Governments of Delaware"

March 2004, revised May 2005 and June 2017

Prepared for
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1. Introduction

Since 1991, water resource protection area (WRPA) zoning ordinances have been a part of source water protection in the state of Delaware. Several WRPA ordinances (such as New Castle County and the City of Newark) limit the amount of impervious cover (such as roof and pavement) to 20% by right for new development in surface water, recharge and wellhead areas. WRPAs are defined as (1) surface water areas such as floodplains, erosion-prone slopes, Cockeysville Formation, limestone aquifers, and reservoir watersheds, (2) wellhead areas, and (3) excellent recharge areas. The purpose of impervious cover thresholds are to allow economic development of land, minimize loss of recharge, and protect the quality and quantity of ground and surface water supplies in WRPAs.

New development in WRPAs may exceed the 20% impervious cover threshold, but not exceed than 50% impervious, provided the applicant submits an environmental assessment report recommending a climatic water budget and facilities to augment recharge. The environmental assessment must document that post-development recharge will be no less than predevelopment recharge when computed on an annual basis. Commonly, the applicant offsets the loss of recharge due to increased impervious cover by constructing recharge basins that convey relatively pure rooftop runoff for infiltration to ground water (Figure 1). The following "Ground-Water Recharge Design Methodology" recommends details on how to design, construct, and maintain recharge facilities in Delaware water resource protection areas.

2. Recharge Hierarchy

Local governments in Delaware should strive to protect ground and surface waters in WRPAs through a recommended source water protection hierarchy (ranked in order of preference):

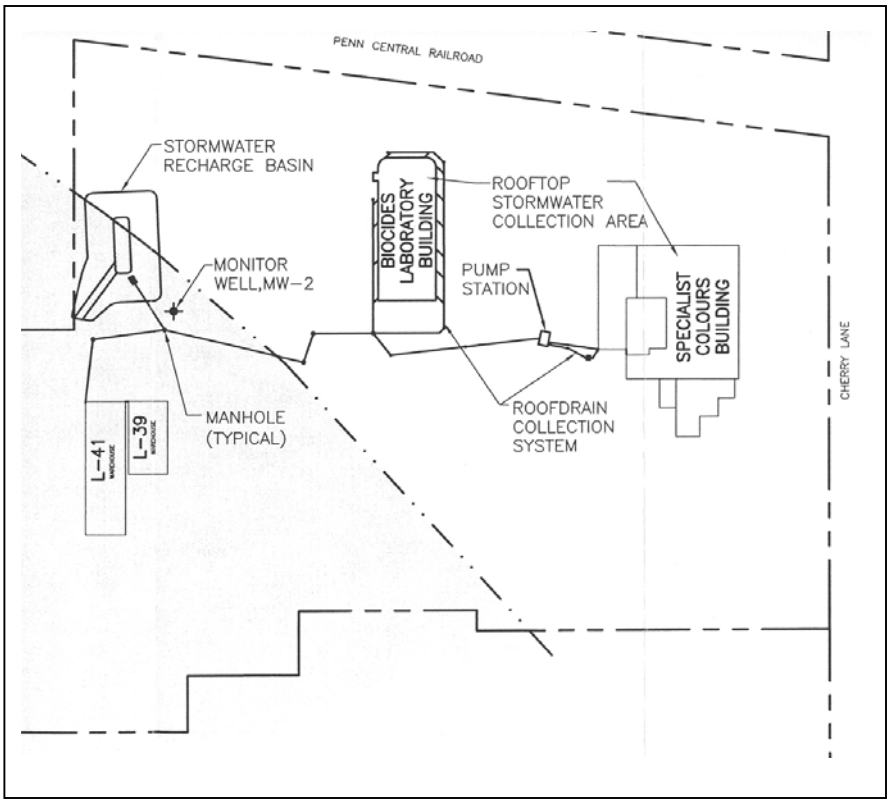
1) Preserve WRPAs as open space and parks by acquisition or conservation easement.

2) Limit impervious cover of new development to 20% by right within WRPAs.

3) Allow impervious cover of new development to exceed 20% within WRPAs (but no more than 50% impervious) provided the applicant develops recharge facilities that directly infiltrate rooftop runoff.

4) Allow impervious cover of new development to exceed 20% within WRPAs (but no more than 50% impervious) provided the applicant develops recharge facilities that infiltrate stormwater runoff from forested and/or grassed surfaces with pretreatment.

Figure 1. Typical Recharge Facility Layout.



(Note: Sources of all figures: Maryland Stormwater Design Manual and Duffield Associates, Inc.)

3. Environmental Assessment Report Components

A Delaware Registered Professional Engineer and/or Professional Geologist prepares an environmental assessment report, usually containing the following elements of planning, design, construction, and maintenance of ground-water recharge facilities:

1) Site description of proposed development within the water resource protection area;

2) Climatic water balance comparing predevelopment and post-development recharge potential;

3) Subsurface exploration including borings, test pits, and infiltration tests;

4) Design of ground-water recharge facilities;

5) Construction and maintenance considerations;

6) Recommended ground-water monitoring plan; and

7) Water management agreement between the applicant and the town, city, or county providing for monitoring and maintenance of the recharge system.

4. Site Description

The first section of the environmental assessment report involves a site description of the proposed development within the water resource protection area:

- Name of Development
- Name of Delaware Registered Professional Engineer and/or Registered Professional Geologist
- Name of Watershed
- Landuse/Landcover
    - Existing site
    - Proposed site
- Type of WRPA
    - Surface water
    - Wellhead
    - Recharge
- Project Area (acres)
    - Entire property
    - Area within water resource protection area (WRPA)
- % Impervious Cover
    - Existing site entire property
    - Existing site within WRPA
    - Proposed site entire property
    - Proposed site within WRPA
- Description of recommended ground-water recharge facilities
    - Infiltration basins
    - Infiltration trenches
    - Bioretention
    - Dry wells
    - Porous pavement
    - Vegetated bioswales
    - Other

5. Climatic Water Balance

The applicant develops an annual climatic water balance to estimate ground-water recharge for pre- and post-development land uses. The water balance computes recharge potential based on the following formula: $P = I + R + ET + \Delta SM$

P = annual precipitation (inches)
I = infiltration (inches)
R = runoff (inches)
ET = evapotranspiration (inches)
Δ SM = change in soil moisture (inches)

The water balance methods draw from the following documents:

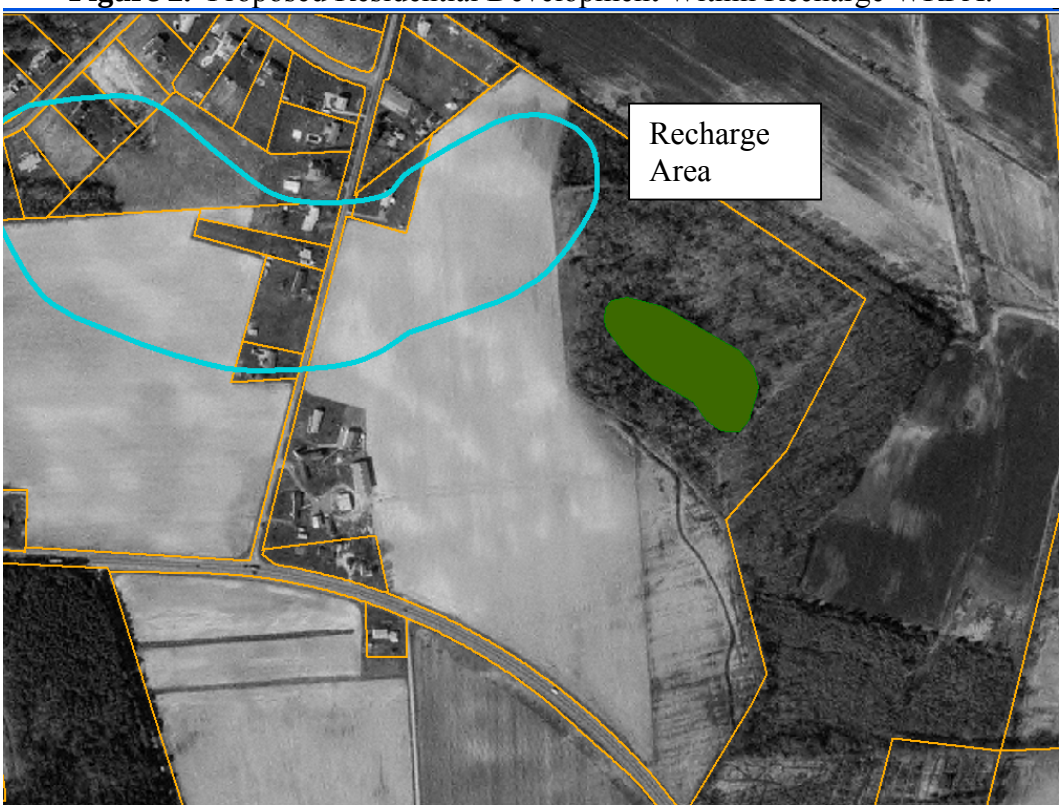
Thornthwaite, C.W. and Mather, J. R. (1957). *Instructions and Tables for Computing Potential Evapotranspiration and Water Balance*.

United States Department of Agriculture, Natural Resources Conservation Service. (1986). *Technical Release 55. Urban Hydrology for Small Watersheds*.

United States Department of Agriculture, Soil Conservation Service. (1970). *Soil Survey of New Castle County, Delaware; Soil Survey of Kent County, Delaware; and Soil Survey of Sussex County, Delaware*.

Example: Compute water balance for pre- and post-development conditions for a 20-acre site near Milford, Delaware within a recharge water resource protection area (Figure 2). The site is underlain by Group B soils. Pre-development land cover types are wooded (10 acres) and crop (10 acres). Post-development land cover types are proposed as wooded (10 acres), crop (5 acres), and single family residential (impervious roof and pavement area = 5 acres).

Figure 2. Proposed Residential Development Within Recharge WRPA.



Step 1: Compute Recharge for Predevelopment Conditions

Compute the annual recharge volume in inches for the predevelopment land use utilizing the climatic water balance approach. Refer to the following definitions of variables.

Precipitation (P): Table 1 summarizes mean monthly precipitation data for weather stations in Delaware (1980-2010). This data can be obtained from the Office of the State Climatologist at the University of Delaware, Department of Geography at http://www.deos.udel.edu/. Note that the example below in Tables 3-4 uses 1970-2000 precipitation data which is now superseded.

Table 1. Mean Monthly Precipitation Volume (inches) for Weather Stations in Delaware.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wilmington Airport	3.01	2.68	3.92	3.50	3.95	3.88	4.56	3.25	4.32	3.42	3.10	3.48	43.07
Wilm. Porter Reservoir	3.71	2.99	4.52	4.21	4.38	4.19	5.36	3.67	4.90	3.81	3.48	34.10	49.32
Middletown	2.83	2.64	3.37	3.43	3.85	3.8	3.74	3.09	3.42	3.17	3.23	3.36	39.93
Newark: Univ. of Del.	3.14	2.74	4.11	3.72	4.10	4.03	4.80	3.96	4.74	3.51	3.55	3.83	46.23
Dover	3.41	3.07	4.31	3.88	4.25	4.00	4.09	4.36	4.13	3.42	3.48	3.65	46.05
Milford	3.57	3.18	3.96	3.48	3.96	3.44	3.60	4.31	3.73	3.33	3.28	3.50	43.34
Georgetown	3.08	2.96	4.32	3.56	3.80	3.67	4.21	6.00	3.96	3.38	3.50	3.49	45.93
Lewes	3.62	3.12	4.40	3.59	3.72	3.39	4.78	4.73	4.04	3.94	3.66	3.85	46.84

Runoff Coefficient (RC): Estimate using the USDA-NRCS curve number method. Refer to table 2-26 of the Technical Release 55 manual (http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html) for CNs based on soil and land cover type. Consult the USDA–Soil Conservation Service Soil Surveys for New Castle County, Kent County, or Sussex County, Delaware to determine Hydrologic Soil Groups A, B, C, or D which underlay the various land cover types. Assume land cover type is in good condition. Table 2 summarizes recommended runoff coefficients for crops, grass/pasture, meadow, and woods in good condition depending on the SCS curve number and hydrologic soil group.

Table 2. Recommended Runoff Coefficients for Crops, Grass/Pasture, Meadow, and Woods.

Land Cover	HSG A	HSG B	HSG C	HSG D
Crops	0.08	0.10	0.12	0.14
Grass/Pasture	0.02	0.04	0.06	0.08
Meadow	0.01	0.02	0.03	0.04
Woods	0.01	0.02	0.03	0.04

Table 3. Climatic Water Balance for Crops in Soil Group B.

Soil Moisture Storage = 8 inches

CN = 75

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Precipitation (P)	3.57	3.18	3.96	3.48	3.96	3.44	3.6	4.31	3.73	3.33	3.28	3.5	43.34
Runoff Coeff. (RC)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Runoff (RO) (= RC x P)	0.36	0.32	0.40	0.35	0.40	0.34	0.36	0.43	0.37	0.33	0.33	0.35	4.33
Infiltration (= P - RO)	3.21	2.86	3.56	3.13	3.56	3.10	3.24	3.88	3.36	3.00	2.95	3.15	
PET	0	0	0.62	2.00	3.72	5.25	6.10	5.31	3.74	2.02	0.75	0	
Infiltration - PET	3.21	2.86	2.94	1.13	-0.16	-2.15	-2.86	-1.43	-0.38	0.98	2.20	3.15	
Cum. Water Loss	0	0	0	0	-0.16	-2.31	-5.17	-6.60	-6.98	0.00	0.00	0.00	
Storage (ST) (T and M 18)	8.00	8.00	8.00	8.00	5.01	4.14	3.72	4.11	5.00	5.76	8.00	8.00	
Change ST	0	0	0	0	-2.99	-0.87	-0.42	0.39	0.89	0.76	2.24	0	
AET	0	0	0.62	2.00	3.72	3.97	3.66	3.49	2.47	2.02	0.71	0.00	22.70
Percolation	3.21	2.86	2.94	1.13	0	0	0	0	0	0.22	-0.04	3.15	13.48

Table 4. Climatic Water Balance for Woods in Soil Group B.

Soil Moisture Storage = 8 inches

CN = 75

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Precipitation (P)	3.57	3.18	3.96	3.48	3.96	3.44	3.60	4.31	3.73	3.33	3.28	3.50	43.34
Runoff Coeff. (RC)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
Runoff (RO) (= RC x P)	0.07	0.02	0.03	0.07	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.07	0.45
Infiltration (= P - RO)	3.50	3.16	3.93	3.41	3.93	3.41	3.57	4.28	3.70	3.31	3.26	3.43	
PET	0	0	0.62	2.00	3.72	5.25	6.10	5.31	3.74	2.02	0.75	0	
Infiltration - PET	3.50	3.16	3.31	1.41	0.21	-1.84	-2.53	-1.03	-0.04	1.29	2.51	3.43	
Cum. Water Loss	0	0	0	0	0	-1.84	-4.37	-5.40	-5.44	0.00	0.00	0.00	
Storage (ST) (T and M 18)	16.00	16.00	16.00	16.00	15.93	14.48	13.11	12.45	12.34	13.29	15.76	16.00	
Change ST	0	0	0	0	-0.07	-1.45	-1.37	-0.66	-0.11	0.95	2.47	0.24	
AET	0	0	0.62	2.00	3.72	4.86	4.94	4.94	3.81	2.02	0.75	0.00	27.66
Percolation	3.50	3.16	3.31	1.41	0	0	0	0	0	0.34	0.04	3.19	15.16

AET: Where P > PET, AET = PET. Where P < PET, AET = P – RO – Change ST.
Percolation: If I – PET < O, then PERC = O. If I – PET > O, then PERC = I – PET – Change ST.

Runoff (RO): Multiply Precipitation (P) by Runoff Coefficient (RC)

Infiltration (I): Precipitation (P) minus Runoff (RO)

Potential Evapotranspiration (PET): Table 5 provides recommended monthly PET values for the State of Delaware.

Table 5. Recommended Monthly Potential Evapotranspiration (PET) Values for Delaware.

Month	PET (in)	Month	PET (in)
JAN	0.00	JUL	6.10
FEB	0.00	AUG	5.31
MAR	0.62	SEP	3.74
APR	2.00	OCT	2.02
MAY	3.72	NOV	0.75
JUN	5.25	DEC	0.00

Infiltration Minus Potential Evapotranspiration (I-PET): Subtract PET from I.

Cumulative Water Loss (CWL): Calculate CWL by adding the current month's I-PET value to the previous month's CWL, starting in the month with the first negative I-PET value and ending in the last month with a negative I-PET value. Use zero for months that have a positive I-PET value.

Soil Moisture Storage Capacity (ST): Table 6 summarizes ST for various land covers depending on hydrologic soil group. In months where P – PET is negative, estimates of ST may be obtained from Thornthwaite and Mather, Tables 11 through 22 for a given PET. Where P – PET is positive, use the Thornthwaite and Mather tabular ST values for each month found in Table 6.

Table 6. Recommended Soil Moisture Storage Capacity for Land Covers in Delaware.

Land Cover	HSG A	HSG B	HSG C	HSG D
Crops	10 in.	8 in.	5 in.	3 in.
Grass	12	10	8	5
Meadow/Pasture	14	12	10	8
Woods	16	16	14	12

Cumulative Change in ST: Beginning in months where negative I – PET occurs, subtract Soil Moisture Storage Capacity from the ST of the preceding month.

Actual Evapotranspiration (AET): Where Precipitation (P) is greater than the Potential Evapotranspiration (PET), the soil remains full of water and the AET will equal the PET. When the precipitation drops below the Potential Evapotranspiration, the soil begins to dry out and the AET equals the P minus RO minus the change in ST.

Percolation: Equals the I – PET minus the change in ST. In months where the I – PET is negative, the Percolation is zero.

Step 2: Compute Recharge Volume (acre-inches) for Predevelopment Land Cover Conditions

Cover Type	Soil Group	Impervious Cover	Area (acres)	Recharge (in)	Recharge Volume (acre-in)
Wooded	B	0 %	10	15.16	152
Crop	B	0 %	10	13.48	135
Total		0 %	20		287

Step 3: Compute Recharge Volume (acre-inches) for Postdevelopment Land Cover Conditions

Cover Type	Soil Group	Impervious Cover	Area (acres)	Recharge (in)	Recharge Volume (acre-in)
Wooded	B	0 %	10	15.16	152
Crop	B	0 %	5	13.48	67
S. F. Resid.	B	100 %	5	NA	NA
Total		25 %	20		219

Step 4: Compute Net Loss in Recharge Due to Development

	Impervious	Recharge Volume
Predevelopment	0 %	287 ac-in
Postdevelopment	25 %	219 ac-in
Net Recharge Loss		68 ac-in (1.8 million gallons)

Therefore, a recharge facility should be designed to infiltrate 1.8 million gallons of water annually.

6. Subsurface Exploration

Subsurface exploration of soils and geology is necessary for satisfactory design of recharge facilities. Test pits and soil borings should be situated at a density of one per 2 acres for the portion of the site within the WRPA. Monitoring wells shall be installed at a density of one per 10 acres for the portion of the site within the WRPA. Permeability tests should be conducted at the locations of proposed recharge facilities. Underlying soils for recharge facilities shall have adequate permeability to fully infiltrate the recharge water within 48 hours after a two-year storm event. The bottom of the recharge facility shall be at least three feet above the seasonal high water table. The applicant should submit the following information as part of the field exploration report:

Site Geology: Description of underlying geologic formations and stratigraphic cross section utilizing reports and mapping prepared by the Delaware Geological Survey (www.udel.edu/dgs).

Soil Survey: Classification, description, and mapping of site soils as published in the United States Department of Agriculture, Soil Conservation Service Soil Surveys for New Castle, Kent, and Sussex Counties, Delaware.

Test Pits: Descriptive logs noting depth to ground-water table, soil description, soil moisture infiltration tests, soil textural classification (Unified Soil and USDA Textural chart), and grain size distribution and soil gradation data (% passing No. 10 and No. 200 sieve).

Standard Penetration Test Borings: Necessary to characterize the general soil profile including depth to ground - water table. Submit boring logs.

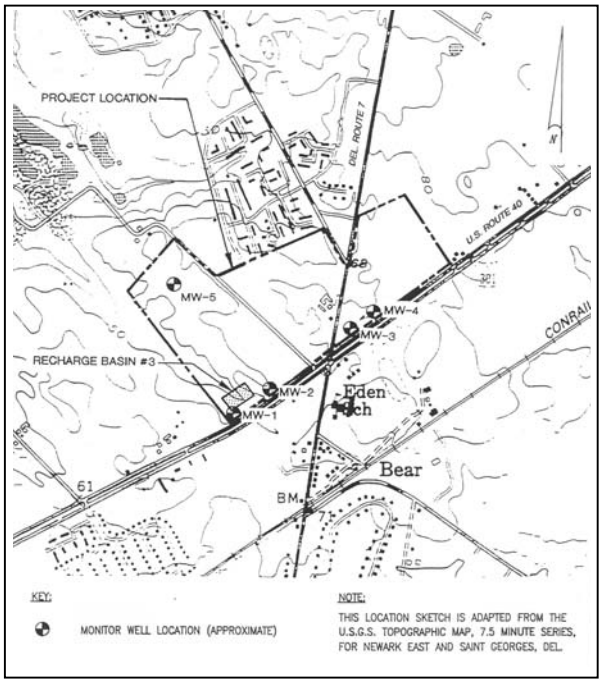
Infiltration Testing: Estimate soil permeability (in/hr) at locations of recharge facilities. Satisfactory infiltration testing methodologies include:

- Single Ring Infiltrometer Test (ASTM D5126)
- Double Ring Infiltrometer Test (ASTM D3385-88)
- Field Scale Falling Head Percolation Test Using Test Pit

Monitoring Wells: Submit monitoring well location (Figure 3) and details. The purpose of the monitoring wells are to measure ground-water levels and obtain water quality samples.

Mapping: Submit copies of USGS topographic map and SCS soil survey map superimposed with site delineation.

Figure 3. Location of Proposed Monitoring Well.



7. Design of Ground-Water Recharge Facilities

Ground-water recharge facilities are designed to augment infiltration and offset increased impervious cover from new development in recharge and wellhead areas. The design of recharge facilities should be in accordance with Section 10.0 of the Delaware Sediment and Stormwater Regulations: (http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/Stormwater/StormWater.htm).

The case study in this manual requires the design of a recharge facility to infiltrate 1.8 million gallons of runoff annually. Recharge basin design should be based on the following criteria:

Soil Permeability: Underlying soils shall have sufficient permeability to infiltrate the runoff volume from a 2-year storm within 48 hours. This is to allow drying of soils and empty the facility before the next precipitation event, which in Delaware occurs once every five days on the average. Soil permeability tests shall be submitted at the locations of the proposed recharge facilities.

Volume: Recharge facilities in Delaware shall have sufficient volume to infiltrate runoff from a 2-yr year storm. Table 7 summarizes precipitation depths for various frequency storms in northern Delaware.

Table 7. 100-Year, 24-Hour Precipitation Volume for Northern Delaware.

Return Interval	Volume (in.)
2-year, 24-hour	3.2
5-year, 24-hour	4.2
10-year, 24-hour	5.2
25-year, 24-hour	5.5
50-year, 24 hour	6.5
100-year, 24 hour	7.5

Depth to ground water: The bottom of the recharge facility should be at least three feet above the seasonal high ground-water table to prevent ground-water mounding.

Side slopes: Maximum sideslopes of recharge basins should be 4 feet horizontal to 1 foot vertical.

Recommended recharge runoff philosophy:

1) Direct infiltration of relatively clean rooftop runoff, no pretreatment required – most preferred.
2) Infiltration of runoff from grass or wooded surfaces which would require pretreatment before infiltration – less preferred.

Further guidance on the design of recharge facilities can be sought from:

Maryland Department of the Environment. (2000). *Maryland Department of Environment Stormwater Design Manual*. www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp. Accessed March 2004.

North Carolina Department of Environment and Natural Resources. (1999). *Stormwater Best Management Practices*. dem.ehnr.state.nc.us/su/PDF_Files/SW_Documents/BMP_Manual.PDF. Accessed March 2004.

Infiltration facilities may consist of the following types:

- *Infiltration basins:* Open air, usually to collect runoff from a larger regional network (Figure 4)
- *Infiltration swales:* Grass lined swales used to convey and infiltrate runoff along the perimeter of properties and pavement edges
- *Infiltration trenches:* Underground, usually to collect runoff from a smaller, constrained site (Figure 5)
- *Dry wells or galleries:* Underground, usually to infiltrate runoff from individual dwellings (Figure 6)
- *Porous pavement:* suitable for low traffic areas

The following types of pretreatment facilities are recommended to cleanse runoff from non-rooftop areas such as pavements and lawns into recharge facilities:

- *Forebays:* Excavated areas along swales that store and treat runoff
- *Vegetative Filter Strips:* Turf lined areas designed to treat overland runoff
- *Water Quality Inlets:* Traps in stormwater inlets designed to remove debris, grease, oil, and sediment
- *Stormwater Wetlands* (Figure 7)
- *Wet Extended Detention Ponds* (Figure 8)
- *Bioretention Swales* (Figure 9)
- *Sand Filters*

Figure 4. Typical Infiltration Basin.

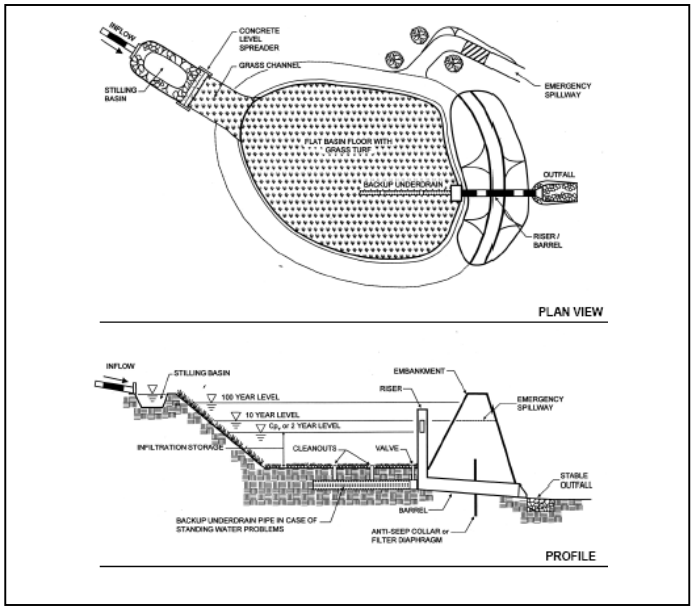


Figure 5. Typical Infiltration Trench.

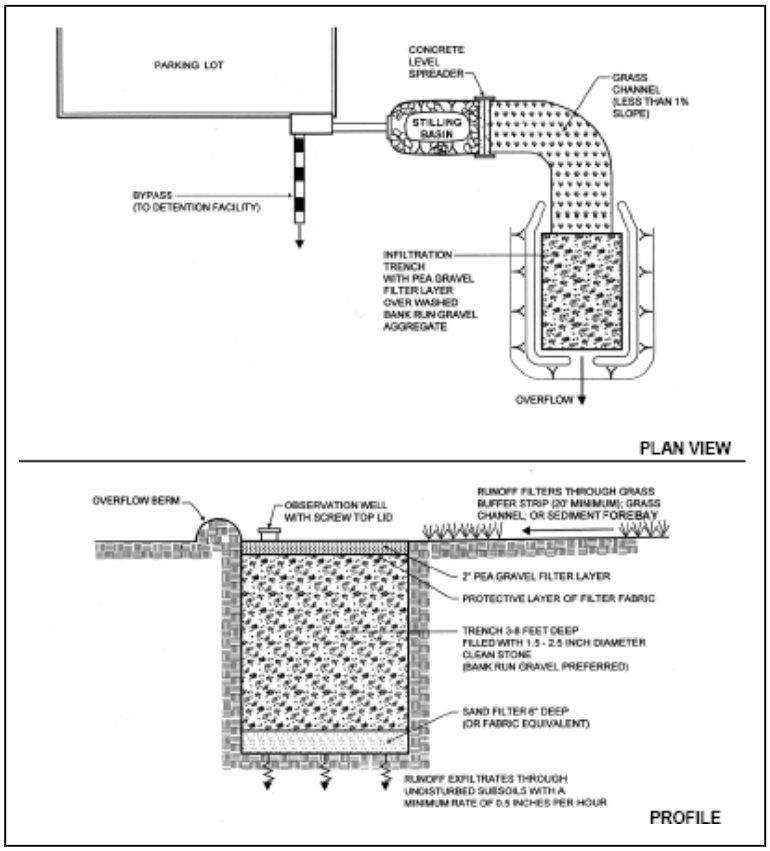


Figure 6. Typical Dry Well or Gallery.

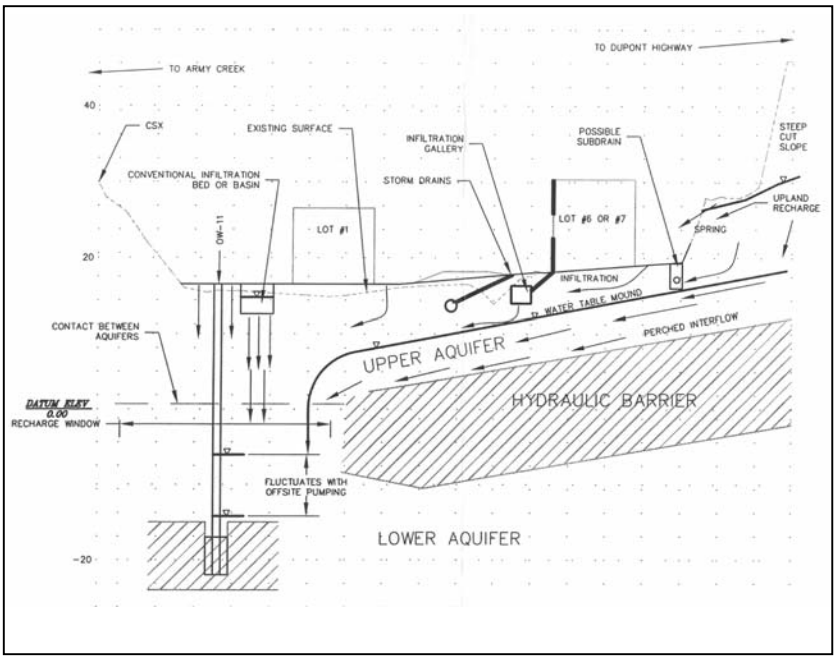


Figure 7. Typical Stormwater Wetland.

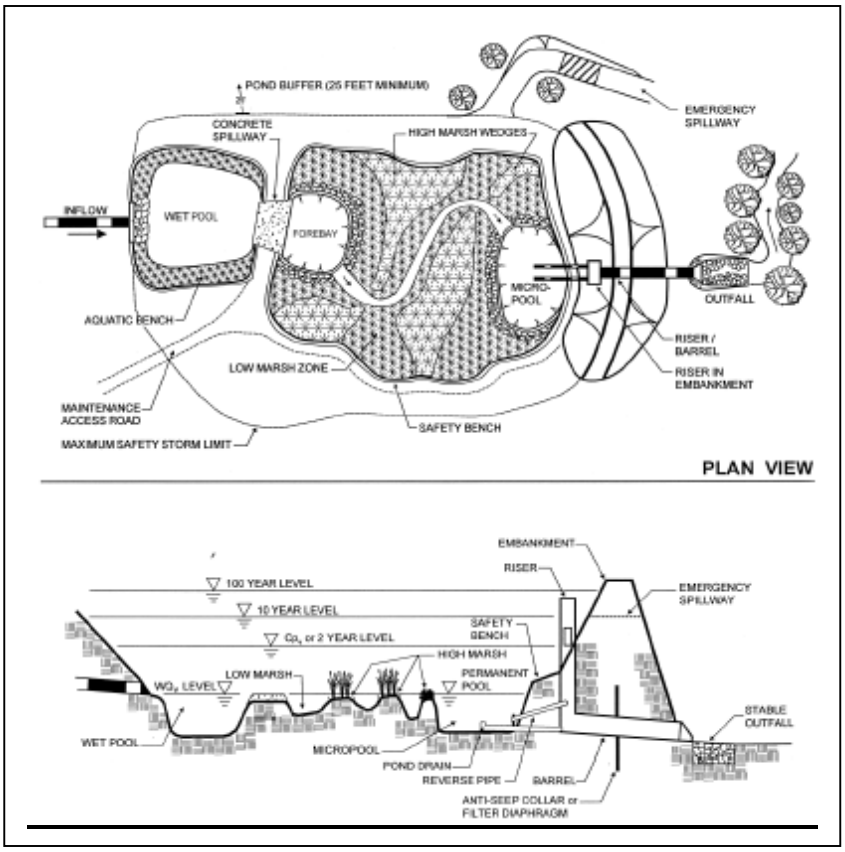


Figure 8. Typical Wet Extended Detention Pond.

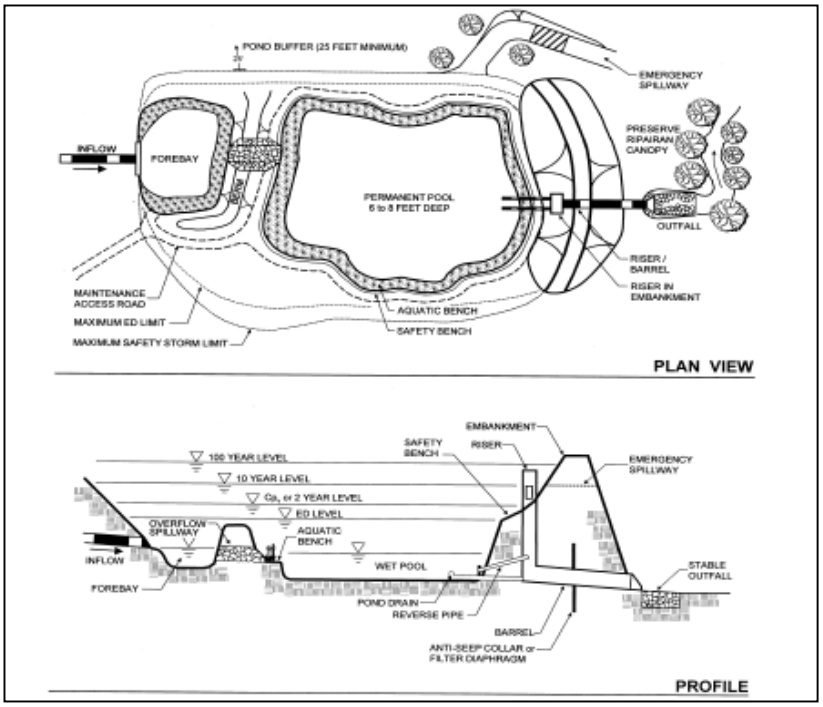
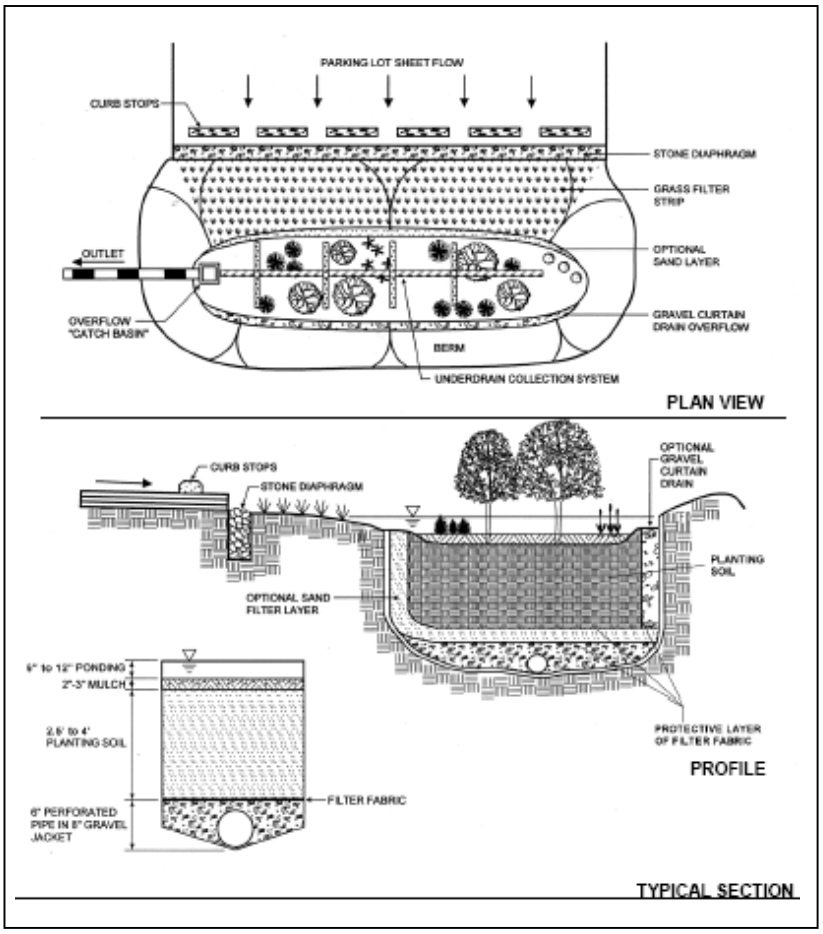


Figure 9. Typical Bioretention Swale.



Design Calculations

The following methodology is recommended for the design of ground-water recharge facilities:

Step 1: Determine infiltration rate

Assume an underlying infiltration rate for design that is greater than or equal to 1.0 in/hr (2 ft/day). This assumed infiltration rate would drain a 4 feet deep recharge facility within the recommended 48 hours. The soil infiltration rate should be based on the results of field permeability testing conducted at the site of the proposed recharge facility.

Step 2: Rooftop area requirement

Determine the rooftop area required to collect enough rainfall to offset the annual loss of recharge due to development. Therefore, the Required Rooftop Area (RFA) = Net Recharge Loss/Annual Precipitation (% Annual Precipitation not Evaporated). Approximately 90% of the annual precipitation is assumed not to be evaporated.

Step 3: Recharge volume requirement

Determine the dimensions of the recharge system required to store the 2-year storm runoff volume. For a rooftop runoff system the 2-year runoff volume is equal to the rooftop area multiplied by the 2-year, 24-hour storm runoff depth which is 3.2 inches in Delaware. Once the 2-year storm runoff volume is determined, calculate the required dimensions of the recharge facility as the:

- Length, width and depth for an open air recharge facility, or
- Length, width and depth multiplied by the void ratio for a stone trench system, or
- Combination of pipe volume and stone volume for a perforated pipe trench system.

Check the time required top drain the system based on the assumed infiltration design rate and the 2-year ponding depth in the system. The recharge facility should be designed to drain within 48 hours after a 2-year storm.

Step 4: Stormwater overflow

Design an overflow or bypass system so that storm events larger than the 2-year storm can be safely passed by the recharge facility.

EXAMPLE: Design ground-water recharge facilities to infiltrate 1.8 million gallons annually to offset the net recharge loss due to development.

Step 1: Determine infiltration rate

Field testing at test pit indicates the soil permeability is 3 ft/day = 1.5 in/hr

Step 2: Rooftop area requirement

Required Rooftop Area (RFA) = Net Recharge Loss/Annual Precipitation (0.90)
RFA = 1,800,000 gal (1 cf/7.48 gal)/ (0.9) (43.34 in) (1 ft/12 in.)
RFA = 74,032 sf of rooftop area required for recharge.

Step 3a: Recharge basin (open air) design

Calculate the dimensions of an open air recharge basin to recharge 74,032 sf of rooftop area for a two-year storm.

Given:
2 yr storm precipitation volume = 3.2 in
Rooftop area (RFA) = 74,032 sf
Rooftop runoff volume (V) = 3.2 in (74,032 sf)(1 ft/12 in) = 19,742 cf
Soil permeability (K) = 3 ft/day
Maximum infiltration time (Tmax) = 48 hours
Maximum depth of pool (D) = 4 ft (for safety reasons).

Find dimensions of infiltration basin to store 19,742 cf using average end area method. Lay out sideslopes at 4:1.

Table 8. Infiltration Basin Volume Calculations.

Elevation (ft)	Depth (ft)	Area (sf)	Avg. Area (sf)	Inc. Vol. (cf)	Cum. Vol. (cf)
90	0	2,500	-	-	-
91	1	3,364	2,932	2,932	2,932
92	1	4,356	3,860	3,860	6,792
93	1	5,476	4,916	4,916	11,708
94	1	6,724	6,100	6,100	17,808
94.3	0.3	7,500	7,112	2,134	19,942>19,742

Calculated volume = 19,942 cf, which is greater than the required volume 19,742 cf (OK).
Area = 7,500 sf = 87 ft x 87 ft
Dimensions = 87 ft x 87 ft at 4.3 ft deep

Check infiltration pool depth based on infiltration time.
Time = D/K = 4.3 ft/(3ft/day) = 1.4 days = 34 hours (< 48 hours)

Step 3b: Infiltration swale

This is essentially a linear, open air recharge facility.
Try trapezoidal swale, b = 30 ft, d = 3 ft, side slopes = 3:1
Cross-section area = 30(3) + (9)2 = 108 sf
The length of the swale would be 19,742 cf / 108 sf = 183 ft

Step 3c: Infiltration trench – underground, backfill with stone and pipe

Calculate the dimensions of an underground recharge basin to recharge 74,032 sf of rooftop for a two-year storm.

Building rooftop area	= 74,032 sf = 0.3 ac
2-year storm rainfall volume	= 3.20 in
2-year storm runoff volume	= (3.20 in)(74,032 sf)(1 ft /12 in)
Runoff	= 19,742 cf
Proposed infiltration trench will consist of perforated corrugated metal pipe and AASHTO #1 stone at length (l), width (w) and depth (d).	
Proposed recharge piping system	= 60 in diameter perforated corrugated metal pipes 2 pipes @ 150 lf = 300 lf
Pipe storage	= (3.1416)(2.5 ft)(2.5 ft)(150 lf) = 5,890 cf
Required stone storage = runoff minus pipe storage	= 19,742 – 5,890 = 13,852 cf

Porosity (volume of voids/volume of stone mass) of AASHTO #1 stone	= 0.4
Required stone volume	= 13,852 cf /0.4 = 34,630 cf
Required pipe + stone volume	= 5,890 + 34,630 = 40,520 cf
Length of recharge facility (1)	= 300 ft
Cross-section area (d x w)	= 40,520 cf / 300 ft = 135 sf use 12 ft x 12 ft = 144 sf
Depth of recharge facility (d)	= 12 ft
Width of recharge facility (w)	= 12 ft
Dimensions of infiltration trench	= 300 ft x 12 ft x 12 ft with 60 in pipe
Infiltration rate required to dewater 2-year runoff in 48 hours	= 12 ft / 2 days = 6.0 ft/day = 3in/hr

Soil permeability tests should be submitted that verify the infiltration rate is more than 6.0 ft/day.

Design Notes

1) The recharge basin(s) should be located within the recharge and/or wellhead water resource protection areas.

2) Construction of the recharge basin shall occur after the contributing drainage area has been stabilized.

3) Infiltration tests should be situated at the locations of the recharge facilities to verify that the underlying soil has adequate permeability to drain the basin within 48 hours after a two-year storm.

4) Excavate the basin through the topsoil layer to intersect with the underlying permeable soil strata.

5) Estimate the dimensions of the recharge basin.

6) For open-air recharge basins, grade and configure the basin to provide sideslopes no steeper than 4 ft horizontal to 1 ft vertical. Provide access for equipment for cleaning and operational maintenance of the basin.

7) Review the basin bottom subgrade during construction for conformance with design conditions summarized in the drawings. The review should be performed by a Delaware registered professional engineer (with at least 4 years soils engineering experience). This review should include hand auger borings, uniformly spaced across the bottom area at a maximum distance of 15 feet on centers (min 4 borings), and advanced to a minimum depth of 6 feet below the design bottom elevation. The purpose is to check for the possible presence of intermittent soil layers. Intervals with potential for impeded drainage such as fine grain soils, mottles, or compacted layers should be undercut and backfilled with clean, washed gravel, or filter sand as directed by the engineer.

8) Provide erosion and scour protection around the inlet/bypass works across the basin bottom and extending up the sideslopes to a height at least one foot above the design storm level. Sideslopes above the scour level should be stabilized with sod to limit potential erosion.

9) Construct a ground-water monitoring well down gradient from the recharge basin.

10) Figure 10 provides details of a recommended monitor well construction.

11) Refer to the recommended construction sequence for the recharge basin.

12) Refer to the recommended maintenance and operation review

13) Refer to the water management agreement that stipulates required ground - water monitoring adjacent to the recharge basin.

8. Construction and Maintenance Considerations

Construction Notes

1) Construction of the recharge basin shall occur after stabilization of the contributing drainage area.

2) Construct a minimum two-foot high diversion berm around the perimeter of the recharge basin area. The berm shall have a minimum 2-foot crest width and maximum 2:1 sideslopes and shall be compacted to at least 95% of the maximum dry density as determined by the Standard Compaction Test (ASTM D 698). Stabilize the berm with seed and mulch. Mulch onto the interior berm areas shall be excelsior blankets. Mulch on the exterior berm slope may be straw. This work shall be completed prior to the start of basin excavation.

3) Strip topsoil from recharge basin area.

4) Work in item 12 as listed below shall not be performed when wet weather or wet subgrade conditions exist at the site.

5) Excavate the recharge basin area using a low grounds pressure, tracked excavator or hoe, to a depth approximately one foot above the design elevation.

6) With the basin bottom one (1) foot above the finished grade perform the hand auger borings to a minimum depth of at least 6 feet below the basin bottom design grade to check for the possible presence of interlayers that might impede drainage of stormwater from the basin. Review the basin bottom subgrade during construction for conformance with design conditions summarized ion the drawings. The review should be performed by a Delaware registered professional engineer (with at least 4 years soils engineering experience). This review should include hand auger borings, uniformly spaced across the

bottom area at a maximum distance of 15 feet on centers (min 4 borings), and advanced to a minimum depth of 6 feet below the design bottom elevation. The purpose is to check for the possible presence of intermittent soil layers. Intervals with potential for impeded drainage such as fine grain soils, mottles, or compacted layers should be undercut and backfilled with clean, washed gravel, or filter sand as directed by the engineer.

7) Construct any at grade berms using soils placed in 12-inch lifts and compacted to at least 95% of maximum dry density as determined by the Standard Proctor Test.

8) Construct the collection system inlet pipe within the limits of the basin. Protect against damage or intrusion of sediment or debris.

9) Spread 4 inches (minimum thickness of topsoil on basin sideslopes) down to the level of any scour protection or other side slope bottom treatments (e.g. filter sand, riprap, stone placement). Place sod or establish grass cover on all sideslopes on the interior of the basin. And seed ad tack straw mulch on other disturbed areas. Work items 4 and 8 shall be completed and erosion stabilization established prior to proceeding with work items 10 and 17.

10) After vegetation is well established and stabilized to the satisfaction of a qualified soils engineer familiar with the recommendations of this report, excavate the basin to the design bottom elevation using a low ground pressure, tracked excavator or hoe.

11) A registered professional engineer shall review the recharge basin sub grade with the design conditions prior to placement of any scour protection. Areas with indication of potentially impeded drainage (e.g.: fine graded soils, mottles) shall be undercut as directed by the engineer and backfilled with washed gravel or filter sand.

12) Remove loose and disturbed soils remove all eroded soils and scarify by hand raking the bottom of the basin and sideslopes to the height of the scour protection or bottom treatments. After scarifying no equipment shall e allowed to run on the exposed bottom prior to placement of the bottom treatments.

13) Place bottom treatments (washed sand gravel, riprap) and inlet structure for collection system pipe.

14) Wash filter sand shall conform to the gradation requirements for fine aggregate as specified in Section 804 "Standards Specifications for Road And Bridge Construction (DELDOT) August 2001.

15) Wash gravel and riprap to be placed in the recharge basin with clean water until free of fines (less than 1% passing No. 10 sieve). The washing operation shall be located so as to prevent runoff of wash water from entering basin area.

16) Washed sand, gravel, and stone bottom shall be stockpiled outside the limits of excavation for the basin and shall be placed in the basin with a hoe bucket, dozer or

loader. Equipment used on bottom of basin shall be low-pressure, tracked equipment and shall run on top of the placed material not the exposed sub grade. The equipment shall be operated in a manner to limit tracking of dirt onto the placed material and disturbance and compaction of the sub grade soils. Under no circumstances shall trucks be driven into the excavated area to dump bottom treatment materials.

17) Remove diversion berm only when vegetation in all areas upslope from the basin has become well established and the area stabilized with respect to erosion. Place 4 inches of topsoil, seed, and tacked straw mulch into berm area.

Operation and Maintenance Review

Operation and maintenance of the recharge system is essential to its operation. It is recommended that all components of the recharge facility be reviewed by a qualified professional engineer semiannually to determine maintenance requirements.

1) Inspect the recharge facility and remove debris and leaves to maintain the infiltrative capacity of the basin.

2) Review the downspout/piping system and perform minor repairs as needed to maintain function.

3) During the first 6-month operation or when a 1-inch rain occurs (as measured at the closest weather station), review the recharge facility immediately. Record the depth and duration (start and stop times) of the rainfall event, water level in the basin and time of water level readings. Monitor the water level in the recharge basin again at 2, 24, 48, and 72 hours after the first review and record the observed water level. After the initial 6 month period perform this same review at least at least once per year after storms in which the rainfall amount equals or exceeds one inch in 24 hours. If an annual review indicates the infiltration rate is slower than the design rate (i.e. failure to drain within 48 hours), repeat the review for the next rainstorm that exceeds one inch in 24 hours.

4) When two consecutive post rainfall reviews indicate that the infiltration capacity if the recharge facility is slower than the design rate, remove the bottom treatments from the recharge basin and dispose of accumulated sediments dry and scarify the subgrade and clean and replace the bottom treatments.

9. Ground-Water Monitoring

Ground-water monitoring well(s) shall be installed down gradient of each recharge facility to assess that the quality and quantity of ground water is not negatively affected by the construction of the development. Figure 10 details the configuration of a 4-inch diameter monitoring well. Ground-water monitoring results should be submitted twice annually to the county, town or city and include the following components:

1) *Frequency*: The quality of surface runoff entering the recharge facility and ground water and shall be sampled (a) before site development to determine baseline conditions and (b) twice annually after construction for at least 2 years. Depth to ground-water levels should be measured semiannually.

2) *Quality*: The following parameters shall be sampled semiannually:

pH	Chlorides	Specific Conductance
Nitrate Nitrogen	Total Dissolved Solids	Total Phosphorus
Chemical Oxygen Demand	Lead	Total Carbon
Copper	Zinc	

The following full suite of substances, those regulated by the Delaware Drinking Water Standards, shall be sampled and analyzed one per year. For further information: http://www.state.de.us/research/register/july2003/waterregs.pdf.

Microbiological Contaminants

Total Coliform	Fecal coliform and E. coli
Turbidity	

Inorganic Contaminants

Antimony	Arsenic
Asbestos	Barium
Beryllium	Cadmium
Chromium	Copper
Cyanide	Fluoride
Lead	Mercury
Nitrate	Nitrite
Nitrate/nitrite (as Nitrogen)	Selenium
Thallium	

Synthetic Organic Contaminants (including Pesticides and Herbicides)

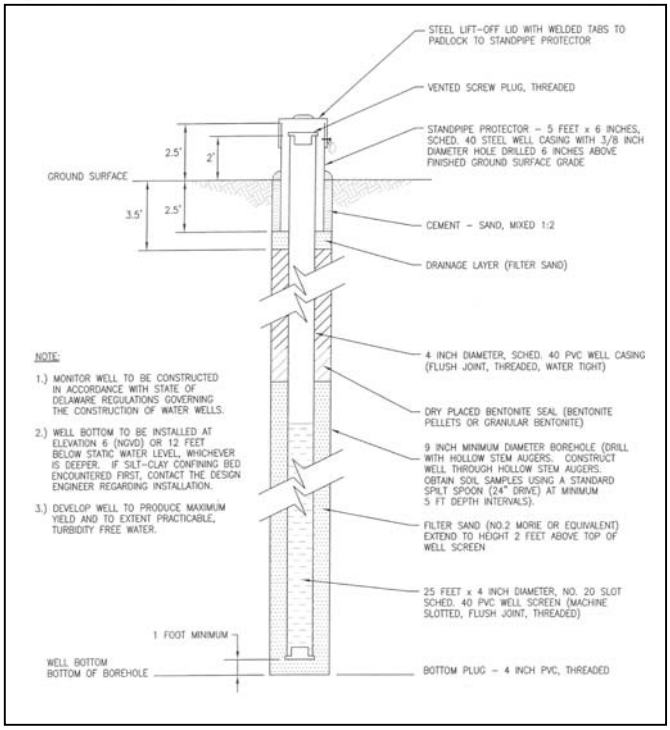
2,4-D	2,4,5-TP [Silvex]
Acrylamide	Alachlor
Atrazine	Benzo(a)pyrene
Carbofuran	Chlordane
Dalapon	Di(2-ethylhexyl)adipate
Di(2-ethylhexyl) phthalate	Dibromochloropropane
Dinoseb	Diquat
Dioxin [2,3,7,8-TCDD]	Endothall
Endrin	Epichlorohydrin
Ethylene dibromide	Glyphosate
Heptachlor	Heptachlor epoxide

Hexachlorobenzene
Lindane
Oxamyl [Vydate]
Pentachlorophenol
Simazine
Aldicarb
Aldicarb sulfoxide
Hexachlorocyclopentadiene
Methoxychlor
PCBs
Picloram
Toxaphene
Aldicarb sulfone

Volatile Organic Contaminants

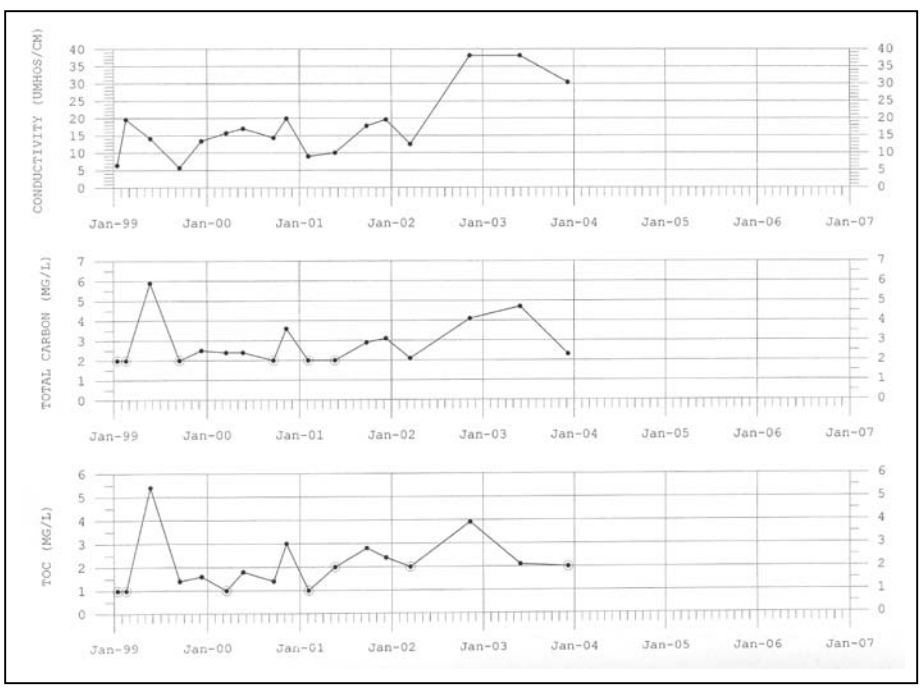
Benzene
Carbon tetrachloride
Chlorine
Chlorine dioxide
o-Dichlorobenzene
1,2-Dichloroethane
cis-1,2-Dichloroethylene
Dichloromethane
Ethylbenzene
Methyl Tert Butyl Ether
Tetrachloroethylene
1,1,1-Trichloroethane
Trichloroethylene
Toluene
Xylenes
Bromate
Chloramines
Chlorite
Chlorobenzene
p-Dichlorobenzene
1,1-Dichloroethylene
trans-1,2-Dichloroethylene
1,2-Dichloropropane
Haloacetic acids
Styrene
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane
TTHMs [Total trihalomethanes]
Vinyl Chloride
Control of DBP Precursors (TOC)

Figure 10. Typical Monitoring Well Detail.



3) *Reporting*: Water quality and ground-water level results should be submitted in tabular and graphical form. The results should be charted starting with the date of the predevelopment baseline levels (Figure 11).

Figure 11. Graphical Reporting of Ground-Water Quality Results.



10. Ground Water Management Agreement

A water management agreement between the owner and the local government is executed to ensure that the groundwater recharge facilities function as designed. The following summarizes a recommended water management agreement format:

Tax Parcel No.
Prepared by and Return to:

WATER MANAGEMENT AGREEMENT

THIS WATER MANAGEMENT AGREEMENT (the "Agreement") is made this _____ day of _____, _____, by and between _____ (hereinafter referred to as "Developer"), and Government, a body politic of the State of Delaware (hereinafter referred to as "Town or County").

WHEREAS, Developer has submitted an application, known in the Town or County records as application no. _____ and desires to develop in accordance with a Record _____ (hereinafter referred to as "Development") located in _____ Hundred, _____, Town or City, County, State of Delaware, consisting of approximately _____ acres of land, more or less (the "Site"), such plan to be recorded in the Office of the Recorder of Deeds, in and for _____ Town or County, State of Delaware (hereinafter referred to as the "Plan"); and

WHEREAS, Town or County requires that all construction in _____ Town or County be so designed and constructed in areas designated as Water Resource Protection Area District overlay zones (i) to conform to all applicable provisions of the Town or County Code, (ii) to provide reasonable means for the recharge of subterranean water resources and (iii) to maintain the quality of subterranean water resources.

NOW, **THEREFORE**, it is agreed, by and between the parties hereto, in consideration of the mutual promises and benefits contained herein that:

1. Developer, at its expense, shall:
    a. Provide the Town or County necessary plans and specifications for all components of the stormwater recharge system(s) (the "Stormwater Recharge System") for subterranean water resources located beneath the Site. The design, construction plans, and Management Plan as defined herein shall conform to all Town or County requirements and shall be incorporated in this Agreement by reference.
    b. Provide to Town or County prior to commencement of any land disturbing activity, a predevelopment water analysis to be used as a standard for future water quality tests as specified herein. Ground water in the installed monitoring well(s) shall be sampled and analyzed as an indication of base levels of the constituents to be monitored per this Agreement.
    c. Construct or cause to be constructed the Stormwater Recharge System and monitoring wells in accordance with designs and construction plans approved by the Town or County and in accordance with the design evaluation report, prepared by _____ and dated _____ (the "Management Plan"). The Management Plan is on file with the Town or County and is incorporated herein by reference.
    d. Operate, monitor, and maintain or cause to be operated, monitored, and maintained the Stormwater Recharge System in accordance with: (i) all applicable laws and regulations, (ii) generally accepted stormwater recharge practices, (iii) the Management Plan, (iv) final

construction plans for the Stormwater Recharge System as approved by the Town or County, and (v) the terms set forth herein.

e. As part of this Agreement, Developer agrees to retain an independent Delaware Registered Professional Engineer (the "Engineer") qualified in hydraulics, hydrology, and water resource management, to provide periodic reviews of construction, operation, testing, and maintenance of the Stormwater Recharge System as hereinafter required:
    i. Developer shall in the months of May and November of each year cause Engineer to review all components of the Stormwater Recharge System and monitoring well(s) to determine the operational status and whether any additional operability or maintenance requirements are necessary.
    ii. If, based upon this review, additional maintenance or operability requirements are necessary, Developer shall undertake said additional maintenance or operability requirements in accordance with schedules provided by the Engineer and approved by the Town or County.

f. Cause Engineer, within forty-five (45) days after each review conducted pursuant to Section 1(e)(i) hereof, to provide two (2) copies of a written report to the Town or County and one (1) copy to the Delaware DNREC, Division of Water Resources, and one (1) copy to the University of Delaware Water Resources Agency (UDWRA), that shall include, as a minimum:
    i. The condition and status of all elements of the Stormwater Recharge System.
    ii. Discussion of any additional maintenance recommended to be performed;
    iii. Status of any maintenance performed since the last reporting period; and
    iv. Results of ground-water level monitoring and water quality testing to include the following:
        - An assessment of the condition of the monitoring well(s), the need for any maintenance required, and the description of any maintenance performed since the last monitoring report;
        - Depth(s) to ground water in the monitoring well(s);
        - The method of obtaining the water samples from the monitoring well(s) and inflow to the Stormwater Recharge System, and the date(s) when the samples were obtained;
        - The results of the water sample tests performed pursuant to Paragraph 1(k) hereof;
        - Comparison of the results of the water sample analyses with previous monitoring results;
        - Discussion of trends based on the results of the testing; and
        - Discussion of possible causes of any observed changes in indicated water quality along with recommendations for remedial actions, if warranted.

g. As a condition of Record Plan approval for the Development, Developer agrees to provide a letter of credit (the "Letter of Credit"), the conditions of draws of such Letter of Credit are discussed herein. The Letter of Credit, an executed copy is attached hereto and set forth in Exhibit "II", shall provide financial assurance that the Stormwater Recharge System and monitoring well(s) shall be sampled, monitored, maintained, operated, and repaired in conformity with this Agreement. The Letter of Credit shall be in the amount of _____. As of the first day of each calendar year, Developer will ensure that the Letter of Credit is in the above stated amount.

h. If contamination to ground water beneath the Site is detected, Developer shall immediately notify the Town or County, DNREC, and UDWRA and cause Engineer (i) to evaluate whether the contamination was caused by activities on the Site, and (ii) to provide a written opinion to the Town or County, DNREC, and UDWRA within thirty (30) days after detection of the contamination with respect to the nature, scope and source of contamination.

i. If it is indicated that contamination to ground water beneath the Site was cause by activities on the Site, Developer shall within thirty (30) days after receipt of either the above written notification by Engineer or by other written notification by Town or County, commence maintenance or remedial activities determined by Engineer to be necessary.

j. Cause Engineer during construction of the Stormwater Recharge System to periodically review construction to determine that it is in conformance with plans and specifications submitted to and approved by the Town or County. Prior to issuance of the last Certificate of Occupancy for the Development, or as otherwise required by the approved construction plans, Engineer shall furnish a written opinion that construction of the Stormwater Recharge System(s) was completed in general accordance with the plans and specifications, and that the Stormwater Recharge System is ready for operation. The last Certificate of Occupancy for the Development shall not be issued until the Stormwater Recharge System is certified by Engineer to be operational. Operational shall mean that the system recharges at the prescribed rate and there is no ground-water contamination in samples as compared with preconstruction testing levels.

k. Cause water quality samples to be taken from the inflow waters to the Stormwater Recharge System and the installed monitoring well(s) once every three (3) months and analyzed for:

- pH (EPA Method 150.1)
- specific conductance (EPA Method 120.1)
- total dissolved solids (EPA Method 160.1)
- total carbon (EPA Method 415.1)
- total organic carbon (EPA Method 415.1)
- chemical oxygen demand (EPA Method 410.4)
- others

Said water quality sampling shall commence not later than thirty (30) days after completing construction of the Stormwater Recharge System and monitoring well(s). Subsequently, sampling shall be performed during the months of May and November.

In subsequent calendar years, in conjunction with the May sampling, samples will be taken from the inflow waters to the Stormwater Recharge System and the installed monitoring well(s), and analyzed for the following classes of substances regulated under the National Primary Drinking Water Regulations, 40 CFR Part 141; 40 FR 59570, December 24, 1975, revised through December 5, 1994 (59 FR 62466);

- Inorganic chemicals (§141.11)
- Organic chemicals (§ 141.12)
- Turbidity (§ 141.13)
- Volatile organic contaminants (§ 141.61)

l. Cause depth to ground-water measurements to be taken in the installed monitoring well(s), prior to sampling for water quality analysis.

m. Not permit underground storage of petroleum products on the Site and require that all above ground storage of petroleum products have secondary containment in accordance with State regulations.

n. As a condition to release of surety pursuant to paragraph 2(c) below, Developer and the Town or County shall meet to determine whether it is advisable to amend the Agreement with respect to the frequency of water sampling and the number of analyses required.

o. Release of surety pursuant to paragraph 2(c) below shall not relieve developer, or any future record owner of the Site, from the responsibility of perpetually maintaining the Stormwater Recharge System in an operational condition and in compliance with all federal, state, and Town or County regulations.

2. The Town or County shall:

a. Check and review the required plans and submissions for compliance with the Town or County Code and the Town or County design criteria, and shall make available all information it deems necessary to design the Stormwater Recharge System in a manner acceptable to the Town or County; and

b. Monitor from time to time, to the extent deemed necessary by the Town or County, the maintenance and operation of the Stormwater Recharge System.

c. Release Developer's surety at such time Developer provides proof satisfactory to the Town or County, including, but not limited to, all reports required by this Agreement, indicating that:

i. the Stormwater Recharge System is structurally sound and requires no structural repairs; and
ii. for a period of two years:
    A. the Stormwater Recharge System has been consistently recharging at the prescribed rate; and
    B. no ground-water contaminates have been detected in excess of the predevelopment levels; and
iii. all other requirements stated on the approved construction plans have been satisfied

3. Developer shall comply with all federal and state laws and regulations applicable to the Stormwater Recharge System in effect at the time of approval of the Plan.

4. The Town or County assumes no responsibility for any cost incurred by Developer in the event the plans and specifications of the Stormwater Recharge System are not approved by the Town or County, or in the event the Stormwater Recharge System, as constructed, does not conform to the final plans and specifications approved by the Town or County.

5. The Town or County may assign inspectors to review the construction of the Stormwater Recharge System to determine conformity to the approved plans and specifications.

6. Developer shall permit inspectors of the Town or County free access to all parts of the site to inspect and review the maintenance and operation of the Stormwater Recharge System and monitoring well(s). Developer shall make Engineer or his/her representative available to the Town or County at reasonable times upon reasonable notice if the Town or County requests the presence of the engineer.

7. (a) If within (30) days following receipt of written notice from Town or County to Developer, its successors or assigns, Developer fails to correct any violation of this Agreement or fails to commence to make a good faith effort to correct any violation of this Agreement not capable of correction within thirty (30) days following receipt of written notice, which violation creates and imminent and substantial danger to public health, Town or County, in addition to any other remedy, may enter upon the Site and correct the violations of this Agreement and charge Developer for all costs incurred including, but not limited to, the direct cost for corrections and administrative and overhead costs, and draw upon the Letter of Credit to recover such expenses. (b) Notwithstanding the foregoing, if Developer fails to monitor the ground water as provided herein within thirty (30) days following receipt of written notice from the Town or County, the Town or County may enter upon the Site to correct such failure and draw upon the Letter of Credit to recover the expenses of such activity.

8. The following provisions apply to draws made under the letter of credit.
    a. (1) A draw may be made under the Letter of Credit by the Town or County pursuant to this Section (a) in the event of a breach under this Agreement by the Developer which is not cured in accordance with this Agreement and which breach the Town or County cures for which the Town or County, its designee, incurs costs and expenses with respect to such cure. (2) A Section A Draw may be made by presenting to the bank issuing the Letter of Credit , in accordance with the Letter of Credit:
        i. A statement from the Town or County bearing reference to the letter of credit and specifying, in general terms, the reason for Town or County's draw.
        ii. A copy of the Letter of Credit.
    b. A draw may be made under the Letter of Credit by Town or County pursuant to this Section (b) in the event that the Issuing Bank gives Town or County notice that it intends to terminate the Letter of Credit and Developer has not delivered to Town or County a substitute or replacement for the Letter of Credit with substantially similar terms within sixty (60) days prior to the expiration date of the Letter of Credit. A Section B draw may be made by presenting to the Issuing Bank, in accordance with the Letter of Credit:
        i. An affidavit signed by the Town or County bearing reference to the Letter of Credit in the amount then available under the Letter of Credit and specifying that the draw has been

made as a result of the Issuing Bank's failure to extend the term of the Letter of Credit; and

ii. a copy of the Letter of Credit.

c. All references to the Letter of Credit shall include any and all letters of credit that are substituted for or replace the original Letter of Credit.

d. All references to the Issuing Bank shall include financial institutions issuing letters of credit that are substituted for or replace the original Letter of Credit.

e. In the event the Town or County incurs costs in excess of the amount of the letter of credit in completing or maintaining the recharge basins or structures related to recharge, or performing any part of this Agreement, Developer agrees to pay Town or County, upon demand, that amount sufficient to pay all costs incurred relating to the above.

f. The Letter of Credit shall remain effective until the Town or County, in writing, agrees to its release.

9. If construction of the Stormwater Recharge System has not commenced within three (3) years from the effective date of this Agreement, this agreement shall be of no further force or effect unless: (a) the plans and specifications for the Water Recharge System, including the Management Plan, are updated to comply with the then-effective Town or County Standards and approved by the Town or County, and (b) within three (3) years, Developer gives written notice to the Town or County requesting an extension of this Agreement and Town or County agrees to such an extension.

10. The provisions of this Agreement shall constitute covenants running with the land and the burdens and benefits herein shall bind and ensure the benefit of the Site. This Agreement shall bind the parties hereto and upon their respective successors interest and assigns.

11. The provisions of this Agreement are for the benefit of the parties hereto and may only be enforced by the parties hereto, and their heirs, signs, and successors in interest.

12. The liability of Developer to the Town or County pursuant to this Agreement shall be limited to liability arising from acts or omissions by Developer that constitute a violation of this Agreement.

13. The laws of the State of Delaware shall govern this Agreement.

14. If, by reason of strikes, acts of God, lawful order of governmental agency or body or other unavoidable causes, Developer is prevented from performing its obligations hereunder, then this Agreement shall be suspended with respect to said obligations during such force majeure period.

15. Developer shall provide Town or County with at least thirty (30) days written notice prior to any transfer, sale or conveyance of the Site. If the Site is conveyed, Developer's obligations under this agreement shall not be released until such time that the new record owner executes a water management agreement with Town or County and provides adequate surety to secure completion of the covenant's imposed by the water management agreement.

16. All notices and approvals to be given one party to the other under this Agreement shall be given in writing, mailed or delivered as follows:

    a. to the developer: Address

    Or to such other person at such other address designated by notice sent to the Town or County.

    b. to the Town or County: Address

    Or to such other person at such other address designated by notice sent to Developer.

Mailed notices shall be sent by United States certified or registered mail, postage prepaid, return receipt requested. Such notice shall be deemed to have been given upon receipt of written notice unless said receipt is refused or otherwise not accepted in which event notice shall be deemed to have been given upon posting in the United States mail. Notice may also be given by reputable overnight couriers, such as Federal Express.

17. This Agreement may not be amended except in writing approved by the Town or County.

18. This Agreement shall have no force or effect until the plan for application no. _____ has been approved by the Town or County and if necessary pursuant to the Town or County Code, Town or County Council approves said plain, and said Plan is recorded in the Office of the Recorder of Deeds in and for Town or County, State of Delaware. The effective date of this Agreement shall be date of recordation of said Plan.

IN WITNESS WHEREOF, the parties hereto have executed this Water Management Agreement under seal the day and year first above written.

[Signature Pages Follow]

DEVELOPER:

By _____ (SEAL)

Attest _____

If Developer is not the legal owner of the Development at time of execution of this Agreement, all legal and equitable owners must be made a party to this Agreement and named in the first paragraph of this Agreement and must execute this Agreement, or Power of Attorney must be attached to the signature page of this Agreement granting Developer the authority to execute this Agreement on behalf of the legal owners.

STATE OF DELAWARE
TOWN OR COUNTY OF _____

BE IT REMEMBERED, that on this _____ day of _____, _____, did personally come before me, the Subscriber, a Notary Public in and for the State and Town or County aforesaid, _____, on behalf of _____, known to me personally to be such, and acknowledge this Indenture to be his act and deed of _____.

GIVEN under my hand and Seal of Office the day and year aforesaid:

_____
Notary Public

_____
(Print Name)

My commission expires: _____

TOWN OR COUNTY
DEPARTMENT APPROVAL

_____

FOR TOWN OR COUNTY

By _____(SEAL)
Town or County Executive

STATE OF DELAWARE
TOWN OR COUNTY OF _____

BE IT REMEMBERED, that on this _____ day of _____, _____, did personally come before me, the Subscriber, a Notary Public in and for the State and County aforesaid, Town or County Executive, known to me personally to be such, and acknowledge this Indenture to be his act and deed of Town or County, Delaware.

GIVEN under my hand and Seal of Office the day and year aforesaid:

_____
Notary Public

_____
(Print Name)

My commission expires: _____

REFERENCES

Maryland Department of the Environment. (2000). *Maryland Department of Environment Stormwater Design Manual*. www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp. Accessed March 2004.

Delaware Department of Health and Social Services, Division of Public Health, Office of Drinking Water. (2003). *State of Delaware Regulations Governing Public Drinking Water Systems.*

Delaware Department of Natural Resources and Environmental Control – Division of Water Resources and Division of Soil and Water Conservation. (2001, revised 2004). *Delaware Sediment and Stormwater Regulations* (draft).

North Carolina Department of Environment and Natural Resources. (1999). *Stormwater Best Management Practices*. dem.ehnr.state.nc.us/su/PDF_Files/SW_Documents/BMP_Manual.PDF. Accessed March 2004.

Thornthwaite, C.W. and Mather, J. R. (1957). *Instructions and Tables for Computing Potential Evapotranspiration and Water Balance*.

United States Department of Agriculture, Natural Resources Conservation Service. (1986). *Technical Release 55. Urban Hydrology for Small Watersheds*.

United States Department of Agriculture, Soil Conservation Service. (1970). Soil Survey of New Castle County, Delaware; Soil Survey of Kent County, Delaware; and Soil Survey of Sussex County, Delaware.