Documenting Compliance

A Stormwater Report must be submitted to document compliance with the Stormwater Management Standards. For projects that are subject to the Stormwater Management Standards and regulated by the Wetlands Protection Act Regulations, 310 CMR 10.00, and or the 401 Water Quality Certification Regulations, the Stormwater Report must accompany the permit application. For each Standard, this Chapter describes the calculations that must be performed and the other information that must be submitted to document compliance. References that may be useful in conducting each computation are listed at the end of the section dealing with each Standard.

<u>Who Prepares The Stormwater Report:</u> The Stormwater Report must be prepared under the direction of a Registered Professional Engineer (RPE) licensed to do business in the Commonwealth pursuant to MGL Chapter 112 Section 81R. The RPE must perform the required calculations. The Stormwater Report Certification and Checklist must be stamped and signed by the RPE.

<u>Who Reviews the Stormwater Report</u>: For projects subject to jurisdiction under the Wetlands Protection Act, Conservation Commissions have the opportunity to review the Stormwater Report when Wetland NOIs are submitted for new development and redevelopment in wetland resource areas and buffer zones. MassDEP has the opportunity to review Report for 401 Water Quality Certification Applications or when there is an appeal of a decision issued by a Conservation Commission.

As more fully set forth below, the Stormwater Report must include the computations required to document compliance with many of the Standards. The required computations described in this chapter include the following:

- Standard 1 - Computations to show that discharge does not cause scour or erosion.
- Standard 2 - Peak Rate Attenuation (see Hydrology Handbook).
- Standard 3 - Recharge
    - Soil Evaluation
    - Required Recharge Volume
    - Sizing
        - *"Static"* Method
        - *"Simple Dynamic"* Method
        - *"Dynamic Field"* Method
    - 72-hour Drawdown Analysis
    - Capture Area Adjustment
    - Mounding Analysis
- Standard 4 - Required Water Quality Volume.
- Standard 5 – 6: Computations used to demonstrate compliance with Standard 4.
- Standard 7: Computations demonstrating that peak rate attenuation, recharge, and water quality treatment is provided to maximum extent practicable
- Standard 8: Computations related to sizing of erosion and sediment controls

REQUIRED DOCUMENTATION INCLUDING COMPUTATIONS FOR EACH STORMWATER STANDARD

STANDARD 1. NO UNTREATED DISCHARGES OR EROSION TO WETLANDS

Applicants must demonstrate that there are no new untreated discharges. To demonstrate that all new discharges are adequately treated, applicants may rely on the computations required to demonstrate compliance with Standards 4 through 6. No additional computations are required.

To demonstrate that new discharges do not cause or contribute to erosion in wetlands or waters of the Commonwealth, the following computations are required.

To evaluate whether the discharge will cause erosion or scour, the first step is to determine the stormwater discharge velocity at each outlet. The second step is to perform computations and select materials or practices to reduce that velocity or armor the ground to withstand the shearing force caused by the discharged stormwater. Computations must be conducted for both point sources and sheet flow.

Stormwater Discharge Velocity: Determine maximum discharge or velocity at each outlet for all conveyances. The maximum discharge or velocity is dependent on the size of the conveyance. Include gravitational forces in the computations when proposing to discharge stormwater above the receiving practice. Tailwater conditions in the receiving wetland must also be factored into the analysis. For sheet flow, the maximum velocity to evaluate is the runoff from the 2-year 24-hour storm. Engineers shall select an accepted method to determine maximum velocity.

Ability of Ground Surface to Resist Erosion: Determine ability of ground or lining materials to resist erosion from the velocity computed in part (a). Banks opposite a stormwater discharge point may need to be evaluated to assess their ability to resist scour when banks are close to the outlets (e.g., a narrow stream channel). This may be done by performing computations to estimate the size/weight of stone or bioengineered materials needed to resist the force of water or comparing the discharge velocity against a "permissible velocity table" that provides information on the ability of different types of materials/vegetation to resist shear.

The references that follow include several different computational methods and permissible velocity tables that are acceptable.

Channel Slope	Lining [1]	Permissible Velocity (feet/second)
0 - 5%	Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains	2.5
5 - 10%	Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater Than 10%	Tall fescue Kentucky bluegrass	3

Table 2.3.1: Example of Permissible Velocity Table, Modified from Soil and Water Conservation Engineering, 1992, Schwab et al, John Wiley and Sons

REFERENCES FOR STANDARD 1

Fletcher, B.P. and Grace, J.L., Jr., 1974, Practical Guidance for Design of Lined Channel Expansions at Culvert Outlets, Technical Report H-74-9, U.S. Army Engineer Experiment Station, Vicksburg, MS., page A12 (specifies methods for sizing riprap blanket dimensions from discharges from circular, square, rectangular and other shaped outlets)

Fangmeier, D.A., Elliot, W.J., Workman, S.R., Huffman, R.L., and Schwab, G.O., 2006, Soil and Water Conservation Engineering, 5th Edition, Thomson – Delmar Learning, Clifton Park, NY (permissible velocity table – page 119)

Gribbon, John E., 1997, Hydraulics and Hydrology for Stormwater Management, Chapter 5.5, Storm Sewer Outfalls, Delmar Publishers, Albany, NY (computation methods)

Lindeburg, Michael R., 2005, Civil Engineering Reference Manual for the PE Exam, 10th Edition (general reference, computational methods)

[1] Before selecting a vegetated lining, consult the list of plants banned for sale, trade, purchase, or distribution in Massachusetts by the Department of Agricultural Resources, pursuant to M.G.L. Chapter 128 Section 2 and Sections 16 through 31A. See http://www.mass.gov/eea/agencies/agr/farm-products/plants/massachusetts-prohibited-plant-list.html

Schwab, G. O., Fangmeier, D.A., Elliot, W.J., and Frevert, R.K., 1992, Soil and Water Conservation Engineering, 4th Edition, John Wiley and Sons (permissible velocity table)

U.S. Agricultural Research Service, 1987, Stability Design of Grass-Lined Open Channels, Agricultural Handbook No. 667. Online at: http://www.info.usda.gov/CED/ftp/CED/AH-667.pdf (computational methods)

U.S. Army Corps of Engineers, Engineering and Design - Hydraulic Design of Flood Control Channels, Engineering Manual (EM) 1110-2-1601. Online at: http://www.usace.army.mil/publications/eng-manuals/em1110-2-1601/toc.htm (computational methods)

U.S. Army Corps of Engineers, Drainage and Erosion-Control Structures for Airfields and Heliports, Technical Manual (TM) 5-820-3/AFM 88-5, Chapter 5. Online at: http://www.usace.army.mil/publications/armytm/tm5-820-3/chap5.pdf (computation methods)

U.S. Army Corps of Engineers, Hydraulic Design Criteria, Sheets 722-1 to 722-7. Online at: http://chl.erdc.usace.army.mil/Media/2/8/4/700.pdf (computational methods)

U.S. Federal Highway Administration, 2006, Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Center Circular No. 14 (HEC-14). Online at: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf (computational methods)

U.S. Federal Highway Administration, 2005, Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular Number 15 (HEC-15), Third Edition. Online at: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/05114/05114.pdf (computational methods)

U.S. Federal Highway Administration, 2001, Urban Drainage Design Manual, Hydraulic Engineering Circular Number 22 (HEC-22), Second Edition, Storm Drain Outfalls, Section 7.1.5. Online at: http://isddc.dot.gov/OLPFiles/FHWA/010593.pdf (general reference)

U.S. Natural Resources and Conservation Service (NRCS), National Handbook of Conservation Practices. Online at http://www.nrcs.usda.gov/Technical/Standards/nhcp.html (practices to reduce erosion)

U.S. Soil Conservation Service (SCS). 1966. Handbook of Channel Design for Soil and Water Conservation (SCS-TP-61). Online at: http://www.info.usda.gov/CED/ftp/CED/tp-61.pdf (permissible velocity table)

U.S. Soil Conservation Service (SCS). 1979. Engineering Field Manual for Conservation Practices, (Structures – Chapter 6, Grassed Waterways - Chapter 7). Washington, D.C., Chapter 7. Online at: http://www.info.usda.gov/CED/Default.cfm?xSbj=53&xAud=24 (computation methods, permissible velocity table, practices)

Young, G.K., et al, 1996. HYDRAIN – Integrated Drainage Design Computer System: Version 6.0 – Volume VI: HYCHL, FHWA-SA-96-064 (computational methods)

STANDARD 2. PEAK RATE ATTENUATION

Required Computations or Demonstrations:

See Hydrology Handbook for Conservation Commissioners:
http://www.mass.gov/eea/docs/dep/water/laws/a-thru-h/hydrol.pdf

REFERENCES FOR STANDARD 2

Nyman, David, 2002, Hydrology Handbook for Conservation Commissions, Massachusetts Department of Environmental Protection. Online at:
http://www.mass.gov/eea/docs/dep/water/laws/a-thru-h/hydrol.pdf

U.S. NRCS, 1986, Urban Hydrology for Small Watersheds Technical, Release 55. Online at:
http://www.info.usda.gov/CED/ftp/CED/tr55.pdf

U.S. NRCS, 2005, Win Technical Release 20. Online at:
http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR20.html

U.S. NRCS, Win Technical Release 55. Online at:
http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR55.html

U.S. ACOE, HEC-HMS (Hydrologic Modeling System). Online at:
http://www.hec.usace.army.mil/software/hec-hms/

STANDARD 3. STORMWATER RECHARGE

Required Computations or Demonstrations:

Multiple computations are necessary:

a. Impervious Area
b. *Required Recharge Volume*
c. Bottom Area Sizing for Infiltration Structures

See below and MassDEP *Hydrology Handbook for Conservation Commissioners*, Chapter 8.

RECHARGE REQUIREMENTS

The following requirements apply to the design of recharge structures. These requirements affect design computations so the following brief synopsis is provided. The "*Static"*, "*Simple Dynamic"*, and "*Dynamic Field"* methods for sizing are explained later in this Section.

- Minimum infiltration rate: Must be at least 0.17 inches/hour at the actual location where infiltration is proposed on site soil. No stormwater recharge systems shall be sited in soils that infiltrate lower than 0.17 inches/hour[2] due to the potential for failure.
  - When "*Static"* or " *Simple Dynamic"* Methods are used to size the recharge practice: whether the soils exfiltrate faster than 0.17 inches/hour is determined based on a soil textural analysis (see Soil Evaluation Section in this Chapter) and the rates specified by Rawls 1982 (See Table 2.3.3).
  - When the "*Dynamic Field"* method is used: whether the soils exfiltrate faster than 0.17 inches/hour is based on 50% of the actual in-situ *saturated hydraulic conductivity* rate. (See Soil Evaluation Section in this Chapter).
- Rapid Infiltration Rate: Rapid infiltration rate for purposes of stormwater infiltration is considered to be *saturated hydraulic conductivity* greater than 2.4 inches/hour at the specific location(s) where infiltration is proposed.
  - When "*Static"* or " *Simple Dynamic"* Methods are used for design, use rate specified by Rawls 1982 (see Table 2.3.3) for the soil type at the location where infiltration is proposed based on a soil textual analysis (see Soil Evaluation Section of this Chapter) to determine whether soil is classified as having a rapid infiltration rate.
  - When the "*Dynamic Field"* Method is used for design: 50% of the actual *in-situ saturated hydraulic conductivity* rate is used to determine whether the soil has a rapid infiltration rate.
    - *Example*: If the *in-situ* rate established by field-testing is 5.1 inches/hour, 50% of that rate = 2.55 inches/hour. The soil has a rapid infiltration rate, since 2.55 inches/hour>2.4 inches/hour.
- TSS Pretreatment: Stormwater Infiltration BMPs are infiltration basins, infiltration trenches, dry wells, subsurface infiltration structures and bioretention cells configured specifically to exfiltrate.
  - At least 44% TSS pretreatment is required prior to discharge to the stormwater infiltration BMP when:
    - The infiltration BMP is located within an area with a rapid infiltration
    - Runoff from a land use with a higher potential pollutant load (LUHPPL) is directed to the infiltration BMP.
    - The infiltration BMP is located within a Zone II or an Interim Wellhead Protection Area (IWPA) of a Public Drinking Water Source/Supply.

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[2] According to Rawls 1982, the lower end of soils assigned to Hydrologic Soil Group C have an average infiltration rate of 0.17 inches per hour. See Table 2.3.3. Hydrologic Soil Groups A and B are more conducive to stormwater recharge than "C" soils, so care must be exercised when designing stormwater recharge system in "C" soils.

- The discharge from the infiltration BMP is to or near another *critical area.* These critical areas are Outstanding Resource Waters, Special Resource Waters, shellfish growing areas, bathing beaches, and cold-water fisheries.

- At least 80% TSS pretreatment is required prior to discharge to stormwater infiltration BMP when:
  - The "*Dynamic Field"* method is proposed for sizing purposes.

SOIL EVALUATION

An evaluation must be undertaken to classify the Hydrologic Soil Groups (HSG) soils on site using classification methodologies developed by U.S. Natural Resources Conservation Service (NRCS). The Hydrologic Soil Groups are used in conjunction with impervious areas on a site to calculate the *Required Recharge Volume*.

The following steps are required to identify the Hydrologic Soil Groups on a site:

STAGE 1) Review NRCS (formerly SCS) Soil Surveys

NRCS soil surveys are to be used as the first step in identifying soils and soil hydrologic groups present at the site. All counties in Massachusetts have been mapped by NRCS. NRCS Soil Survey information is available online at:
http://www.ma.nrcs.usda.gov/technical/soils/index.html or
http://nesoil.com/massachusetts_soil_survey.htm. Locate the site using the electronic Soil Survey or on plans included in a hard copy of the Soil Survey. Identify the NRCS soil type and associated Hydrologic Soil Group by consulting the Soil Survey lists for the site.

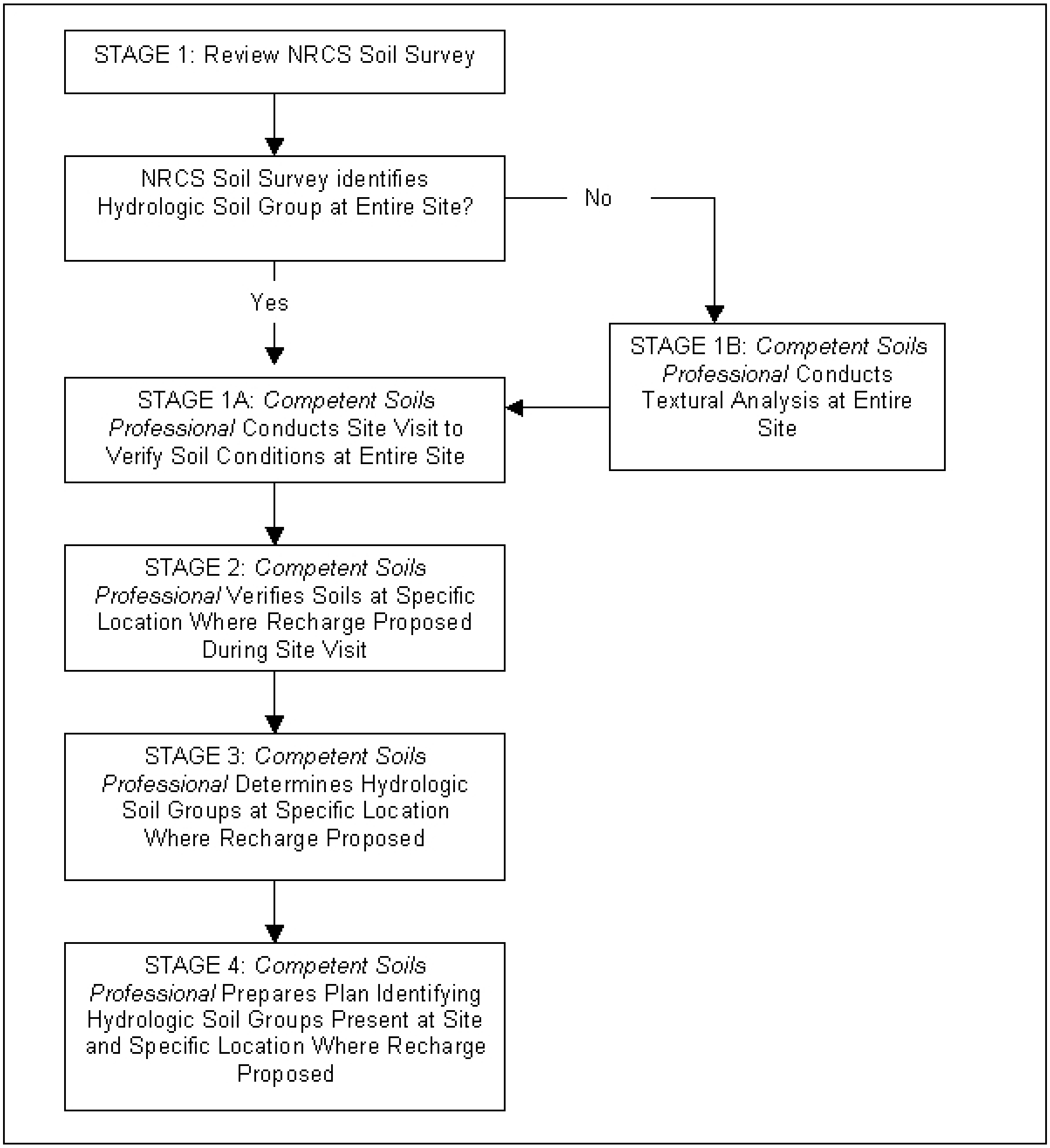

Figure 2.3.1: Determining Hydrologic Soil Group(s)

STAGE 1A) Site Visit

After completion of STAGE 1, a "*Competent Soils Professional*[3]*"* must conduct a site visit to confirm the NRCS soil survey.   The site visit will allow for observation of noticeable deviations in site conditions (i.e., bedrock outcrops, open gravel/sand areas, recent filling). The site visit

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[3] A *Competent Soils Professional* is an individual with demonstrated expertise in soil science, including, but not limited to, a Massachusetts Registered Professional Engineer, Engineer in Training (EIT certificate) with a concentration in civil, sanitary or environmental engineering, or Bachelor of Arts or Sciences degree or more advanced degree in Soil Science, Geology, or Groundwater Hydrology from an accredited college or university.

must establish whether the on-site soils have been disturbed, filled, or altered in a way that affects the natural drainage of the site.

The "*Competent Soils Professional*" shall perform the following tasks:

a. Conduct site visit. Determine whether any noticeable deviations on site exist from the NRCS Soil Survey (i.e., bedrock outcrops, open gravel/sand areas, recent filling). Determine whether the on-site soils have been disturbed, filled, or altered in any way.

b. Review any existing field test pit data and available boring logs and compare with NRCS information published in the Soil Survey. Boring logs and test pit data often indicate the soil textural class and varying soil strata (i.e., restrictive layers) and may assist in further refinements of soil delineations.

c. Review any existing USGS geologic maps for general rock types and bedrock depths. The presence of bedrock, including rock outcrops, is a significant factor in the potential for groundwater recharge. Knowledge of the bedrock and rock type at the site will be beneficial in further characterizing existing recharge conditions.

d. Review available aerial photographs. If a detailed site map is not available at the time of the initial investigation, an aerial photograph may provide additional information for delineating impervious and pervious areas.

e. When the Soil Survey does not identify the Hydrologic Soil Group(s) at the site or when the site conditions are not consistent with the NRCS Soil Survey, the *Competent Soils Professional* shall complete STAGE 1B. When the NRCS Soil Survey identifies the Hydrologic Soil Group(s) at the site, and the STAGE 1A investigation indicates site conditions are consistent with the NRCS Soil Survey, proceed to STAGE 2.

STAGE 1B) Additional Measures When the NRCS Soil Survey Does Not Identify Hydrologic Soil Group(s) At the Site or When Site Conditions Are Found That Are Inconsistent with the NRCS Soil Survey

Where the NRCS Soil Survey does not identify the Hydrologic Soil Group or when the site conditions are inconsistent with the NRCS Soil Survey, the site visit in STAGE 1A must include a soils textural analysis of the soils present throughout the entire site to determine the Hydrologic Soil Group(s). This investigation is needed to calculate the *Required Recharge Volume*. STAGE 1B is conducted for the entire site whereas the STAGE 2 investigation is conducted only at the actual location(s) where stormwater recharge is proposed.

The NRCS Soil Surveys may not identify the Hydrologic Soil Group(s) at sites located in urban areas. Most counties in Massachusetts have areas that have been mapped by NRCS as urban land or complexes of urban land and a soil series. When soils are mapped as urban land or complexes of urban land, the NRCS does not assign the soils to a Hydrologic Soil Group. Further, the NRCS does not typically identify the Hydrologic Soil Group(s) for soils mapped as Udorthents, udipsamments, nomans land, pits, gravels and quarries. The total area of urban complex soils in Massachusetts is approximately 150,000 acres or 3 % of the mapped area in the state. Soils mapped as urban and other soils comprise approximately 255,000 acres or 5.5% of the total mapped area.

For sites with soils that have not been assigned to a Hydrologic Soil Group by NRCS, the *Competent Soils Professional* must conduct a *Soil Textural Analysis* (see STAGE 2 for description) to identify the Hydrologic Soil Group(s) at the site (see STAGE 3), using test pits or soil borings. For a typical site, it is recommended that one test pit or boring be completed per acre with a minimum of 4 test pits or borings per site. The *Soil Textural Analysis* must be completed using standard USDA soil physical analyses (Black, et. al., 1965), i.e., particle size analyses. Classification of soil texture shall be consistent with the USDA Textural Triangle. The soil textural analysis for STAGE 1B must be conducted in the surface soil horizons. NRCS Soil Survey evaluations typically cover the first 60-inch soil depth. The field investigation for STAGE 2 must occur in the actual soil layer where recharge is proposed.

Stormwater recharge is not permitted through fill materials composed of asphalt, brick, concrete, construction debris, and materials classified as solid or hazardous waste. When the STAGE 1B field investigation indicates fill is present, the *Competent Soils Professional* must conduct a soil textural analysis of the parent material below the fill layer.

STAGE 2) Determine Site Conditions at Specific Location Where Recharge is Proposed

The following actions shall be performed to determine soil conditions at actual location on the site where recharge is proposed:

a. Conduct tests at the point where recharge is proposed. The tests are a field evaluation conducted in the actual location and soil layer where stormwater infiltration is proposed (e.g., if the O, A and B soil horizons are proposed to be removed, the tests need to be conducted in the C soil layer below the bottom elevation of the proposed recharge system). The tests shall be conducted by the *Competent Soils Professional*. The tests shall evaluate the following:

   - ❑ *Soil Textural Analysis* using NRCS methods
   - ❑ Depth to seasonal high groundwater
   - ❑ When *"Dynamic Field"* Method is proposed for sizing a field-derived *saturated hydraulic conductivity* must be determined as part of the site investigation.
   - ❑ When the "*Static*" or "*Simple Dynamic*" Methods or LID Site Design Credits are proposed for sizing stormwater recharge BMPs, in-situ tests for *saturated hydraulic conductivity* are not required for purposes of the Stormwater Standards and the *saturated hydraulic conductivities* listed by Rawls 1982 (see Table 2.3.3) shall be used.[4]

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[4] When NRCS Soil Surveys indicate a lower saturated hydraulic conductivity than Rawls 1982, care must be exercised in the design process. NRCS Soil Surveys may indicate multiple saturated conductivities for the same soil, depending on the soil depth.

Soil Textural Analysis (For STAGES 1B and 2)

Soil texture represents the relative composition of sand, silt and clay in soil. Soil texture is determined using procedures described in the USDA, 2007, National Soil Survey Handbook, Section 618.67 (Texture Class, Texture Modifier, and Terms Used in Lieu of Texture). See http://soils.usda.gov/technical/handbook/contents/part618.html#67. Soils must not be composited from one test pit or bore hole with soils from another test pit or bore hole for purposes of the textural analysis.

The NRCS also has online tools to assist in soil texture analysis, once the relative proportions of sand, silt, and clay have been determined. See http://soils.usda.gov/technical/aids/investigations/texture/

Soil textual analysis may also be completed using the methods described by MassDEP Soil Evaluator Course Chapter 2. These methods are based on the USDA NRCS methods http://170.68.97.68/dep/water/compliance/sech2.pdf

The number of locations where the soil textural analysis must be conducted at the actual point(s) where stormwater recharge is proposed depends on the type and size of the infiltration BMP. The BMP Specifications in Volume 2, Chapter 2 list the number of test locations needed for specific infiltration BMPs.

Determining Saturated Hydraulic Conductivity for Design Purposes (for STAGE 2)

Saturated hydraulic conductivity rates must be determined at the actual location and soil layer where recharge is proposed when the "*Dynamic Field"* method is proposed. When the "*Static"* or "*Simple Dynamic"* methods are proposed, the Rawls Rates at the location and soil depth where recharge is proposed shall be presumed to represent the *saturated hydraulic conductivity*, and no field evaluation is required.

a. Field test methods to assess *saturated hydraulic conductivity* for the "*Dynamic Field"* method must simulate the "field-saturated" condition. See ASTM D5126-90 (2004) Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone. The *saturated hydraulic conductivity* analysis must be conducted by the *Competent Soils Professional*. Acceptable tests include:
    i. Guelph permeameter - ASTM D5126-90 Method
    ii. Falling head permeameter – ASTM D5126-90 Method
    iii. Double ring permeameter or infiltrometer - ASTM D3385-03[5], D5093-02[6], D5126-90 Methods
    iv. Amoozemeter or Amoozegar permeameter – Amoozegar 1992
b. A Title 5 percolation test is not an acceptable test for *saturated hydraulic conductivity*. Title 5 percolation tests overestimate the *saturated hydraulic conductivity* rate.

[5] ASTM D3385-03 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer

[6] ASTM D5093-02 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.

c. The number of test locations is dependent on the type and size of the infiltration BMP. The BMP Section in Volume 2, Chapter 2 lists the number of test locations needed for specific infiltration BMPs.
d. For the "*Dynamic Field"* method, the tests results for *saturated hydraulic conductivity* measured in the field must use the lowest of the values recorded for sizing the stormwater recharge BMP, and not an average.
e. For the "*Static"* and "*Simple Dynamic"* Methods, the *saturated hydraulic conductivity* is determined using the Rawls Rate associated with the slowest of the Hydrologic Soil Groups determined to exist at the point where recharge is actually proposed.

    Example: Assume three samples are taken at a proposed infiltration basin in the actual soil layer where recharge is proposed. Two samples indicate sandy soils. The last sample indicates a sandy loam soil. The Rawls Rates used for the exfiltration analysis must use the sandy loam rate and not the sandy soil rate. Soils must not be composited for purposes of the soil textural analysis.

Determining Seasonal High Groundwater

Seasonal high groundwater represents the highest groundwater elevation. Depth to seasonal high groundwater may be identified based on redox features in the soil (see Fletcher and Venneman listed in References). When redox features are not available, installation of temporary push point wells or piezometers should be considered. Ideally, such wells should be monitored in the spring when groundwater is highest and results compared to nearby groundwater wells monitored by the USGS to estimate whether regional groundwater is below normal, normal or above normal (see: http://ma.water.usgs.gov).

When Fill Materials Are Determined To Be Present

When fill materials are present or are added prior to construction of the system, a soil textural analysis must be conducted in both the fill material and the underlying parent materials, and the Hydrologic Soil Group of the more restrictive layer shall be used to size the infiltration BMP. If fill is present that is composed of asphalt, brick, concrete, construction debris, or if materials classified as solid or hazardous waste are identified at the specific location where recharge is proposed, recharge elsewhere on site must be considered. Alternatively, the debris or waste may be removed in accordance with all applicable Solid and Hazardous Waste Regulations (see 310 CMR 19.000 and 40.0000) and replaced with clean material suitable for infiltration. Any solid or hazardous wastes present on the site must be managed in strict accordance with MassDEP Solid Waste Regulations, 310 CMR 19.000, Hazardous Waste Regulations, 310 CMR 30.00, and the Massachusetts Contingency Plan Regulations, 310 CMR 40.000.

STAGE 3: Identify Hydrologic Soil Groups On-site and At Location Where Recharge Proposed

The *Competent Soils Professional* shall use the information collected in STAGES 1 and 2 to identify the Hydrological Soil Group(s) throughout the entire site (for purposes of a Registered Professional Engineer calculating the *Required Recharge Volume*) and in the actual location and soil horizon and/or layer where stormwater infiltration is proposed (for purposes of a Registered Professional Engineer sizing the Recharge BMP).

In making the determination of the Hydrologic Soil Group at the location where recharge is proposed, the *Competent Soils Professional* may not be able to rely on the classification by NRCS. For undisturbed soils in Massachusetts, NRCS has assigned each soil type to a Hydrologic Soil Group. However, that classification is based on the upper and not lower soil horizons. When the lower soil horizons or layers are proposed for stormwater infiltration, the soils must be assigned to a Hydrologic Soil Group by the *Competent Soils Professional***.** USDA NRCS, 2007, Part 630 Hydrology National Engineering Handbook, Chapter 7, Hydrologic Soil Groups, and USDA NRCS 2007 National Soil Survey, Part 618.36, describe this process. See: http://policy.nrcs.usda.gov/media/pdf/H_210_630_7.pdf and http://soils.usda.gov/technical/handbook/contents/part618.html#36

After determination of the Hydrologic Soil Group(s) on site and at the actual points(s) where recharge is proposed, Registered Professional Engineers shall use Table 2.3.2 to calculate the volume of stormwater required to be recharged.

When the *"Static"* or *"Simple Dynamic"* Methods are used, the Rawls Table (Table 2.3.3) must be used to establish the exfiltration rate associated with the soil textures determined at the actual location on site where infiltration is proposed. When the "*Dynamic Field"* Method is used, the exfiltration rate for design purposes must be assumed to be no more than 50% of the *in-situ saturated hydraulic conductivity* rate at the actual location on site where infiltration is proposed.

STAGE 4: Prepare a Plan identifying Hydrologic Soil Groups for the Site

After review of the available data, prepare a plan of the site clearly delineating the Hydrologic Soil Groups throughout the entire site and the specific point(s) where recharge is proposed. Deviations from the NRCS Soil Surveys and special conditions discovered during additional investigations (relative to recharge potential) must be noted on the plan and described. The plan shall identify the location of all borings and test pits, including the location of any known prior test pits or borings. Test pit or boring logs shall be appended to the plan, identifying in cross section the soil types, seasonal high groundwater elevation, confining layers, and other appropriate information.

Note that many areas with Hydrologic Soil Group “D” soils (as well as other areas mentioned above) may be within wetland resource areas that are subject to the Wetlands Protection Act Regulations (310 CMR 10.00).

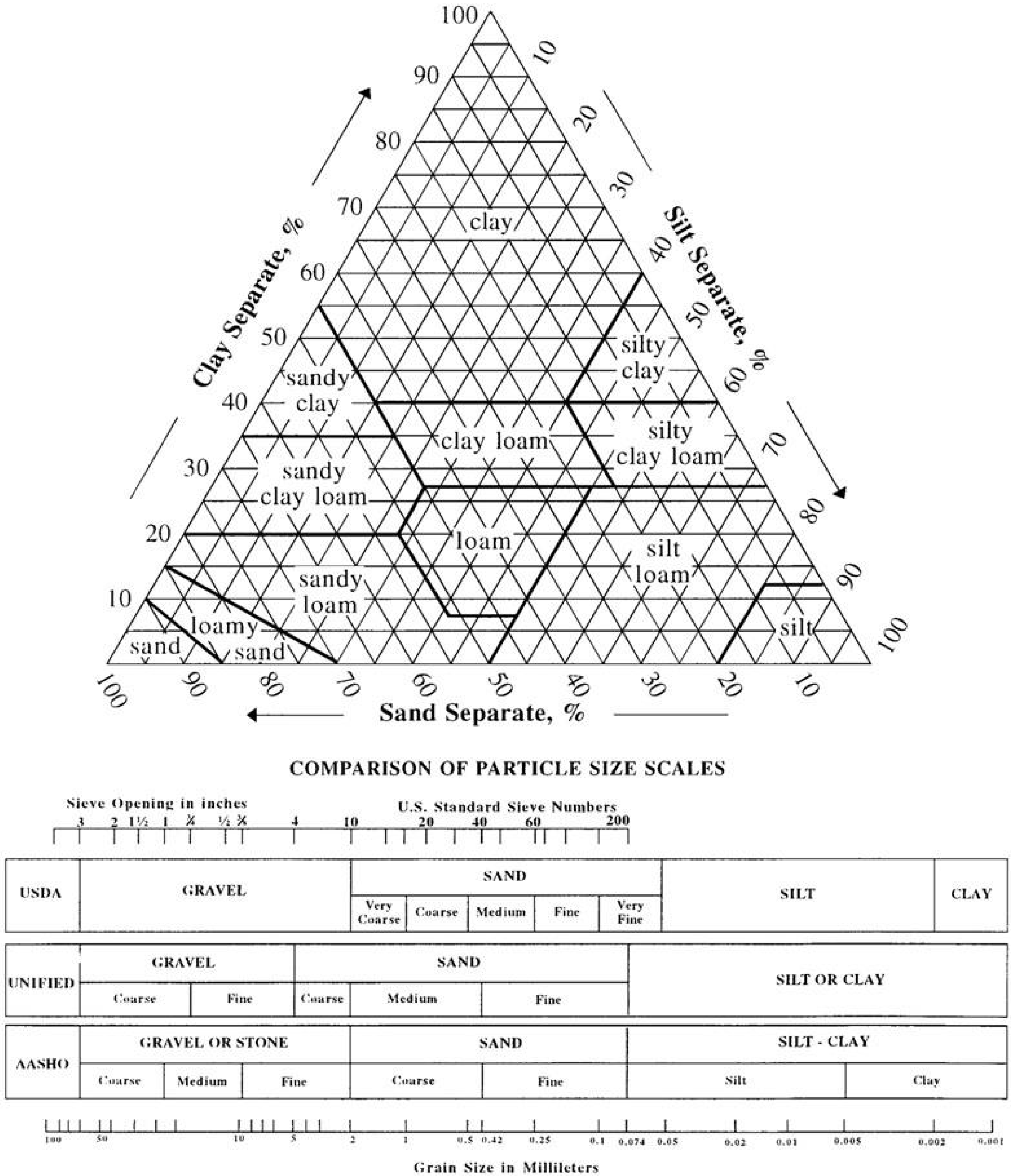

Figure 2.3.2: USDA, NRCS, 2007 National Soil Survey Handbook, Part 618, Exhibit 8,
http://soils.usda.gov/technical/handbook/contents/part618ex.html#ex8

CONTRIBUTING DRAINAGE AREA

The contributing drainage area must be determined for purposes of determining compliance with Standards 2, 3, and 4. The contributing drainage area for Standard 2 includes all areas contributing drainage to a site, including off-site locations. For purposes of Standards 3 and 4, only the impervious areas on the project site are used for purposes of calculating the *Required Recharge Volume* and the *Required Water Quality Volumes.*

IMPERVIOUS AREA

Impervious area must be determined in order to calculate the *Required Recharge Volume* and the *Required Water Quality Volume.* The impervious area is a subset of the contributing drainage area. For purposes of Standards 3 and 4, impervious surfaces include roads, rooftops, parking lots, and sidewalks, when they are paved with concrete, asphalt, or brick pavers. Various credits can be used to reduce the *Required Recharge Volume* and the *Required Water Quality Volume,* for Standards 3 and 4. See LID Site Design Credit Section of this Chapter.

Porous pavement is considered to be an impervious surface for purposes of calculating the *Required Water Quality Volume* and the *Required Recharge Volume.* When using porous pavement, the larger of the *Required Water Quality Volume* or *Required Recharge Volume* must be used to size the storage media under the porous pavement.

Similarly, a green roof is considered to be an impervious surface for purposes of sizing the growing media that treats the *Required Water Quality Volume* and determining the total *Required Recharge Volume* for the site. A green roof is a treatment device and does not recharge the groundwater.

RECHARGE VOLUME

STEP 1) REQUIRED RECHARGE VOLUME

Calculate *Required Recharge Volume*.[7] The *Required Recharge Volume* equals a depth of runoff corresponding to the soil type times the impervious areas covering that soil type at the post-development site.

$$Rv = F \times \text{impervious area} \quad \textbf{Equation (1)}$$

Rv = *Required Recharge Volume*, expressed in Ft^3, cubic yards, or acre-feet
F = Target Depth Factor associated with each Hydrologic Soil Group
Impervious Area = pavement and rooftop area on site

[7] MassDEP recognizes that along MassHighway Projects, because of right-of-way limitations it may be difficult to recharge the *Required Recharge Volume* at every point along redevelopment and add-a-lane projects. MassHighway may use a macro approach to meet this requirement by recharging more than the *Required Recharge Volume* at certain locations within a subwatershed (rest stops, exit ramps, median strips) to compensate for other locations within the same subwatershed where it is not able to infiltrate the *Required Recharge Volume*. MassDEP and MassHighway intend to work together to revise the 2004 MassHighway Handbook for Highways and Bridges to elaborate on this approach as it applies to redevelopment and add-a-lane projects and to reflect the 2008 changes to the Stormwater Management Standards.

Attention must be given to ensure consistency in units. In particular, the Target Depth Factors must be converted to feet.

NRCS HYDROLOGIC SOIL TYPE	APPROX. SOIL TEXTURE	TARGET DEPTH FACTOR (F)
A	sand	**0.6-inch**
B	loam	**0.35-inch**
C	silty loam	**0.25-inch**
D	clay	**0.1-inch**

Table 2.3.2: Recharge Target Depth by Hydrologic Soil Group

When a site contains multiple Hydrologic Soil Groups, determine the *Required Recharge Volume* for each impervious area by Hydrologic Soil Group and then add the volumes together.

Example: Assume a ten (10) acre site. 5.0 acres are proposed to be developed for a retail use. A section of the entrance roadway is to be bridged over a stream that is classified as land under water. As such, the bridging is subject to the Wetlands Protection Act Regulations, and the Stormwater Management Standards apply to stormwater runoff from all proposed roads, parking areas, and rooftops. Of the 5.0 acres proposed to be developed, 2 acres of impervious surfaces are proposed atop Hydrologic Soil Group (HSG) "A" soils, 1 acre of impervious surfaces atop HSG "B" soil, 1.5 acres of impervious surfaces atop HSG "C" soil, and 0.5 acres are proposed to be landscaped area. The remaining 5.0 acres, located on HSG "A" soil, are proposed to remain forested. Determine the *Required Recharge Volume*.

Solution: The *Required Recharge Volume* is determined only for the impervious surfaces. The 5.0-acre forested area and the 0.5-acre landscaped area are not impervious areas. Although converted from forest, landscaped area is pervious area for purposes of Standard 3. Use *Equation (1)* to determine the *Required Recharge Volume* for each Hydrologic Soil Group covered by impervious area. Add together the *Required Recharge Volumes* determined for each HSG.

Rv = F x impervious area

$Rv = [(F_{HSG\ "A"})(Area_1)] + [(F_{HSG\ "B"})(Area_2)] + [(F_{HSG\ "C"})(Area_3)] + [(F_{HSG\ "D"})(Area_4)]$ ***Equation (2)***

Rv = [(0.6-in/12)(2 acres)] + [(0.35-in/12)(1 acre)] + [(0.25-in/12)(1.5 acres)] + [(0.1-in/12)(0 acres)]

Rv = 0.1605 acre-feet

Rv = 0.1605 acre-feet x 43560 square feet/acre-feet = 6,991 cubic feet or *258.9 cubic yards*

Evaluate Where Recharge Is Directed

The infiltration BMP must be evaluated to determine if the proposed recharge location will alter a Wetland Resource Area by causing changes to the hydrologic regime. For example, if Watershed “A” contains a vernal pool within a Bordering Vegetated Wetland, and the vernal pool is fed by groundwater, and runoff from Watershed “A” is proposed to be directed to Watershed “B” for infiltration, an evaluation is necessary to determine if redirecting the runoff will cause an alteration to the vernal pool. In such instances, Water Budgeting using the Thornthwaite method or equivalent must be employed. TR-20/TR-55 methods are not sufficient for water budgeting purposes. Water budgeting analysis is not required, if the recharge is directed to the same subwatershed where the impervious surfaces are proposed.

STEP 2) SIZING STORAGE VOLUME

Determine the Storage Volume. The Storage Volume is the volume of the basin, chamber, or voids that must be constructed in order to hold the *Required Recharge Volume*. Three methods may be used to determine the Storage Volume:

1. The "*Static" Method;*
2. The "*Simple Dynamic" Method;* or the
3. The "*Dynamic Field" Method.*

The "*Static*" Method assumes that there is no exfiltration until the entire recharge device is filled to the elevation associated with the *Required Recharge Volume*. The two "*Dynamic"* Methods assume stormwater exfiltrates into the groundwater as the storage chamber is filling. [8] The *"Simple Dynamic"* Method assumes that the *Required Recharge Volume* is discharged to the infiltration BMP over 2 hours and exfiltrates over the 2-hour period at the Rawls Rate. The "*Dynamic Field"* Method assumes that the *Required Recharge Volume* discharges to the infiltration BMP over 12 hours and infiltrates at no more than 50% of the *in-situ saturated hydraulic conductivity rate*.[9] The "*Static"* Method produces a larger storage volume than either *Dynamic* Method and produces the most conservative result. The "*Dynamic Field"* Method may be used only for sizing an infiltration BMP that is used solely for disposal of stormwater (i.e., 80% TSS removal must occur prior to directing runoff to the infiltration BMP)[10].

When using the "*Static"* or "*Simple Dynamic"* Methods, only a textural soil analysis is required to determine the corresponding Hydrologic Soil Group. Textural soil analysis is explained in the Hydrologic Soil Group Section above. The "*Dynamic Field"* Method requires more soil testing to determine the *in-situ saturated hydraulic conductivity.*

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[8] Rich Claytor, Bethany Eisenberg, and Tom Maguire were instrumental in the development of the two *Dynamic* Methods.

[9] 50% is used as a factor of safety to represent the anticipated long-term exfiltration rate due to clogging of the underlying media/soil that occurs over time.

[10] Even if 80 % TSS removal is not required because the *“Dynamic Field”* Method has been used to size the infiltration BMP, 44% TSS removal may be required prior to discharge to the infiltration BMP. 44% TSS removal is required prior to discharge to an infiltration BMP if the *saturated hydraulic conductivity* is greater than 2.4 inches/hour based on the Rawls Rate for the "*Static"* and "*Simple Dynamic"* Methods. 44% TSS removal is also required prior to discharge to the infiltration BMP if runoff is from a LUHPPL or directed to a Zone II or IWPA, or near or to another critical area.

If using the "*Static"* Method, go to STEP 3. If using either *Dynamic* Method, skip STEP 3 and go to STEP 4.

STEP 3) *STATIC* METHOD:

a. Assume the entire *Required Recharge Volume* determined by following the procedures set forth in STEP 1 is discharged to infiltration device before infiltration begins.
b. Size the volume of the basin, chamber or total voids to hold the *Required Recharge Volume* determined under STEP 1.
c. Go to STEP 5 to confirm that the bottom of the infiltration BMP is large enough to ensure that the system will completely drain in 72 hours or less.

Example: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The soils are classified as Hydrologic Soil Group "A." An infiltration structure is proposed to meet Stormwater Standard 3. Use the *"Static"* Method to determine the storage volume of the infiltration structure.

Solution: The *Required Recharge Volume* is based on 0.60 inches (see Table 2.3.2) of runoff. Using *Equation (1):*

$$Rv = F \times \text{impervious area}$$
$$Rv = (F_{\text{HSG "A"}}) \times (\text{impervious area})$$
$$Rv = [(0.6 \text{ inches}/12 \text{ inches/foot})][(0.75 \text{ acre})(43{,}560 \text{ square feet/acre})]$$
$$Rv = 1{,}633.5 \text{ cubic feet or } 60.5 \text{ cubic yards}$$

Assuming that the stored runoff will exfiltrate completely into the ground within 72 hours, the infiltration structure must have a storage volume of 1,633.5 cubic feet.[11]

STEP 4) *"SIMPLE DYNAMIC"* AND "*DYNAMIC FIELD"* METHODS

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[11] If the infiltration structure is a trench filled with stone, the excavated volume of the trench must be determined to account for the stone in the trench. . The minimum excavated *infiltration trench* volume is determined as follows:

$$\text{Infiltration Trench Excavated Volume} = \frac{Rv}{n}$$

Where:
Rv = Required Recharge Volume
n = porosity or percentage of void space between the stone

Assuming *n* = 0.35 (35% voids) between the stone, the minimum Infiltration Trench Excavated Volume for design purposes would be:

$$\text{Infiltration Trench Excavated Volume} = \frac{1{,}633.5 \text{ cubic feet}}{0.35} = \text{[illegible] cubic feet}$$

Where an applicant chooses to size the recharge practice to take into account the fact that stormwater is exfiltrating from the recharge practice at the same time that the storage chamber is filling, one of the two methods specified in this Handbook must be used. These methods are referred to as the "*Simple Dynamic"* and "*Dynamic Field"* Methods. They result in smaller storage volumes than would otherwise be required by the "*Static"* Method. In Hydrologic Soil Group B, C, and D soils, all three methods produce similar sized storage. However, in sandy soils (Hydrologic Soil Group A), the "*Simple Dynamic"* and "*Dynamic Field"* Methods can produce smaller storage requirements. Since the "*Simple Dynamic"* and "*Dynamic Field"* Methods are less conservative than the *"Static"* Method, maintenance over the life of the recharge practice is especially critical to ensure that the recharge practice will function as designed over the long-term.

"Simple Dynamic"

Of the two "*Dynamic"* Methods, the "*Simple"* Method requires less time to complete. *Saturated hydraulic conductivity* is based on a soil textural analysis[12] performed at the location (actual depth/elevation) where the exfiltration is proposed to confirm or determine the Hydrologic Soil Group classification and the associated Rawls Rate. The "*Simple Dynamic"* Method is more conservative than the *"Dynamic Field"* Method, because it limits the allowable infiltration time that is used to reduce size of the infiltration BMP to the peak two hour period of a "typical storm". The *"Simple Dynamic"* Method can be performed by using the formulas set forth below.

Rv = F *x* impervious area
A =Rv ÷ (D+KT)
V=A*x*D
Rv is the *Required Recharge Volume*
F=Target Depth Factor. See Table 2.3.2.
A is the minimum required surface area of the bottom of the infiltration structure
V is the Storage Volume determined in accordance with the *"Simple Dynamic"* Method
D is a depth of the infiltration facility[13]
K is the saturated hydraulic conductivity. For " *Simple Dynamic"* Method, use Rawls Rate (See Table 2.3.3), and
T is the allowable drawdown during the peak of the storm (use 2 hours)

Example: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The soils are classified as Hydrologic Soil Group "A." An infiltration structure that is 4 feet deep is proposed to meet Standard 3. Determine the storage volume of the infiltration structure, using the "*Simple Dynamic"* Method.

Rv= F *x* impervious area
Rv= [(0.6 inches/12 inches/foot)][(0.75 acre)(43,560 square feet/acre)]
Rv =1,633.5 cubic ft or 60.5 cubic yards

[12] See Hydrologic Soil Group section above for information related to soil textural analysis.
[13] If the infiltration facility is a practice that uses stone or another media such as a dry well, only the void spaces must be considered. In those circumstances, use nd instead of d, where n is the percent porosity of the stone or other media. See footnote 11.

A=Rv÷(d+Kt)
A=1633.5cubic ft ÷[4 ft +(8.3"/hr/12"/ft *x* 2hr)]
A=303.4 sq. ft.
V=A *x* D
V=303.4 square ft *x* 4 ft
V=1203.6 cubic ft.[14]

To size an infiltration BMP using the "*Simple Dynamic*" Method, applicants may also use a computer model based on TR-20 as described below. As more fully set forth below, this computer model assumes that the *Required Water Quality Volume* is entering the infiltration BMP during the peak two hours of the storm and that runoff is being discharged from the BMP during the same two hour period at the Rawls Rate. This contemporaneous exfiltration allows a proponent to reduce the size of the infiltration BMP.

a. Use Equation 1 to determine the *Required Recharge Volume*
b. Select a 24-hour rainfall event that generates the *Required Recharge Volume* during the peak 2 hours. Use only the Site's impervious drainage area and the default NRCS Initial Abstraction of 0.2S and Type III storm. Set the storm duration for 24 hours, but use a start time of 11 hours and an end time of 13 hours. This creates a truncated hydrograph where most of the rainfall typical of a 24-hour Type III Storm occurs in just 2 hours. Selecting the correct precipitation depth is an iterative process. Various precipitation depths must be tested to determine which depth generates the *Required Recharge Volume*, using the Win TR-20 method (or other software based on TR-20). Each precipitation depth evaluated generates a runoff hydrograph. The area under the hydrograph is a volume. The correct result is achieved when the volume under the inflow hydrograph equals the *Required Recharge Volume.*
c. Using the resulting inflow hydrograph, choose an appropriate exfiltration structure with an appropriate bottom area and storage volume.[15]
d. Use recharge system bottom as maximum infiltrative surface area. Do not use sidewalls.[16]
e. Assume stormwater exfiltrates from the device over the peak 2-hour period of the rainfall event determined in step b above
f. Set exfiltration rates no higher than the Rawls Rates for the corresponding soil at the specific location where infiltration is proposed (see Table 2.3.3).
g. Assume exfiltration rate is constant.
h. Using the computer model, confirm adequate *Storage Volume*.
i. Go to STEP 5 to confirm that the bottom of the proposed infiltration BMP is large enough to ensure that the practice will drain completely in 72 hours or less. For purposes of the STEP 5 evaluation, assume the exfiltration rates are no higher than the Rawls Rates.

[14] The storage volume calculated using this "*Simple Dynamic"* Method is measurably less than the 1633.5 cubic feet that resulted from the *"Static"* Method.

[15] An applicant may have to select several different size infiltration structures before s/he identifies a structure that is adequately sized.

[16] If the recharge system includes stone or other media, remember that the effective storage volume only includes the voids between the stone or other media. See footnote 11.

Example Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The soils are classified as Hydrologic Soil Group "A." To meet Standard 3, an infiltration structure is proposed with a bottom that has a surface area of 303 square feet and a storage volume of 1212 cubic feet. Use the *"Simple Dynamic"* Method to confirm that this storage volume is adequate.

Solution using the computer model

The *Required Recharge Volume* is calculated using Equation 1 as follows:
Rv=F *x* impervious area
Rv= [(0.6 inches/12 inches/foot)][(0.75 acre)(43,560 square feet/acre)]
Rv =1,633.5 cubic feet or 60.5 cubic yards

The amount of precipitation is determined iteratively by developing a hydrograph that generates the 1,633.5 cubic feet, the *Required Recharge Volume*, during the peak two hours of the storm. A hydrograph is generated for a storm that produces 1.29" of precipitation and indicates the runoff is entering the infiltration structure at a maximum rate of 0.87 cfs during the most intense two hours of the storm. An exfiltration system is sized to store the difference between the inflow volume and the outflow volume using an infiltration rate of 8.3 inches/hour for HSG "A" soil (based on the Rawls Rates) over the 2-hour period. The outflow hydrograph reveals that runoff will leave the infiltration structure at a constant rate of 0.06 cfs during the peak two hours of the storm. The results yield an infiltration structure with a surface a ponding depth of 4.0 feet and a storage volume of 1,212 cubic feet.[17]

Type III 24-hr Rainfall=1.29"

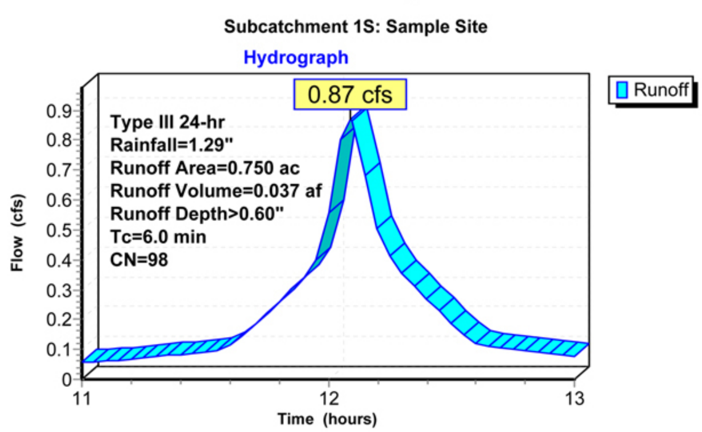
Subcatchment 1S: Sample Site

Runoff = 0.87 cfs @ 12.09 hrs, Volume= 0.037 af, Depth> 0.60"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 11.00-13.00 hrs, dt= 0.05 hrs
Type III 24-hr Rainfall=1.29"

Area (ac)	CN	Description
0.750	98	Paved roads w/curbs & sewers

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Minimum**



[17] The storage volume calculated using software based on TR-20 is 1216 cubic feet, is nearly identical to the storage volume using the formula set forth herein.

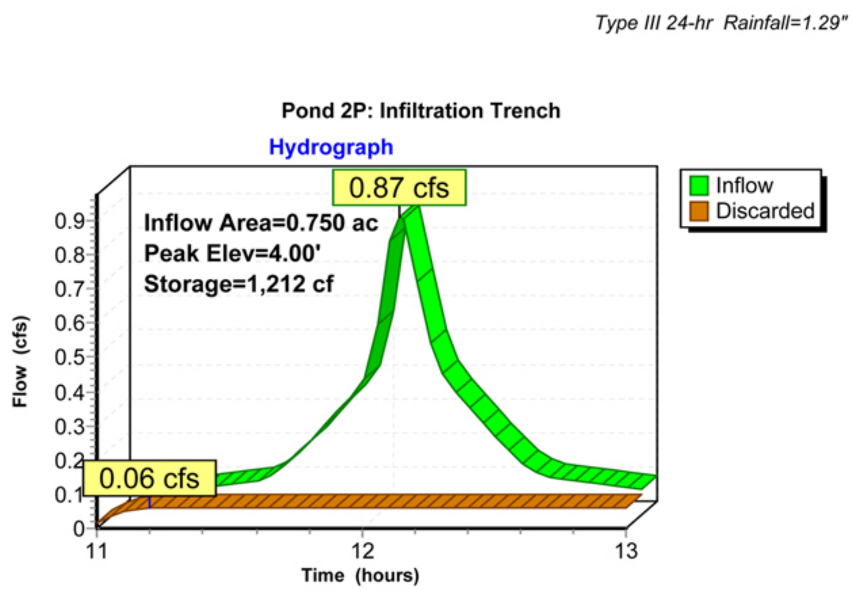


Table 2.3.3. 1982 Rawls Rates[18]

Texture Class	NRCS Hydrologic Soil Group (HSG)	Infiltration Rate Inches/Hour
Sand	A	8.27
Loamy Sand	A	2.41
Sandy Loam	B	1.02
Loam	B	0.52
Silt Loam	C	0.27
Sandy Clay Loam	C	0.17
Clay Loam	D	0.09
Silty Clay Loam	D	0.06
Sandy Clay	D	0.05
Silty Clay	D	0.04
Clay	D	0.02

18 Rawls, Brakensiek and Saxton, 1982

"Dynamic Field"

The "*Dynamic Field"* method may be used only for sizing infiltration structures that are used solely for disposal of stormwater (i.e., 80% TSS removal has been achieved prior to directing runoff to the infiltration BMP). *Saturated hydraulic conductivity* testing is required at the actual location where exfiltration is proposed.

a. Use Equation 1 to determine *Required Recharge Volume*
b. Select a 24-hour rainfall event that generates the *Required Recharge Volume* over 12 hours. Use only the Site's impervious drainage area and the default NRCS Initial Abstraction of 0.2S and Type III storm. Set the storm duration for 24 hours, but use a start time of 6 hours and an end time of 18 hours. This creates a truncated hydrograph where most of the rainfall typical of a 24-hour Type III storm occurs in just 12 hours. Selecting the correct rainfall depth is an iterative process. Various precipitation depths must be tested to determine which depth generates the *Required Recharge Volume,* using the Win TR-20 method (or other software based on TR-20). Each precipitation depth evaluated generates a runoff hydrograph. The area under the hydrograph is a volume. The correct result is achieved when the volume under the inflow hydrograph equals the *Required Recharge Volume.*
c. Using the resulting inflow hydrograph, choose an appropriate infiltration structure with an appropriate bottom area and storage volume.[19]
d. Use recharge system bottom as maximum infiltrative surface area. Do not use sidewalls.
e. Assume that exfiltration begins immediately at 6 hours and continues for 12 hours. Infiltration of the *Required Recharge Volume* may take more than 12 hours.
f. Set exfiltration rate used in the analysis to no higher than 50% of the *in-situ saturated hydraulic conductivity* rate in the soil layer where infiltration is proposed (e.g., if the *in-situ* rate is 10 inches/hour, 50% x 10 in/hr = 5 inches/hour).
g. Assume exfiltration rate is constant
h. Using computer model confirm adequate STORAGE VOLUME.
i. Go to STEP 5 to ensure that the bottom of the infiltration BMP is large enough to ensure that the system will completely drain in 72 hours using 50% of the *in-situ saturated hydraulic conductivity* rate determined using field-testing.

Example: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The soils are classified as Hydrologic Soil Group "A." An *in-situ* field evaluation reveals a *saturated hydraulic conductivity* rate of 20" per hour. An infiltration structure with a bottom surface area of 303 square feet is proposed to meet Standard 3. Use the *"Dynamic Field"* Method to determine the storage volume of the infiltration basin.

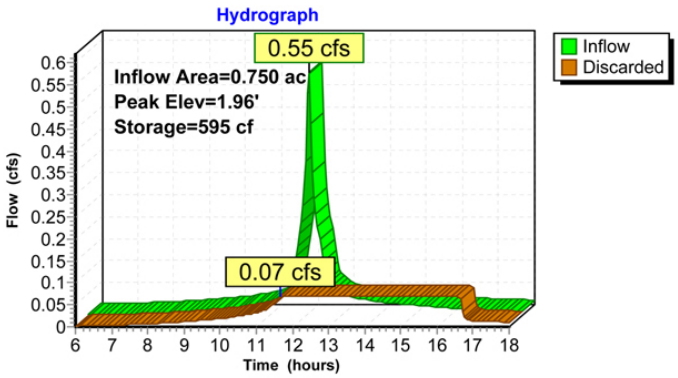
Solution: The *Required Recharge Volume* is calculated using Equation 1 as follows.
Rv=F *x* impervious area
Rv= [(0.6 inches/12 inches/foot)][(0.75 acre)(43,560 square feet/acre)]
Rv =1,633.5 cubic feet or 60.5 cubic yards

[19] An applicant may have to try different size infiltration structures before an infiltration structure that is adequately sized is identified.

The amount of precipitation is determined iteratively by developing a hydrograph that generates the *Required Water Quality Volume* over a 24-hour period. Based on this process, a hydrograph that generates 0.6 inches of runoff (this is the Target Depth Factor for HSG A soils in Table 2.3.2) during the peak 12 hours of a storm. A hydrograph is generated for a storm that produces 0.87 inches of precipitation over 24 hours with runoff entering the infiltration structure at a maximum rate of 0.55 cfs during the most intense period of the storm. Assume the bottom has a surface area of 303 square feet and that runoff exfiltrates at 10 inches per hour (50% of the *in-situ saturated hydraulic conductivity* rate determined by field-testing). Based on the hydrograph, runoff leaves the infiltration structure at 0.07 cfs. The model calculates a storage capacity of 595 cubic feet. Note: the peak elevation calculated by the model is 1.96 feet, approximately half of the ponding depth produced by the "*Simple Dynamic*" Method. The smaller peak elevation arises, because infiltration is assumed to occur over a longer period in the "*Dynamic Field*" Method than the "*Dynamic Simple*" Method, i.e., 12 hours instead of two hours, and the infiltration rate for the *"Dynamic Field"* Method is 10 inches per hour instead of the 8.3 inches per hour (Rawls Rate) for the "*Dynamic Simple*" Method.

Type III 24-hr Rainfall=0.87"

Pond 2P: Infiltration Trench



Type III 24-hr Rainfall=0.87"

Subcatchment 1S: Sample Site

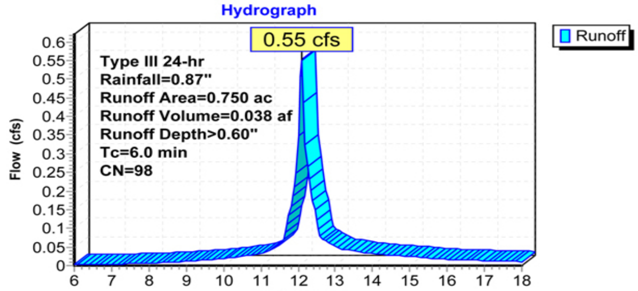
Runoff = 0.55 cfs @ 12.09 hrs, Volume= 0.038 af, Depth> 0.60"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
Type III 24-hr Rainfall=0.87"

Area (ac)	CN	Description
0.750	98	Paved roads w/curbs & sewers

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Minimum**

Subcatchment 1S: Sample Site



STEP 5) DRAWDOWN WITHIN 72 HOURS

Use the same infiltration rate that is used for sizing the infiltration BMP to confirm that the infiltration BMP will drain completely within 72 hours. For the "*Static"* and "*Simple Dynamic"* Methods, the Rawls Rates associated with the slowest of the Hydrologic Soil Groups determined to exist at the point where recharge is actually proposed shall be used. For the "*Dynamic Field"* Method, 50% of the lowest value obtained from the test results for *saturated hydraulic conductivity* measured in the field at the actual location and soil layer where recharge is proposed shall be used.

a. For infiltration BMPs sized using the "*Static"* Method or the "*Simple Dynamic*" Method, the drawdown analysis is based on the *Required Recharge Volume* exfiltrating at the Rawls Rates based on the soil textural analysis conducted at the proposed exfiltration location. The slowest Rawls Rate (1982) at the actual location where the recharge is proposed is used for purposes of the drawdown analysis.
b. For infiltration BMPs sized using the "*Dynamic Field"* Method, the drawdown analysis must be based on the *Required Recharge Volume* infiltrating at 50% of the lowest *in-situ saturated hydraulic conductivity* rate at the location and specific soil layer where exfiltration is proposed.
c. The infiltration rate shall be assumed to be constant for purposes of the drawdown analysis. [20]
d. Only the bottom surface shall be considered. No credit shall be afforded to sidewall exfiltration.
e. If the drawdown analysis indicates the entire volume cannot be drawn down within 72 hours, the bottom area of the infiltration BMP must be increased or the *Required Recharge Volume* must be reduced. The *Required Recharge Volume* may be reduced by reducing the amount of impervious surfaces on the site or by taking advantage of the Low Impact Development Site Design Credits.

To determine whether an infiltration BMP will drain within 72 hours, the following formula must be used[21]:

$$Time_{drawdown} = \frac{Rv}{(K)(Bottom\ Area)}$$

Where:
Rv = Storage Volume
K = Saturated Hydraulic Conductivity For "Static" and "Simple Dynamic" Methods, use Rawls Rate (see Table 2.3.3). For "Dynamic Field" Method, use 50% of the in-situ saturated hydraulic conductivity.
Bottom Area = Bottom Area of Recharge Structure[22]

[20] The drawdown analysis also assumes that the water table does not fluctuate during the draw down period.

[21] In some cases, the infiltration structure may be designed to treat the *Required Water Quality Volume* and/or to attenuate peak discharges in addition to infiltrating the *Required Recharge Volume*. In that event, the storage volume of the structure must be used in the formula for determining drawdown time in place of the *Required Recharge Volume*.

Drawdown Analysis Example for "Static" and "Simple Dynamic" Methods: Assume a one-acre site. An area that is 0.75 acre is proposed to be developed as impervious area. The soils are Hydrologic Soil Group "A" soils. An infiltration structure is proposed to meet Standard 3. Using Equation 1, the *Required Recharge Volume* is determined to be 1633.5 cubic feet. The soil textural analysis determined the soil layer for the proposed infiltration basin bottom is "sand," which is classified by the NRCS as Hydrologic Soil Group "A". The bottom area of the proposed basin is 303 square feet. Determine whether the proposed infiltration structure will draw down the 1633.5 cubic feet of water within 72 hours.

$$Time_{drawdown} = \frac{1633.5 \text{ cubic feet}}{(8.27 \text{ in/hr})(1 \text{ foot}/12 \text{ inches})(303 \text{ square feet})}$$

$Time_{drawdown}$ = 7.8 hours

7.8 hours < 72 hours so result is satisfactory for design purposes

The infiltration structure as designed is estimated to drawdown in 7.8 hours, well within the 72-hour requirement. If the analysis indicated that the recharge took longer than 72 hours, the bottom area of the infiltrative surface would need to be increased (e.g., instead of an infiltration structure with 303 square foot bottom area, evaluate a structure with a bottom area of 350 square feet, etc.) or the *Required Recharge Volume* would have to be reduced. The *Required Recharge Volume* could be reduced by reducing the amount of impervious surfaces or by taking advantage of the Low Impact Design Site Design Credits.

Drawdown Analysis Example for "Dynamic Field" Method: Assume a one-acre site. 0.75 acres is proposed to be developed. The soils are classified in the NRCS County Soil Survey as Hydrologic Soil Group "A" soils. An infiltration structure is proposed to meet Standard 3. Although the *Required Recharge Volume* is 1633.*5* cubic feet, the *Storage Volume* of the infiltration basin was determined to be 595 cubic feet using the "*Dynamic Field"* Method. The saturated hydraulic conductivity tests in the actual soil horizon where infiltration is proposed indicates that the lowest rate is 20 inches/hour. The bottom area of the proposed basin is 303 square feet (sized approximately 30 long by 10 feet wide). Determine whether the proposed infiltration basin will draw down the *Required Recharge Volume* for design purposes within 72 hours.

Solution: The exfiltration rate used for purposes of design is 50% of the in-situ rate. Assuming the infiltration rate is constant, the time to drawdown the *Required Recharge Volume* for design purposes would be:

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[22] To account for the porosity of the stone, a different formula is required to determine whether the Required Recharge Volume drains within 72 hours if the infiltration structure is a trench filled with stone**.** In that event, the drawdown time would be calculated as follows with n = porosity of the stone:

$$Time_{drawdown} = \frac{Rv}{(n)(K)(Trench\ Bottom\ Area)}$$

$$Time_{drawdown} = \frac{Rv}{(K)(Bottom\ Area)}$$

Where
Rv= Required Recharge Volume
K = 50% of the in-situ Saturated Hydraulic Conductivity
Bottom Area = Bottom Area of Recharge Structure

$$Time_{drawdown} = \frac{[illegible]}{[illegible]}$$

$Time_{drawdown}$ = 6.5 hours

6.5 hours < 72 hours so result is satisfactory for design purposes.

OTHER CONSIDERATIONS FOR STANDARD 3
CAPTURE AREA ADJUSTMENT: DETERMININING IF ENOUGH RUNOFF IS DIRECTED TO THE RECHARGE PRACTICE[23]

Sufficient runoff must be directed to the infiltration BMPs to ensure infiltration of the *Required Recharge Volume*. In some cases, designers size exfiltration practices based on the *Required Recharge Volume*, but then direct only a portion of the site's impervious area to the practice. As a result, the infiltration BMPs may not be able to capture sufficient rainfall on an average annual basis to meet the *Required Recharge Volume*. In this case, designers and reviewers have two options: either redesign the site so that runoff from more of the impervious areas located on the site is directed to the infiltration BMPs, or increase the storage capacity of the infiltration BMPs so that they may capture more of the runoff from the impervious surfaces located within the contributing drainage area. The following procedure describes the method that must be used where runoff from only a portion of the impervious area on a site is directed to one or more infiltration BMPs. This procedure is required to ensure that the infiltration BMPs are able to capture sufficient runoff from the impervious surfaces within the contributing drainage area to infiltrate the *Required Recharge Volume*. This procedure is not required for those sites where all impervious surfaces drain to an infiltration BMP. In no case shall runoff from less than 65% of the site's impervious cover be directed to the BMPs intended to infiltrate the *Required Recharge Volume.* When less than 65% of impervious surfaces on a site are directed to infiltration BMPs, the system cannot capture sufficient runoff to infiltrate the *Required Recharge Volume.*

1) Calculate the *Required Recharge Volume* based on total site impervious cover and underlying soil classification and size the infiltration BMP using the "*Static*" Method or one of the "*Dynamic*" Methods

[23] A similar adjustment must be made if runoff from all impervious surfaces is not directed to the treatment BMPs.

2) Calculate the site's impervious area that drains to proposed recharge facilities.

3) Divide the total site impervious area by the impervious area draining to the proposed recharge facilities.

4) Multiply the resulting quotient from Step 3 by the original *Required Recharge Volume* calculated under Step 1 to determine the adjusted minimum storage volume needed to meet the recharge volume requirement. The *"Static"* Method or either of the *Dynamic* Methods may be used to determine the storage volume.

Example:

A 1.5-acre site with 1 acre of impervious cover overlays Hydrologic Soil Group "A" soils. Based on site and topographic constraints, runoff from only 0.7 acres of the impervious cover will be discharged to one or more recharge facilities. Find the minimum recharge storage volume needed for the site, assuming the *"Static"* Method.

Solution:

1) Rv = F x impervious area
2) Rv = [(0.6 inches/12 inches/foot)(1.0 acre)(43,560 sq. ft./acre)]
Rv = 2,178 cubic feet
3) Site area draining to recharge facilities = 0.70 (1.0 acre) = 0.7 acres
4) Ratio of total site area to site area draining to recharge facilities = 1.0 acre/0.7 acre = 1.43
5) Adjusted minimum required recharge volume = [(1.43)(2,178 cubic feet)] = 3,1154 cu. ft.

Assuming that the analysis indicates that the stored runoff will exfiltrate completely into the ground within 72 hours, the recharge facility needs to be sized, at a minimum, to hold 3,114 cubic feet of runoff.

MOUNDING ANALYSIS

Mounding analysis is required when the vertical separation from the bottom of an exfiltration system to seasonal high groundwater is less than four (4) feet *and* the recharge system is proposed to attenuate the peak discharge from a 10-year or higher 24-hour storm (e.g., 10-year, 25-year, 50-year, or 100-year 24-hour storm). In such cases, the mounding analysis must demonstrate that the *Required Recharge Volume* (e.g., infiltration basin storage) is fully dewatered within 72 hours (so the next storm can be stored for exfiltration). The mounding analysis must also show that the groundwater mound that forms under the recharge system will not break out above the land or water surface of a wetland (e.g., it doesn't increase the water sheet elevation in a Bordering Vegetated Wetland, Salt Marsh, or Land Under Water within the 72-hour evaluation period).

The Hantush[24] or other equivalent method may be used to conduct the mounding analysis. The Hantush method predicts the maximum height of the groundwater mound beneath a rectangular or circular recharge area. It assumes unconfined groundwater flow, and that a linear relation exists between the water table elevation and water table decline rate. It results in a water table recession hydrograph depicting exponential decline. The Hantush method is available in proprietary software and free on-line calculators on theWeb in automated format. If the analysis indicates the mound will prevent the infiltration BMP from fully draining within the 72-hour period, an iterative process must be employed to determine an alternative design that drains within the 72-hour period.

Mounding analysis is also needed when recharge is proposed at or adjacent to a site classified as contaminated, was capped in place, or has an Activity and Use Limitation (AUL) that precludes inducing runoff to the groundwater, pursuant to MGL Chapter 21E and the Massachusetts Contingency Plan 310 CMR 40.0000; or is a solid waste landfill pursuant to 310 CMR 19.000; or groundwater from the recharge location flows directly toward a solid waste landfill or 21E site. In this case, the mounding analysis must determine whether infiltration of the *Required Recharge Volume* will cause or contribute to groundwater contamination.

REFERENCES FOR STANDARD 3

Akan, A.O., Sizing Stormwater Infiltration Structures, 2002, Journal of Hydraulic Engineering, Vol. 128, No. 5, pp. 534 – 537

American Society of Civil Engineers (ASCE), 1996, Hydrology Handbook, Second Edition, ASCE Manuals and Reports on engineering Practice No. 28, ASCE, New York, NY

ASTM D3385-03 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer

ASTM D5093-02 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring

ASTM D5126-90, 2004, Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone.

Amoozegar, Aziz, 1992, Compact Constant Head Permeameter: A Convenient Device for Measuring Hydraulic Conductivity, Soil Science Society of America. Advances In Measurement of Soil Physical Properties: Bringing Theory into Practice.

Bagarello, V., and Provenzano, G., 1996, Factors Affecting Field and Laboratory Measurement of Saturated Hydraulic Conducivity, Transactions of the American Society of Agricultural Engineers, Vol. 39, No. 1, pp 153-159.

[24] Hantush 1967 – See Reference for Standard 3.

Black C. A. (Ed). 1965. Methods of Soil Analysis, Part I, Physical and Mineralogical Properties, Including Statistics of Mesurement and Sampling, American Society of Agronom, Inc., Madison, WI

Black. C. A. (Ed.) 1965. Methods of Soil Analysis Part II, Chemical and Microbiological Properties, American Society of Agronomy, Inc. Madison, WI

Bouwer, Herman, 2002, Artificial Recharge of Groundwater: Hydrogeology and Engineering, Hydrogeology Journal, 10:121-142

Carter, Timothy L., Rasmussen Todd C., 2006, Hydrologic behavior of vegetated roofs, Journal of the American Water Resources Association, 42 (5): 1261-1274

Comprehensive Environmental Inc., 2002, Stormwater: Best Engineering Criteria No. 6.

Ferguson, B.K., 1994, Stormwater Infiltration, CRC Press, Boca Raton, Florida

Fletcher, P.C. and Veneman, P.L.M., Soil Morphology as an Indicator of Seasonal High Water Tables, http://nesoil.com/properties/eshwt.htm

Frimpter, M.H. 1981. Probable High Ground-Water Levels in Massachusetts. USGS Open-File Report 80-1205.

Hantush, M. S. 1967. “Growth and Decay of Groundwater Mounds in Response to Uniform Percolation.” *Water Resources Research*, Vol.3, 227-234.

Hantush, M.S. and Jacob, C.E. 1955. Nonsteady radial flow in an infinite leaky aquifer. *Trans. Amer. Geophys. Union*. 36. pp. 95-100.

Jabro, J.D. and Evans, R.G., 2006, Discrepancies Between Analytical Solutions of Two Borehole Permeameters for Estimating Field-Saturated Hydraulic Conductivity, Applied Engineering in Agriculture, Vol. 22(4): 549-554, http://naldc.nal.usda.gov/catalog/1920.

Massachusetts Department of Environmental Protection, Title 5 Soil Evaluator Course, Chapters 2 and 4.

Mohanty, B.P., Kanwar R.S., and Everts C.J., 1994, Comparision of Saturated Hydraulic Conductivity Measurement Methods for a Glacial Till Soil, Soil Science Society of America Journal, Vol. 58, No. 3.

Nimmer, M.A., Thompson, A.M., Misra, D., 2007, Groundwater Mounding Beneath Stormwater Infiltration Basins, 2007 ASAE Annual Meeting

Nolan, Bernard T., Healy, Richard W., Taber, Patrick E., Perkins, Kimberlie, Hitt, Kerie J., Wolock, David M., 2007, Factors influencing ground-water recharge in the eastern United States, Journal of Hydrology, Volume 332, Issue 1-2, pp. 187-205.

Ostendorf, D.W., DeGroot D.J., and Hinlein E.S., 2007, Unconfined Aquifer Response to Infiltration Basins and Shalow Pump Tests, Journal of Hydrology, Vol. 338 No. 1-2, Pp. 132-144

Pitt, R., Clark, S., and Parmer, K., 1993, Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration, Cooperative Agreement CR 819573, U.S. EPA, Cincinnati, Ohio

Pitt, R., Clark, S., Parmer, K., and Field, R., 1996, Groundwater Contamination from Stormwater Infiltration, Ann Arbor Press, Michigan.

Rawls, Brakensiek and Saxton, 1982, Estimation of Soil Water Properties, Transactions American Society of Agricultural Engineers 25(5): 1316 - 1320, 1328

Rawls, W.J., Gimenez, and Grossman, R., 1998. Use of Soil Texture, Bulk Density and Slope of Water Retention Curve to Predict Saturated Hydraulic Conductivity, Transactions American Society of Agricultural Engineers 41(4): 983-988.

Scanlon, B.R., Healy, R.W., Cook, P.G., 2002, Choosing appropriate techniques for quantifying groundwater recharge, *Hydrogeology Journal* 10 (2002), pp. 18–39.

S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55

U.S. Department of Agriculture, Natural Resources Conservation Service, 2007. National Soil Survey Handbook, title 430-VI, http://soils.usda.gov/technical/handbook/

United States Department of Agriculture, Natural Resource Conservation Service, 2007, Part 630 Hydrology National Engineering Handbook, Chapter 7, Hydrologic Soil Groups, http://policy.nrcs.usda.gov/media/pdf/H_210_630_7.pdf

Veneman, P.L.M. and P.C. Fletcher. 1997. Massachusetts soil evaluator program. In: M.S. Bedinger, A.I. Johnson and J.S. Fleming (eds.) Site characterization of onsite septic systems. ASTM STP 1324. Am. Soc. Testing Materials.

Warner, James W., Molden, David, Chehata, Mondher, and Sunada, Daniel K., 1989. Mathematical Analysis of Artificial Recharge from Basins, Journal of the American Water Resources Association 25 (2), 401–411.

Winkler, E, et al, 2000, Final Report Addendum: Assessment Of The Relative Importance Of Hydraulic Parameters On Infiltration Basin Performance, University of Massachusetts. (PDF File, April, 2001)

Winkler, E, Ahlfeld, D., Askar, G., Minihane, M., 2001, Final Report: Development of a Rational Basis for Designing Recharging Stormwater Control Structures and Flow and Volume Design Criteria. Prepared for Massachusetts Department of Environmental Protection Project 99-06/319. University of Massachusetts. (PDF File, April, 2001)

Wisconsin Department of Natural Resources, 2004, Conservation Practice Standards, Site Evaluation for Stormwater Infiltration, Practice 1002, http://dnr.wi.gov/runoff/pdf/stormwater/techstds/post/dnr1002-Infiltration.pdf

Wisconsin Department of Natural Resources, 2004, Conservation Practice Standards, Infiltration Basin Sizing, Practice 1003, http://dnr.wi.gov/runoff/pdf/stormwater/techstds/post/InfiltrationBasin_1003.zip

Wisconsin Department of Natural Resources, 2006, Conservation Practice Standards, Bioretention for Infiltration, Practice 1004, http://dnr.wi.gov/runoff/pdf/stormwater/techstds/post/Bioretention_1004a.zip

Wisconsin Department of Natural Resources, 2004, Compost, Specification S100, http://dnr.wi.gov/runoff/pdf/stormwater/techstds/post/SpecificationS100Compost.pdf

Kaveh Zomorodi, 2005, Simplified Solutions for Groundwater Mounding Under Stormwater Infiltration Facilities, AWRA 2005 Annual Water Resources Conferences, Seattle, WA, http://www.dewberry.com/uploadedFiles/SimplifiedSolutionsforGroundwaterMounding.pdf

STANDARD 4. WATER QUALITY

Required Computations or Demonstrations:

Source Control and Pollution Prevention Measures must be identified in the Pollution Prevention Plan[25]

Computations that are or may be necessary:

a. *Required Water Quality Volume*
b. TSS removal rate
c. Weight determination

WATER QUALITY TREATMENT VOLUME[26]

$$V_{WQ} = (D_{WQ}/12 \text{ inches/foot}) * (A_{IMP} * 43{,}560 \text{ square feet/acre}) \qquad \textbf{Equation (3)}$$

V_{WQ} = *Required Water Quality Volume* (in cubic feet)

D_{WQ} = Water Quality Depth: one-inch for discharges within a Zone II or Interim Wellhead Protection Area, to or near another critical area, runoff from a LUHPPL, or exfiltration to soils with infiltration rate greater than 2.4 inches/hour or greater; ½-inch for discharges near or to other areas.

A_{IMP} = Impervious Area (in acres)

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25 See Volume 1, Chapter 1 and Volume 2, Chapter 1.

26 Some proprietary BMPs are sized based on a flow rate. Applicants proposing such BMPs must provide documentation that the BMPs have been sized to treat the *Required Water Quality Volume.* MassDEP intends to provide detailed guidance on how to convert a flow rate to the *Required Water Quality Volume.*

Example for ½-inch D_{WQ}: Assume a two (2) acre site. One (1) acre is proposed to be developed for a retail store and parking lot. The parking lot is proposed to have 50 parking spaces, and generate less than 1,000 vehicle trips/day. The discharge is to be directed to a wetland resource area not determined to be a critical area, the land use is not a Land Use with a Higher Potential Pollutant Load ("LUHPPL"), and the soil does not have a rapid infiltration rate. The *Required Water Quality Volume* is to be directed to a wet basin, and not a stormwater infiltration BMP. Determine the *Required Water Quality Volume*.

Solution: The *Required Water Quality Volume* is determined for the impervious surfaces. Use Equation (3).

V_{WQ} = (D_{WQ}/12 inches/foot) * (A_{IMP} * 43,560 square feet/acre)
V_{WQ} = (½-inch/12 inches/foot) * (1 acre * 43,560 square feet/acre)
V_{WQ} = 1815 cubic feet

Example for 1-inch D_{WQ}: Assume a two (2) acre site. One (1) acre is to be developed for a retail store and parking lot. The parking lot is proposed to have 50 parking spaces, and generate less than 1,000 vehicle trips/day. The discharge is proposed to be directed to a wetland resource area that is a cold-water fishery. A cold-water fishery is defined as a critical area by the Wetland Protection Act Regulations. The *Required Water Quality Volume* is to be directed to a filtering Bioretention Area that is not designed to infiltrate. Determine the *Required Water Quality Volume*.

Solution: The *Required Water Quality Volume* is determined for the impervious surface

V_{WQ} = (D_{WQ}/12 inches/foot) * (A_{IMP} * 43,560 square feet/acre)
V_{WQ} = (1-inch/12 inches/foot) * (1 acre * 43,560 square feet/acre)
V_{WQ} = 3630 cubic feet

TSS REMOVAL PERCENTAGE COMPUTATIONS

MassDEP has two forms available to prepare the TSS removal computations; one is an automated EXCEL spreadsheet and the other is a hard copy version (that must be completed by hand). Both forms are the same, except that the Excel Spreadsheet performs the computations automatically. The automated Excel Spreadsheet is much easier to use than the hand method. A completed version of either form must be submitted as part of the Stormwater Report to demonstrate that the proposed treatment options will remove 80% of the TSS load on a design basis. A separate form must be completed for each stormwater outlet. For stormwater discharges that require 44% TSS pretreatment (e.g., within areas with rapid infiltration rates, Zone IIs, Interim Wellhead Protection Areas, or near or to other Critical Areas), the form must also be submitted to demonstrate that 44% TSS removal has been achieved prior to discharge to an infiltration BMP.

Information on the automated method is available on the MassDEP web site. When proposing proprietary structural treatment practices or when using the Low Impact Site Design Credit, proponents must use the manual form, since neither the proprietary treatment practices nor the

Low Impact Site Design Credit are listed in the dropdown menu in the automated Excel spreadsheet. An example that demonstrates how to use the manual form is set forth below.

Figure 2.3.4 Example of TSS Removal Form

INSTRUCTIONS:
1. Complete Blue Blocks
2. In BMP Column, Click on Blue Cell to Activate Drop Down Menu
3. Select BMP from the Drop Down Menu

Location:

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[2]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
	0.00	1.00	0.00	1.00
	0.00	1.00	0.00	1.00
	0.00	1.00	0.00	1.00
	0.00	1.00	0.00	1.00
	0.00	1.00	0.00	1.00

Total TSS Removal = 0%

Project:
Prepared By:
Date:

*Equals remaining load from previous BMP (E) which enters the BMP

1. BMP From Table on Page 1-7 of MassDEP Stormwater Mgt. Policy Handbook, Volume 1
2. TSS Removal Rate from Table on page 1-7 of the MassDEP Stormwater Mgt. Policy, Volume 1

Example for 44% TSS Pretreatment: Sheet runoff from a high-intensity parking lot with greater than 1,000 vehicle trips per day is directed to a series of off-line Deep Sump Catch Basins. The runoff from the deep sump catch basins is directed to an Oil/Grit Separator for further pretreatment, and then to an infiltration basin. There is a single stormwater outlet from the infiltration basin directed to a stream. MassDEP assigns a TSS annual removal rate for a properly designed Deep Sump Catch Basin of 25% and a properly designed Oil/Grit Separator of 25%. Use the Manual Form to determine whether the 44% pretreatment requirement is met.[27]

Solution: The TSS removal table (Figure 2.3.4) must be completed and presented with the Stormwater Report accompanying the Wetlands NOI. Manually, write in the name “Deep Sump Catch Basin” into Cell B1. In Cell C2, manually write in the assigned 25% TSS removal rate for Deep Sump Catch Basins. Only 25% TSS credit is provided, even though multiple Deep Sump Catch Basins capture runoff and direct it to the Oil/Grit Separator. Write 1.00 in Cell D1 (100% of the TSS load is presumed to be directed to the Deep Sump Catch Basin inlets). Multiply the 25% TSS removal rate for the Deep Sump Catch Basin by the starting TSS load of 1. Fill the result of 0.25 or 25% in Cell E1. Next determine the remaining TSS load, after stormwater leaves the device. The remaining load is the Starting TSS Load minus the TSS removed by the device. In this case, the remaining load is 1 – 0.25 = 0.75 or 100% - 25% = 75%. Write 75% in Cell F1.

[27] If runoff is directed to a BMP like an extended dry detention basin that is required to include a sediment forebay, no additional credit is given to the sediment forebay when determining whether 80% TSS removal is achieved. However, the 25% removal credit given to the sediment forebay can be used to satisfy the 44% pretreatment requirement prior to discharge to the infiltration structure for runoff from LUHPPLs, within an area with a rapid infiltration rate, within a Zone II or Interim Wellhead Protection Area, or near or to other critical areas.

Next, manually write in the name of the second structural BMP, the Oil/Grit Separator, into Cell B2. In Cell C2, manually write in 0.25 or 25%, the assigned TSS removal rate for the Oil/Grit Separator properly designed in accordance with the Volume 2, Chapter 2 specifications. In Cell D2, manually write in 0.75 or 75%, which is the remaining load listed in Cell F1 that is being directed to the Oil/Grit Separator. Multiple Cells C2 by D2, which would be 0.25 x 0.75. The result is 0.1875 or 0.19, rounded. Write this result in Cell E2. The remaining load is then determined by subtracting Cell E2 from D2, or 0.75 – 0.19 = 0.56. The result of 0.56 or 56% is manually written into Cell F2. Since the stormwater is not routed through any other devices for pretreatment, the final result is determined by adding 25% and 19% to obtain 44%. Manually write this result in Cell E6.

Please note that the TSS removal rates for each device as set forth in the TSS chart included in Volume 1, Chapter 1 must not added. If the TSS removal rates set forth in the chart for each device were added, it would appear that the Deep Sump Catch Basins and Oil/Grit Separator would remove 50% of the presumed annual TSS load (25% +25% = 50%). This is not the case. Adding the removal rates for the Deep Sump Catch Basins and Oil/Grit Separator does not take into account the fact that the influent TSS load is reduced when stormwater is routed from the first structural BMP to the second structural BMP. In this example, the influent load to the Oil/Grit Separator is only 75%, not 100%, because the Deep Sump Catch Basin is presumed to have removed 25% of the initial TSS load for runoff enters the Oil/Grit Separator.

***De Minimis* Stormwater Discharges for Purposes of Standard 4**

The 80% TSS removal rate must be achieved at each outlet discharging to a receiving wetland. The only exception to this is when the discharge is considered to be *de minimis*.[28] The stormwater discharge from an individual outlet is considered *de minimis* when all the following conditions are satisfied:

- Physical site conditions preclude installation of a TSS treatment practice prior to discharge (e.g., lack of space between a wetland and a road, lack of head differential).
- The discharge is less than or equal to 1 CFS for the runoff associated with the 2-year 24-hour storm.
- 80% TSS removal is achieved on an average weighted basis from the site as a whole using the weighted average method described below. This will require more than 80% TSS removal at some stormwater outlets to compensate for the outlets that achieve less than 80% TSS removal and achieve an overall weighted average reduction in TSS of 80% or more across the entire site.

[28] MassDEP and MassHighway recognize that it may be difficult to meet the 80% TSS removal rate at each outlet along a MassHighway redevelopment or add-a-lane project. For redevelopment projects, MassHighway and MassDEP have identified a "macro" approach that allows MassHighway to propose more than 80% TSS at some points along the portion of a roadway within a subwatershed to compensate for those locations within the same subwatershed where, because of right-of way constraints, it is not possible to achieve 80% TSS removal. Information on this approach is contained in the 2004 MassHighway Handbook for Roads and Bridges. MassDEP and MassHighway intend to develop a similar approach for add-a-lane projects when the MassHighway Handbook is revised. MassDEP and MassHighway intend to work together to revise the MassHighway Handbook in light of the 2008 changes to the Stormwater Management Standards.

- The stormwater outlets where additional controls are used to achieve more than 80% TSS removal must discharge to the same reach of the same wetland or water body as the outlets that achieve less than 80% TSS removal. A discharge is not *de minimus* if stormwater from an outlet discharging untreated or partially treated stormwater is discharged to one wetland or water body and stormwater that achieves more than 80% TSS removal is discharged to another wetland or water body.
- Controls are placed at the outlet to prevent erosion or scour of the wetland/stream channel and bank.
- Standard 2 (Peak rate attenuation) and Standard 3 (recharge) must be achieved on a site-wide basis.
- Source control and pollution prevention measures that mitigate the impact of the untreated or partially treated discharges are identified in the Pollution Prevention Plan required by Standard 4 and fully implemented (e.g., such as street sweeping).
- The size of the drainage area contributing runoff to the untreated outlet has been reduced to the maximum extent practicable.

If all these conditions are met, the discharge is considered *de minimus*. In that event, the Weighted Average Method described below must be used to determine if the 80% TSS removal rate is achieved on a site-wide basis for purposes of design.

Weighted Average = [illegible] ***Equation (4)***

Area = size, expressed in acres, square feet, or other units
TSS% = Assigned TSS removal rate, expressed as % (e.g. 25%)

Weights must be based on the size of each drainage area.

Example – De minimus discharge: Assume a site with 10 acres of impervious surfaces with two outlet points discharging to the same reach of a wetland resource area. Runoff from 9.995 impervious acres is to be directed to one outlet, after receiving 90% TSS removal. Drainage from a low point in the entry road from the remaining 0.005 acres (218 square feet) is to be directed to another outlet to the same wetland resource area, with no TSS treatment. Measures such as source reduction of winter sanding and quarterly street sweeping with vacuum sweepers are incorporated into the Pollution Prevention Plan required by Standard 4 to reduce TSS loading from the outlet point. In-pipe storage is proposed to reduce the peak rate of the discharge. Erosion controls such as riprap are proposed at the outlet to reduce the velocity of the discharge so it does not scour the wetland (Standard 1). The discharge is calculated to be less than 1 CFS. The size of the drainage area where treatment is not feasible has been reduced to the maximum extent practicable. No TSS treatment is possible, because there is insufficient head between the road sag point and the surface elevation of the wetland resource area. The overall weighted average is determined to be 89% using Equation 4. The impact to the wetland resource area from stormwater is considered *de minimis*, because the calculated discharge is less than 1 CFS and all the other conditions set forth above are met.

Example – Discharge is not de minimus: Assume a site with 10 acres of impervious surfaces with two outlet points discharging to the same reach of a wetland resource area. Runoff from 9 impervious acres is to be directed to one outlet, after receiving 90% TSS removal. Runoff from the remaining one acre is to be directed to another outlet, with no TSS treatment. The discharge rate from the one acre is determined to be 10 CFS. The overall weighted removal average is determined to be 81% TSS using Equation 4.

Solution: The discharge is not *de minimis*, because the 1 CFS threshold is exceeded. Therefore, weighting cannot be used. The discharge would result in a violation of Standard 1, because an untreated discharge is being made to waters of the Commonwealth.

WHEN ONE PRACTICE IS SIZED TO MEET BOTH STANDARDS 3 AND 4

Often one practice is sized to provide both water quality treatment and recharge. Unless 80% of the TSS load is proposed to be fully removed prior to discharge to the infiltration BMP, the infiltration BMP is being used to fulfill the requirements of both Standards 3 (Recharge) and 4 (Water Quality Treatment).[29] In such instance, the infiltration BMP must be sized to treat or hold the Target Volume, the larger of the *Required Water Quality Volume* and the *Required Recharge Volume*. For example, if the *Required Water Quality Volume* to be recharged is 1 inch and the *Required Recharge Volume* is 0.6-inches, the recharge system needs to be sized to handle the *Required Water Quality Volume*, since it is larger than the *Required Recharge Volume.* Only that portion of the *Required Water Quality Volume* directed to the infiltration BMP must be considered.

Example: Assume a two (2) acre site. One (1) acre is proposed to be a retail store and parking lot. The parking lot is proposed to have 50 parking spaces and generate less than 1,000 vehicle trips/day. The proposed retail building has a non-metal roof. The location is not near a critical area, the land use is not a land use with a higher potential pollutant load, and the soil was determined by in-situ testing to not have a rapid infiltration rate. The soils are Hydrologic Soil Group "A" soils. The recharge system, an infiltration basin, is proposed to meet both Standards 3 (recharge) and 4 (Water Quality). Runoff in excess of the *Water Quality Volume* is proposed to be routed to a dry detention basin for peak rate attenuation. Determine the storage volume of the infiltration basin, using the Static Method.

Solution: The *Required Water Quality Volume* is based on 0.5 inch of runoff and the *Required Recharge Volume* is based on 0.6-inches (see Table 2.3.2). (0.6 inches is more than 0.5 inches.) In this case, the Target Volume is the *Required Recharge Volume*, since it is larger than the *Required Water Quality Volume*.

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[29] The only exception is for rooftop runoff from a non-metal roof, or runoff from a metal roof that is located outside an industrial site and outside an Interim Wellhead Protection Area or Zone II.

REFERENCES FOR STANDARD 4

Claytor, R.A., and Schueler, T.R., 1996, Design of Stormwater Filtering Systems. Center for Watershed Protection, Silver Spring, MD.

Dewberry Companies, 2002, Land Development Handbook, Second Edition, McGraw Hill, New York, New York.

Dorman, M.E., J.P. Hartigan, R.F. Steg, and T.F. Quasebarth, 1996, Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Volume I: Research Report. FHWA-RD-96-095. Federal Highway Administration, Office of Research, Development and Technology.

Dorman, M.E., T.S. George, J.P. Hartigan, and T.F. Quasebarth, 1996, Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Volume II: Design Guidelines. FHWA-RD-96-096. Federal Highway Administration, Office of Research, Development and Technology.

Horner, Richard, R., Skupien, Joseph, J., Livingston, Eric, H., and Shaver, H., Earl, 1994, Fundamentals of Urban Runoff Management, Technical and Institutional Issues, Terrene Institute in cooperation with the U.S. EPA.

Minton, G., 2002, Stormwater Treatment, Resource Planning Associates, Seattle, WA.

Schueler, T. 1995. Site Planning for Urban Stream Protection. Metropolitan Washington Council of Governments, Washington, DC.

Winkler, E, Ahlfeld, D., Askar, G., Minihane, M., 2001, Final Report: Development of a Rational Basis for Designing Recharging Stormwater Control Structures and Flow and Volume Design Criteria. Prepared for Massachusetts Department of Environmental Protection Project 99-06/319. University of Massachusetts. (PDF File, April, 2001)

STANDARD 5. LAND USES WITH HIGHER POTENTIAL POLLUTANT LOADS

Source controls and pollution prevention measures to minimize or eliminate the exposure of any LUHPPLs to rain, snow, snow melt, and runoff must be identified in the Long-Term Pollution Prevention Plan.[30]

BMPs determined to be suitable for treating runoff from LUHPPL must be used.

One-inch rule applies when calculating *Required Water Quality Volume.*

Pretreatment Requirement 44% TSS removal must be achieved before discharge to infiltration structure.

If there is a potential for runoff with high concentrations of oil and grease, an oil grit separator, sand filter, filtering bioretention area or equivalent must be used to provide pretreatment.

For computations, see Standard 4.

<u>REFERENCES FOR STANDARD 5</u>

Massachusetts Department of Environmental Protection, Surface Water Quality Discharge Standards, 314 CMR 3.00 and 4.00

U.S. EPA, 2000, Multi-Sector General Permit

STANDARD 6. CRITICAL AREAS

Required Computations or Demonstrations

Standard 6 applies to discharges within Zone II, Interim Wellhead Protection Areas or near or to other Critical Areas: Shellfish Growing Areas, Bathing Beaches, Outstanding Resource Waters, Special Resource Waters, and Cold-Water Fisheries.

Source control and pollution prevention prevention measures must be identified in a long-term pollution prevention plan.

Use BMPs determined to be suitable for the particular critical area.

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[30] Some land uses with higher potential pollutant loads may be covered under the Multi-Sector General Permit. See Volume 1, Chapter 2. In that event, a SWPPP is required. Applicants may use one document to fulfill the SWPPP requirements of the Multi-Sector General Permit and the pollution prevention plan requirements of Standard 4. If there is a discharge to an ORW, MassDEP WM09 must be submitted.

One-inch rule is used to calculate the *Required Water Quality Volume.*

44% TSS removal must be achieved prior to discharge to the infiltration BMP.

See Standard No. 4 for computations.

STANDARD 7. REDEVELOPMENT

Required Computations or Demonstrations

Submit a Source Control and Pollution Prevention Prevention Plan as required by Standard 4.

Submit a Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan as required by Standard 8.[31]

Submit an Operation and Maintenance Plan as required by Standard 9.

Submit Illicit Discharge Compliance Statement required by Standard 10.[32].

Demonstrate that there are no new discharges that cause or contribute to erosion of wetlands or waters of the Commonwealth. Standard 1.

Complete computations to determine whether proposed structural BMPs fully meet the requirements of Standards 2 through 6. At a minimum, demonstrate that proposed stormwater management system meets Standards 2, 3, and the structural BMP requirements of Standards 4, and, if applicable, 5 and 6 to the maximum extent practicable. Demonstrate that measures have also been proposed to improve existing conditions. The "Redevelopment Checklist" set forth in Volume 2 Chapter 3 may be used to make these demonstrations.

STANDARD 8. CONSTRUCTION PERIOD CONTROLS

Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan as required by Standard 8.[33]

Computations or Demonstrations

Necessary computations:

a. Area to be disturbed[34]

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31 See Standard 8

32 See Standard 10

33 For projects subject to jurisdiction under the Wetlands Protection Act, the construction period pollution prevention erosion and sedimentation control plan should be included as part of the Stormwater Report submitted with the Notice of Intent. For highly complex projects where the proponent demonstrates that submission with the Notice of Intent is not possible, the issuing authority has discretion to issue an Order of Conditions authorizing the project prior to submission of the construction period erosion and sedimentation control plan. All Orders of Conditions shall provide that the construction period erosion and sedimentation control plan shall be submitted prior to the commencement of any land disturbance activity. Information on the erosion and sedimentation control plan is set forth in Volume 2, Chapter 1.

b. Computations demonstrating that control proposed measures are properly sized.

CONTROL PRACTICES PROPERLY SIZED

Computations must be provided to demonstrate that all control measures are properly sized in accordance with any relevant manufacturer specifications, good engineering practices, requirements specified in the Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas, and EPA Construction General Permit, whichever is more stringent. Special sizing is required for construction period sediment traps.

Sediment Trap Sizing: Sediment traps must provide storage for a calculated volume of runoff from the 2-year, 24-hour storm to meet EPA Construction General Permit requirements. The Massachusetts Erosion and Sedimentation Control Guidelines require that the construction period control sediment trap must be sized to provide 3,600 cubic feet of storage per acre drained. When computing the number of acres draining into a common location, it is not necessary to include flows from off-site areas and flows from on-site areas that are either undisturbed or have undergone final stabilization where such flows are diverted around both the disturbed area and the sediment trap.

Potential Soil Loss: Where potential soil loss needs to be evaluated as part of sizing a control practice, the Revised Universal Soil Loss Equation2 (RUSLE2) may be used. RUSLE2 is an automated method, based on the Universal Soil Loss Equation (USLE).

RUSLE2 NRCS Method[35](5)

REFERENCES FOR STANDARD 8

Fifield, J.S., 2002, Field Manual on Sediment and Erosion Control Best Management Practices for Contractors and Inspectors, Forester Press.

Fifield, J.S., 2004, Designing for Effective Sediment and Erosion Control on Construction Sites, Forester Press

Massachusetts Department of Environmental Protection, 2003, Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas, http://www.mass.gov/eea/docs/dep/water/esfull.pdf.

34 Land disturbances greater or equal to 1 acre required to obtain coverage under EPA NPDES Construction General Permit. If a stormwater discharge is proposed to an ORW, MassDEP Application WM09 must be submitted.

35 RULSE2 may be downloaded from NRCS via the web at: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

Pitt, R., Clark, S., and Lake, D., 2007, Construction Site Erosion and Sediment Controls: Planning, Design and Performance, Forester Press

U.S. EPA, 2003, Construction General Permit for Small and Large Construction Activities

STANDARD 9. OPERATION AND MAINTENANCE PLAN

Operation and Maintenance Plan as required by Standard 9 must be submitted.[36]

No computations are necessary.

STANDARD 10. ILLICIT DISCHARGES TO DRAINAGE SYSTEM

Measures to prevent illicit discharges must be included in Pollution Prevention Plan.

Illcit Discharge Compliance Statement must be submitted[37].

No computations are necessary.

LOW IMPACT DEVELOPMENT SITE DESIGN CREDITS

The Low Impact Development Site Design Credits encourage environmentally sensitive site design and Low Impact Development techniques for managing stormwater that minimize impervious surfaces and preserve natural hydrologic conditions. The credits allow project proponents to reduce or eliminate the structural stormwater BMPs otherwise required to meet Standards 3 and 4 by directing stormwater runoff to qualifying pervious surfaces that provide recharge and treatment. The credits are based on research published by Schueler 1994 and others indicating that the greater the impervious area, the more stream channel erosion, water quality impacts, and reductions in base flow. Schueler 1994 estimated that water quality is good in streams from watersheds with less than 10% impervious cover, degraded in watersheds with 10 to 25% impervious cover, and poor when impervious cover exceeds 25%. The credit system is also based on the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) Smart Growth Toolkit, Appendix A.

THE IMPACT OF THE CREDITS:
As more fully detailed below, the credits may be used to reduce the *Required Recharge Volume* and the *Required Water Quality Volume* provided that any pervious surfaces used to treat and infiltrate stormwater runoff meet the requirements set forth herein.

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[36] Information on the Operation and Maintenance Plan is set forth in Volume 1, Chapter 1 and Volume 2, Chapter 1.

[37] For projects subject to jurisdiction under the Wetlands Protection Act, the Illicit Discharge Compliance Statement may be included in the Stormwater Report submitted with the Notice of Intent. The Illicit Discharge Compliance Statement must be submitted before stormwater is discharged to the post-construction stormwater BMPs.

A proponent of a project that is eligible for the site design credit is required to:

- Develop and implement a construction period pollution prevention and erosion and sedimentation control plan and a long-term pollution prevention plan and operation and maintenance plan in accordance with all applicable provisions of Standards 4, 5, 6, 8, and 9 and to remove illicit discharges in accordance with Standard 10.
- Attenuate the peak discharge rate in accordance with Standard 2.
- Comply with the requirements of Standard 1 regarding new stormwater outfalls.

The application of these credits does not relieve the design engineer or reviewer from the standard of engineering practice associated with safe conveyance of stormwater runoff and good drainage design.

NOT ELIGIBLE FOR CREDIT:

The Low Impact Site Design Credit may not be applied to reduce the *Required Recharge Volume* and the *Required Water Quality Volume:*

- at sites in a Zone II with impervious surfaces covering 15% of the site or 2500 square feet, whichever is greater;
- at sites where stormwater runoff is directed to non-permeable soils, such as bedrock and soils classified as Hydrologic Soil Group D; and
- at sites with urban fill, soils classified as contaminated pursuant to the Massachusetts Contingency Plan (MCP), and soils with seasonal high groundwater –groundwater elevation within 2 feet of the land surface.

Sites with LUHPPL are not eligible for Credit No. 1.

Sites with LUHPPL are eligible for Credits 2 and 3, provided that no runoff from the areas or activities that may generate runoff with higher potential pollutant loads is directed to the pervious surfaces used to satisfy the credit, and provided further that the proposal satisfies all the other requirements set forth herein.

Runoff from metal roofs is only eligible for Credit 2 when the metal roof is located outside a Zone II or Interim Wellhead Protection Area and the building is not used for industrial purposes.

Runoff from green roofs is not eligible for Credit 2.

AVAILABLE CREDITS:

CREDIT 1. Environmentally Sensitive Development
CREDIT 2. Rooftop Runoff Directed to Qualifying Pervious Area
CREDIT 3. Roadway, Driveway or Parking Lot Runoff Directed to Qualifying Pervious Area

"Qualifying Pervious Areas" are defined as natural or landscaped vegetated areas fully stabilized, with runoff characteristics at or lower than the NRCS Runoff Curve Numbers in the table set forth below. The Qualifying Pervious Area may be located in the outer 50-foot portion of a wetland buffer zone. However, it must not be located in the inner 50-foot portion of a wetland buffer zone (that portion of the buffer zone immediately adjacent to a wetland).

Maximum NRCS Runoff Curve Numbers for Qualifying Pervious Area

Cover Type	HSG A	HSG B	HSG C
Natural: Woods Good Condition	30	55	70
Natural: Brush Good Condition	30	48	65
Landscaped: Good Condition (grass cover > 75% or equivalent herbaceous plants)	39	61	74

CREDIT EXPLANATION

Credit 1: Environmentally Sensitive Development

This credit is given for environmentally sensitive site design techniques that "cluster development" or reduce development scale, to leave a significant amount of the site undisturbed in its natural state. If a site is designed, constructed, operated and maintained in accordance with the requirements of this credit, a project proponent need not develop and implement additional structural stormwater BMPs to meet Standards 3 and 4.

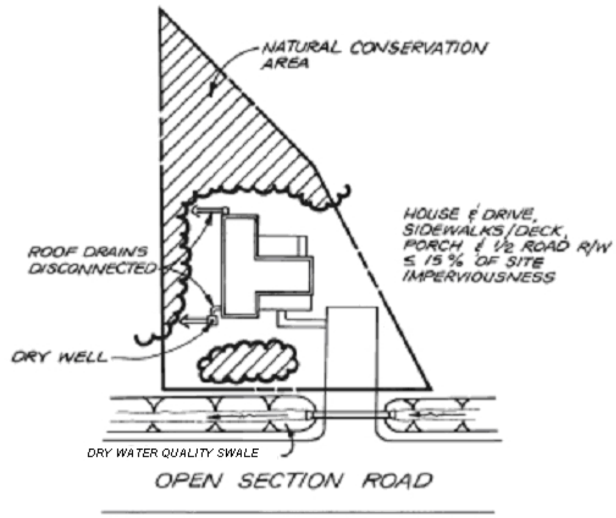

FIGURE 1: Credit No. 1 (Environmentally Sensitive Development) Example

Minimum Criteria for Credit

The *Required Recharge Volume* and the *Required Water Quality Volume* requirements are completely met without the use of structural practices in certain low density (less than 1 dwelling unit per acre) or cluster residential developments when the following conditions are met:

- The total impervious cover footprint must be less than 15 % of the base lot area. Because alterations are limited in these areas under the Wetlands Protection Act Regulations, 310 CMR 10.00, the following wetland resource areas may not be included in the base lot area used for purposes of determining compliance with this requirement: any vegetated wetlands (Bordering Vegetated Wetland (BVW), Isolated Vegetated Wetland (IVW), Salt Marsh); Land Under Water and Waterways; Land Under Ocean; Bank; Coastal Bank; or 5,000 square feet or 10% of the Riverfront Area, whichever is greater.
- No alteration may occur in any coastal wetland resource areas other than Land Subject to Coastal Storm Flowage.
- No alteration may occur in BVW or IVW.
- A minimum of 25% of the site must be protected as a natural conservation area. To qualify as a natural conservation area, an EEA Conservation Restriction must be placed on the protected area. Because alterations are limited in these areas under the Wetlands Protection Act Regulations, 310 CMR 10.00, the Natural Conservation Area must not include the following wetland resource areas: any vegetated wetlands (BVW, IVW, Salt Marsh); Land Under Water and Waterways; Land Under Ocean; Bank; Coastal Bank; or more than 5000 square feet or 10% of the Riverfront Area, whichever is greater.
- Stream buffers must be incorporated into the design of any areas adjacent to perennial and intermittent streams on the site. A stream buffer is the inner 50 feet of the buffer zone adjacent to the bank. At a minimum, no work, including any alteration for stormwater management, may be proposed in the 50-foot-wide area in the buffer zone along any wetland resource area. The proposed project shall not include any impervious surfaces in the 50-foot-wide area in the buffer zone along any wetland resource area.

- The amount of impervious surface shall not exceed 40% of the area of the buffer zone between 50 and 100 feet from any resource area or the amount of existing impervious surface, whichever is greater.
- No work may be proposed in a buffer zone that:
  - Borders an Outstanding Resource Water,
  - Contains estimated wildlife habitat which is identified on the most recent Estimated Habitat Map of State-listed Rare Wetlands Wildlife prepared by the Natural Heritage and Endangered Species Program,
  - Contains slopes greater than 15% prior to any work
- Rooftop runoff must be disconnected in accordance with the requirements applicable to Credit 2.
- Qualifying pervious areas are used to convey runoff from roads and driveways instead of curb and gutter systems.

Environmentally Sensitive Development Credit Example Application

Given the following base data:
Site Data: a single-family lot that is part of an 8-acre low-density subdivision in a critical area
Lot Area = 2.5 ac
Conservation Area = 0.65 ac
Conservation Area and Site is 10% wetland resource area
Impervious Area = 0.35 ac = 14%
Site Soils Types: 100% Hydrologic Soil Group "B" Soil
F = 0.35 inches, where F is the Recharge Factor required for "B" soils
Original required water quality volume = (1.0"/12 IN/FT) (0.35 acres) (43,560 SF/ACRE) = 1,270.5 ft^3
Original Required recharge volume = (2.5 acres) (0.14) (0.35"/12 IN/FT) (43,560 SF/ACRE) = 445 ft^3

Environmentally Sensitive Development Credit (see Figure 1)
Required Recharge Volume is considered met by site design**.**
Required Water Quality Volume is considered met by site design**.**

Percent Reductions Using Environmentally Sensitive Development Credit:
• *Required Water Quality Volume* = 100%
• *Required Recharge Volume* = 100%

Credit 2: Rooftop Runoff Directed to Qualifying Areas

This credit is available when rooftop runoff is directed to a qualifying pervious area where it can either infiltrate into the soil or flow over it with sufficient time and reduced velocity to allow for filtering. Qualifying pervious areas are flat locations, where the discharge is directed via sheet flow and not as a point source discharge. Dry water quality swales are not "qualifying pervious areas" for purposes of this credit. The credit may be obtained by grading the site to induce sheet flow over specially designed flat vegetated areas that can treat and infiltrate rooftop runoff.

If rooftop runoff is adequately directed to a qualifying pervious area, the rooftop area can be deducted from total impervious area, therefore reducing the *Required Water Quality Volume* and the size of the structural BMPs used to meet the TSS removal requirement of Standard 4. As more fully set forth below, redirected rooftop runoff can also be used to meet the recharge requirement as a non-structural practice.

Minimum Criteria for Credit

- ❑ The qualifying pervious area must be designed to prevent basement seepage. To prevent basement seepage, at a minimum, runoff must be directed away from the building foundation and be at least 10 feet away from the foundation.
- ❑ The rooftop area contributing runoff to any one downspout cannot exceed 1,000 ft^2.
- ❑ The rooftop cannot be a metal roof unless the building is located outside a Zone II or IWPA and the building must not be used for industrial purposes.
- ❑ The roof area contributing the runoff is not a "Green Roof."
- ❑ The length of the qualifying pervious area (in feet) shall be equal to or greater than the contributing rooftop area (in ft^2) divided by 13.3 (e.g., for 1,000 ft^2 roof/13.3 = 75 ft).
- ❑ The width of the qualifying pervious area (in feet) shall be equal to or greater than the roof length. For example, if a roof section is 20 feet wide by 50 feet long (1,000 ft^2 roof), the width of the qualifying pervious area shall be at least 50 feet.
- ❑ Although they may abut, there shall be no overlap between qualifying pervious areas. For example, the runoff from two 1,000 square foot sections of roof must be directed to separate qualifying pervious areas. They may not be directed to the same area.
- ❑ The lot must be greater than 6,000 sq. ft.
- ❑ The slope of the qualifying pervious area shall be less than or equal to 5.0%.
- ❑ Where provided, downspouts must be at least 10 feet away from the nearest impervious surface to prevent reconnection to the stormwater management system.
- ❑ Where a gutter/downspout system is not used, the rooftop runoff must be designed to sheet flow at low velocity away from the structure housing the roof.
- ❑ Qualifying pervious areas should be located on relatively permeable soils (HSG "A" and "B"). A soil evaluation by a *Competent Soils Professional* is required to confirm the soil type. The soil evaluation shall also confirm that the depth to groundwater is 2 feet or more and that the long-term *saturated hydraulic conductivity* of the soil is at least 0.17 inches/hour. The soil evaluation must identify the soil texture, Hydrologic Soil Group and depth to groundwater. See Soil Evaluation section of this Chapter. For *saturated hydraulic conductivity*, use Rawls Rates for the actual location where the qualifying pervious area is located.
- ❑ If a qualifying pervious area is located in less permeable soils (HSG "C"), the water table depth and permeability shall be evaluated by a Registered Professional Engineer to determine if a spreading device is needed to sheet flow stormwater over vegetated surfaces.
- ❑ The flow path through the qualifying pervious area shall comply with the setbacks established for structural infiltration BMPs (e.g., 50 feet away from any septic system components – such as a soil absorption system or leach field, 50 feet from vegetated wetlands and land under water).

- ❑ For those rooftops draining toward land under water (e.g., stream) or vegetated wetlands, the end of the flow path length must be at least 50 feet from the edge of a vegetated wetland and bank.
- ❑ To take credit for rooftop disconnection associated with a Land Use with Higher Potential Pollutant Loads, the rooftop runoff must not commingle with runoff from any paved surfaces or activities or areas on the site that may generate higher pollutant loads.
- ❑ To prevent compaction of the soil in the qualifying pervious area, construction vehicles must not be allowed to drive over the area. If it becomes compacted, the soil must be amended, tilled and revegetated to restore its infiltrative capacity once construction is complete.
- ❑ Ponding of water directed to the qualifying pervious area is not permitted.
- ❑ The Operation and Maintenance Plan required by Stormwater Standard No. 9 must include measures to inspect the qualifying pervious area at least yearly for evidence of ponding. The Plan shall incorporate measures to address any ponding that is observed during the inspection. The Plan shall also include measures to replace any soil eroded from the qualifying pervious area and to replace any vegetation detrimentally impacted by the drainage.
- ❑ The qualifying pervious area may not include any wetland resource areas other than Riverfront, Land Subject to Coastal Storm Flowage, and Lands Subject to Flooding. Where a portion of the Buffer Zone is proposed to serve as part of the qualifying pervious area, the qualifying pervious area shall not extend into the inner 50 feet of the Buffer Zone.
- ❑ The qualifying pervious area must be owned or controlled (e.g., drainage easement) by the property owner.
- ❑ In locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding, the credit may not be utilized.

The rooftop areas contributing runoff to the qualifying pervious area can be deducted from the impervious surfaces used to calculate the *Required Water Quality Volume.*

The rooftop areas contributing runoff to the qualifying pervious area can also be used to reduce the *Required Recharge Volume* by calculating the *Required Recharge Volume* Rv using the "*Static"* Method and the *Recharge Area Requiring Treatment* Rea using the **Percent Area Approach.**

Derive equation from Equation 1.

$$Rv = F \text{ x Impervious Area}$$

$$Rv = (F)(\text{Site Area})(\text{I})/12 \qquad \textbf{\textit{Equation (14)}}$$

Rv is the storage volume of a structural infiltration practice determined using the "*Static*" Method.

Where: *Rv* = Recharge volume (acre-feet)
F = Recharge factor (dimensionless)
A = Site area (in acres)

I = Site imperviousness percentage (expressed as a decimal)

Table No.

Hydrologic Soil Group	**Recharge Factor (*F*)**
A	0.60 inches
B	0.35 inches
C	0.25 inches
D	0.10 inches

Rea = Recharge area requiring treatment (acres)

$$Rea = (F)(A)(I) \qquad \textbf{\textit{Equation (15)}}$$

F = Recharge factor based on Hydrologic Soil Group (HSG) (same values as above, but dimensionless)
A = Site area in acres
I = Site imperviousness percentage (expressed as a decimal)

The required recharge area (*Rea*) is equivalent to the recharge volume and can be achieved by a non-structural practice (e.g., filtration of sheet flow from redirected impervious surfaces).

1. Calculate both the *Rv* and *Rea* for the site;
2. The site impervious area draining to an approved nonstructural practice is subtracted from the *Rea* calculation from Credit Step 1, above;
3. The remaining *Rea* is divided by the original *Rea* to calculate a pro-rated[38] percentage that must be directed to structural infiltration BMPs;
4. The pro-rated percentage is multiplied by the original *Rv* to calculate a new *Rv* that must be met by an approved structural practice(s).

Credit 2 Rooftop Runoff Example

<u>*Given the following base data*</u>:
Site Data: 108 Single-Family Residential Lots (~ ½-acre lots)
Site Area = 45.1 ac
Original Impervious Area = 12.0 ac;
Site Soils Types: 78% "C", 22% "D"
Composite Recharge Factor, F = .78 (0.25) + .22 (0.1) = 0.217
Original *Required Recharge Volume Rv* = [(0.217)(45.1 ac)(12ac/45.1 ac)] /12 = 0.22 acre feet;
Recharge Area Requiring Treatment Rea = (0.217)(45.1)(12/45.1) = 2.60 ac
Original *Required Water Quality Volume* = 1.0"/impervious acre = 1.0"(12.0 ac)/12 = 1.0 acre foot
(site is located near a critical area)

[38] If the disconnected area is large enough, the Credit could meet the full Recharge and Water Quality Volumes required by Standards 3 and 4.

<u>Rooftop Credit (see Figure 3)</u>
42 houses disconnected
Average house area = 2,500 ft^2
Net impervious area reduction = (42)(2,500 ft2) / (43,560 ft^2/ac) = 2.41 acres
New impervious area = 12.0 – 2.41 = 9.59 acres;

Required recharge area (*Rea*) is 2.60 acres and 2.41 acres were disconnected, therefore 0.19 ac of impervious cover need to be met by an approved structural practice.
New *Required Recharge Volume Rv* = (0.19/2.60)(0.22 ac-ft) = 0.016 ac-ft

New *Required Water Quality Volume* = 1.0” (9.59)/12 = 0.80 acre-feet; or a 0.20 acre-foot reduction

Percent Reductions Using Rooftop Disconnection Credit:
- *Required Recharge Volume Rv* = (0.22-0.016)/0.22 = 0.927 = 92.7% Reduction
- *Required Water Quality Volume* = (1.0 – 0.8) /1.0 = 0.20 = 20.0% Reduction

Credit No 3: Roadway, Driveway or Parking Lot Runoff Directed to Qualifying Area

Credit is given for practices that direct runoff from impervious roads, driveways, and parking lots to pervious areas where plants provide filtration (through sheet flow) and the ground provides exfiltration. This credit can be obtained by grading the site to promote overland vegetative filtering. This credit is available for paved driveways, roads, and parking lots associated with all land uses, except for high-intensity parking lots that generate 1,000 or more vehicle trips per day or runoff not segregated from LUHPPL.

Disconnected impervious areas can be subtracted from the site impervious area when computing the *Required Water Quality Volume*. In addition, disconnected impervious surfaces can be used to reduce the *Required Recharge Volume* as determined by calculating the *Required Recharge Volume: Rv* using the "*Static"* Method and the *Recharge Area Requiring Treatment: Rea* using the **Percent Area Approach**. See example for Credit 2 - disconnection of rooftop runoff.

Minimum Criteria for Credit

The credit is subject to the following restrictions:

- The maximum contributing impervious flow path length shall be 75 feet.
- The length of the qualifying pervious area must be equal to or greater than the length of the contributing impervious area.
- The width of the qualifying pervious area shall be no less than the width of the contributing impervious surface. For example, if a driveway is 15 feet wide, the qualifying pervious area width shall be no less than 15 feet.
- The entire qualifying pervious area shall be on a slope less than or equal to 5.0%.
- The impervious area draining to any one discharge location cannot exceed 1,000 ft^2;
- Qualifying pervious areas should be located on relatively permeable soils (HSGs A and B). A soil evaluation is required to confirm the soil type. The soil evaluation shall also

confirm that the depth to groundwater is 2 feet or more, and that the long term *saturated hydraulic conductivity* of the soil is at least 0.17 inches/hour. See Soil Evaluation section of this Chapter. For *saturated hydraulic conductivity*, use Rawls Rates for the actual location where the qualifying pervious area is located.

- In less permeable soils (HSGs C), the water table depth and permeability shall be evaluated by a Registered Professional Engineer to determine if a spreading device is needed to sheet flow stormwater over vegetated surfaces.
- For those non-rooftop areas draining toward land under water (e.g., stream) or vegetated wetlands, the end of the flow path length must be at least 50 feet from the edge of a vegetated wetland or bank,
- To prevent compaction, construction vehicles must not be allowed to drive over the qualifying pervious area. If compacted, the soil must be amended, tilled, and revegetated once construction is complete to restore its infiltrative capacity.
- Ponding of water directed to the qualifying area is not permitted.
- The Operation and Maintenance Plan required by Standard 9 must include measures to inspect the qualifying pervious area at least yearly for evidence of ponding, sediment deposition, and vegetation dieback. The Plan shall incorporate measures to remove any deposited sediment (e.g., sand from winter sanding operations), address any ponding, and replant any vegetation that has died (such as vegetation impacted by road salt applied during the winter). The Plan shall also include measures to replace any eroded soil from the qualifying pervious area. The Operation and Maintenance Plan shall not allow sealcoats containing coal-tar emulsions. The Operation and Maintenance Plan must address how future scarifying and repaving operations will be conducted to ensure that stormwater contaminated during repaving operations will not detrimentally impact regulatory wetland areas and buffer zones.
- Runoff from driveways, roadways and parking lots may be directed over soft shoulders, through curb cuts, or level spreaders to qualifying pervious areas. Measures must be employed at the discharge point to the qualifying pervious area to prevent erosion and promote sheet flow.
- The flow path through the qualifying pervious area shall comply with the setbacks established for structural infiltration Best Management Practices (e.g., 50 feet away from any septic system components including soil absorption systems, 50 feet from vegetated wetlands, bank, and land under water.)
- The qualifying pervious area may not include any wetland resource areas other than Riverfront and Land Subject to Coastal Storm Flowage, and Lands Subject to Flooding. Where a portion of the Buffer Zone is proposed to serve as part of the qualifying pervious area, the qualifying pervious area shall not extend into the inner 50 feet of the Buffer Zone.
- The qualifying pervious area must be owned or controlled (e.g., drainage easement) by the property owner.
- In locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding, the credit may not be used.

<u>REFERENCES FOR CREDITS:</u>

Center for Watershed Protection, 1998, Better Site Design: A Handbook for Changing Development Rules in Your Community. Ellicott City, MD.

Center for Watershed Protection, No date, Stormwater Design Manual Builder, Site Design Credits, Ellicott City, MD http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/Site%20Design%20Credits%20Intro.htm

Councell T.B. et al, 2004, Tire-Wear Particles as a Source of Zinc to the Environment, Environmental Science and Technology, Vol. 38, pp. 4206-4214, WEB: http://tx.usgs.gov/coring/pubs/zinc%20and%20tires.pdf

Georgia, State of, 2001 (First Edition), Georgia Stormwater Management Manual, Volume 2: Technical Handbook, Stormwater Better Site Design, Section 1.4, WEB: http://www.georgiastormwater.com/vol2/1-4.pdf

Lacey, J. and R. Arendt 1990. An Examination of Market Appreciation for Clustered Housing with Permanently Protected Open Space. Center for Rural Massachusetts, Amherst, MA.

Mahler, B.J., Metre P.C., Bashara T.J., Wilson, J.T., and Johns D.A., 2005, Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons, Environmental Science and Technology, Vol. 39, pp. 5560 – 5566, WEB: http://tx.usgs.gov/coring/pubs/parking%20lot%20sealants.pdf

Maryland Department of the Environment, 2000, Maryland Stormwater Design Manual, Volume I, Stormwater Credits for Innovative Site Planning, Chapter 5, WEB: http://www.mde.state.md.us/assets/document/chapter5.pdf

Massachusetts Division of Conservation Services, 1991, Massachusetts Conservation Restriction Handbook.

Massachusetts Executive Office of Environmental Affairs, 2006, Smart Growth Toolkit, *Appendix A,*

Minnesota Pollution Control Agency, Minnesota Stormwater Manual, Applying Stormwater Credits to Development Sites, Chapter 11, http://www.pca.state.mn.us/publications/wq-strm9-17.pdf

New Jersey Department of Environmental Protection, 2006, New Jersey Stormwater Best Management Practices Manual DRAFT revision, Development Design Credits and Total Suspended Solids Removal Criteria, Chapter 3, WEB: http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/chapter3.PDF

Puget Sound Action Team, 2005, Low Impact Development Technical Guidance Manual for Puget Sound, Washington Department of Ecology Low Impact Development Design and Flow

Modeling Guidance, Chapter 7, WEB: http://www.psat.wa.gov/Publications/LID_tech_manual05/07_guidance.pdf.

Schueler, Thomas, 1994. The Importance of Imperviousness, Watershed Protection Techniques. 1:100-111, Center for Watershed Protection

Union County, Pennsylvania, 2003, Subdivision & Land Development Ordinance, Ordinance 2003-3, Stormwater Credits for Effective Site Planning, Appendix O, WEB: http://www.seda-cog.org/union/lib/union/appendix_o_-_stormwater_credits.pdf

Van Metre, P.C. and Mahler, B.J., 2003, The Contribution of Particles Washed from Rooftops to Contaminant Loading to Urban Streams, Chemosphere, Vol. 52, pp. 1727-1741, WEB: http://tx.usgs.gov/coring/pubs/rooftops%20Chemosphere.pdf

Vermont Agency of Natural Resources Geological Survey, 1999, Watershed Hydrology Protection and Flood Mitigation Project Phase II – Technical Analysis, Stream Geomorphic Assessment

Vermont Agency of Natural Resources, 2002 (5th Printing), Vermont Stormwater Management Handbook, Stormwater Treatment Standards, Section 3, WEB: http://www.vtwaterquality.org/stormwater/docs/sw_manual-vol1.pdf

Washington State Department of Ecology, 2005, Stormwater Management Manual for Western Washington, Volume III, Hydrologic Analysis and Flow Control Design/BMPs, WEB: http://www.ecy.wa.gov/pubs/0510031.pdf

Washington State Department of Ecology, Western Washington Hydrology Model (WWHM) VERSION 2.0, WEB: http://www.ecy.wa.gov/programs/wq/stormwater/wwhm_training/wwhm/wwhm_v2/instructions_v2.html