

# **APPENDIX F** Requirements for Discharges to Impaired Waters with an Approved TMDL

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## **A. Requirements for Discharges to Impaired Waters with an Approved MassDEP In State TMDL**

### **I. Charles River Watershed Phosphorus TMDL Requirements**

On October 17, 2007, EPA approved the *Final TMDL for Nutrients in the Lower Charles River Basin* (Lower Charles TMDL)<sup>1</sup> and on June 10, 2011 EPA approved the *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River* (Upper/Middle Charles TMDL)<sup>2</sup>. The following phosphorus reduction requirements address phosphorus in MS4 discharges.

1. To address the discharge of phosphorus from its MS4, the permittee shall develop a Phosphorus Control Plan (PCP) designed to reduce the amount of phosphorus in stormwater (SW) discharges from its MS4 to the Charles River and its tributaries. The PCP shall be completed in phases and the permittee shall add it as an attachment to its written SWMP upon completion and report in annual reports pursuant to part 4.4 of the Permit on its progress toward achieving its Phosphorus Reduction Requirement. The PCP shall be developed and fully implemented as soon as possible but no later than 20 years after the permit effective date in accordance with the phases and schedule outlined below. Each Phase shall contain the elements required of each phase as described in parts a. through c below. The timing of each phase over 20 years from the permit effective date is:

| 1-5 years after permit effective date | 5-10 years after permit effective date | 10-15 years after permit effective date | 15-20 years after permit effective date |
|---------------------------------------|----------------------------------------|-----------------------------------------|-----------------------------------------|
| Create Phase 1 Plan                   | Implement Phase 1 Plan                 |                                         |                                         |
|                                       | Create Phase 2 Plan                    | Implement Phase 2 Plan                  |                                         |
|                                       |                                        | Create Phase 3 Plan                     | Implement Phase 3 Plan                  |

#### **a. Phase 1**

- 1) The permittee shall complete a written Phase 1 plan of the PCP five years after the permit effective date and fully implement the Phase 1 plan of the PCP as soon as possible but no longer than 10 years after the permit effective date.
- 2) The Phase 1 plan of the PCP shall contain the following elements and has the following required milestones:

| Item Number | Phase 1 of the PCP Component and Milestones | Completion Date                     |
|-------------|---------------------------------------------|-------------------------------------|
| 1-1         | Legal analysis                              | 2 years after permit effective date |

<sup>1</sup> Massachusetts Department of Environmental Protection. 2007. *Final TMDL for Nutrients in the Lower Charles River Basin*. CN 301.1

<sup>2</sup> Massachusetts Department of Environmental Protection. 2011. *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River Basin, Massachusetts*. CN 272.0

|      |                                                                                                                                                                                                                                                                                                                                                                                                               |                                            |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| 1-2  | Funding source assessment.                                                                                                                                                                                                                                                                                                                                                                                    | 3 years after permit effective date        |
| 1-3  | Define scope of PCP (PCP Area) Baseline Phosphorus Load and Phosphorus Reduction Requirement and Allowable Phosphorus Load                                                                                                                                                                                                                                                                                    | 4 years after permit effective date        |
| 1-4  | Description of Phase 1 planned nonstructural controls                                                                                                                                                                                                                                                                                                                                                         | 5 years after permit effective date        |
| 1-5  | Description of Phase 1 planned structural controls                                                                                                                                                                                                                                                                                                                                                            | 5 years after permit effective date        |
| 1-6  | Description of Operation and Maintenance program for structural controls                                                                                                                                                                                                                                                                                                                                      | 5 years after permit effective date        |
| 1-7  | Phase 1 implementation schedule                                                                                                                                                                                                                                                                                                                                                                               | 5 years after permit effective date        |
| 1-8  | Estimated cost for implementing Phase 1 of the PCP                                                                                                                                                                                                                                                                                                                                                            | 5 years after permit effective date        |
| 1-9  | Complete Written Phase 1 PCP                                                                                                                                                                                                                                                                                                                                                                                  | 5 years after permit effective date        |
| 1-10 | Full implementation of nonstructural controls                                                                                                                                                                                                                                                                                                                                                                 | 6 years after permit effective date        |
| 1-11 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                        | 6, and 7 years after permit effective date |
| 1-12 | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.80<br>$P_{exp} \leq P_{allow} + (P_{RR} \times 0.80)$ | 8 years after permit effective date        |
| 1-13 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                        | 9 years after permit effective date        |
| 1-14 | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.75                                                    | 10 years after permit effective date       |

|  |                                                 |  |
|--|-------------------------------------------------|--|
|  | $P_{exp} \leq P_{allow} + (P_{RR} \times 0.75)$ |  |
|--|-------------------------------------------------|--|

**Table F-1: Phase 1 of the PCP components and Milestones**

## 3) Description of Phase 1 PCP Components

Legal Analysis- The permittee shall develop and implement an analysis that identifies existing regulatory mechanisms available to the MS4 such as by-laws and ordinances, and describes any changes to regulatory mechanisms that may be necessary to effectively implement the entire PCP. This may include the creation or amendment of financial and regulatory authorities. The permittee shall adopt necessary regulatory changes by the end of the permit term.

Funding source assessment – The permittee shall describe known and anticipated funding mechanisms (e.g. general funding, enterprise funding, stormwater utilities) that will be used to fund PCP implementation. The permittee shall describe the steps it will take to implement its funding plan. This may include but is not limited to conceptual development, outreach to affected parties, and development of legal authorities.

Scope of the PCP, Baseline Phosphorus Load ( $P_{base}$ ), Phosphorus Reduction Requirement ( $P_{RR}$ ) and Allowable Phosphorus Load ( $P_{allow}$ ) - The permittee shall indicate the area in which it plans to implement the PCP. The permittee must choose one of the following: (1) to implement its PCP in the entire area within its jurisdiction (for municipalities this would be the municipal boundary) within the Charles River Watershed; or (2) to implement its PCP only in the urbanized area portion of the permittee's jurisdiction within the Charles River Watershed. The implementation area selected by the permittee is known as the "PCP Area" for that permittee. Table F-2<sup>3</sup> and Table F-3<sup>4</sup> list the permittees subject to phosphorus reduction requirements along with the estimated Baseline Phosphorus Loads in mass/yr, the calculated Allowable Stormwater Phosphorus Load in mass/yr, the Stormwater Phosphorus Reduction Requirement in mass/yr and the respective percent reductions necessary. The two tables contain different reduction requirements for each permittee based on the PCP Area they choose (see above). If the permittee chooses to implement the PCP in its entire jurisdiction, the permittee may demonstrate compliance with the Phosphorus Reduction Requirement and Allowable Phosphorus Load requirements applicable to it through structural and non-structural controls on discharges that occur outside the regulated area. If the permittee chooses to implement the PCP in its regulated area only, the permittee must demonstrate compliance with the Phosphorus Reduction Requirement and Allowable Phosphorus Load requirements applicable to it through structural

<sup>3</sup> The estimated Baseline Phosphorus Load, Allowable Phosphorus Load, Phosphorus Reduction Requirement and percent reductions presented in Table F-2 apply to the entire watershed land area that drains to the Charles River and its tributaries within the permittee's jurisdiction.

<sup>4</sup> The estimated Baseline Phosphorus Load, Allowable Phosphorus Load, Phosphorus Reduction Requirement and percent reductions presented in Table F-3 apply only to the urbanized area portion of the permittee's jurisdiction that drains to the Charles River or its tributaries.

and non-structural controls on discharges that occur within the regulated area only.

The permittee shall select the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load that corresponds to the PCP Area selected. The selected Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load will be used to determine compliance with PCP milestones of this Phase and Phase 2 and Phase 3. If the permittee chooses to implement its PCP in all areas within its jurisdiction within the Charles River Watershed, then the permittee shall use Table F-2 to determine the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load for its PCP Area. If the permittee chooses to implement its PCP only within the regulated area within the Charles River Watershed, then the permittee shall use Table F-3 to determine the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load for its PCP Area.

The Permittee may submit more accurate land use data from 2005, which is the year chosen as the baseline land use for the purposes of permit compliance, for EPA to recalculate baseline phosphorus stormwater loads for use in future permit reissuances. Updated land use maps, land areas, characteristics, and MS4 area and catchment delineations shall be submitted to EPA along with the year 4 annual report in electronic GIS data layer form for consideration for future permit requirements<sup>5</sup>. Until such a time as future permit requirements reflect information submitted in the year 4 annual report, the permittee shall use the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load Table F-2 (if its PCP Area is the permittee's entire jurisdiction) or Table F-3 (if its PCP Area is the regulated area only) to calculate compliance with milestones for Phase 1, 2, and 3 of the PCP.

Description of Phase 1 planned non-structural controls – The permittee shall describe the non-structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-1. The description of non-structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions that are expected to result from their implementation in units of mass/yr. Annual phosphorus reduction from non-structural BMPs shall be calculated consistent with Attachment 2 to Appendix F.

Description of Phase 1 planned structural controls – The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of structural phosphorus controls during Phase 1. The ranking shall be developed through the use of available

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<sup>5</sup> This submission is optional and needs only be done if the permittee has more accurate land use information from 2005 than information provided by MassGIS (<http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/lus2005.html>, retrieved 10/1/2013) or the permittee has updated MS4 drainage area characteristics and the permittee would like to update the Baseline Phosphorus Load.

screening and monitoring results collected during the permit term either by the permittee or another entity and the mapping required pursuant to part 2.3.4.6 of the Permit. The permittee shall also include in this priority ranking a detailed assessment of site suitability for potential phosphorus control measures based on soil types and other factors. The permittee shall coordinate this activity with the requirements of part 2.3.6.8.b of the Permit. A description and the results of this priority ranking shall be included in Phase 1 of the PCP. The permittee shall describe the structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-1. The description of structural controls shall include the planned and existing measures, the areas where the measures will be implemented or are currently implemented, and the annual phosphorus reductions in units of mass/yr that are expected to result from their implementation. Structural measures to be implemented by a third party may be included in a municipal PCP. Annual phosphorus reductions from structural BMPs shall be calculated consistent with Attachment 3 to Appendix F.

Description of Operation and Maintenance (O&M) Program for all planned and existing structural BMPs – The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit as part of Phase 1 of the PCP. This includes BMPs implemented to date as well as BMPs to be implemented during Phase 1 of the PCP. The Operation and Maintenance Program shall become part of the PCP and include: (1) inspection and maintenance schedule for each BMP according to BMP design or manufacturer specification and (2) program or department responsible for BMP maintenance.

Phase 1 Implementation Schedule – A schedule for implementation of all planned Phase 1 BMPs, including, as appropriate: obtaining funding, training, purchasing, construction, inspections, monitoring, operation and maintenance activities, and other assessment and evaluation components of implementation. Implementation of planned BMPs must begin upon completion of the Phase 1 Plan, and all non-structural BMPs shall be fully implemented within six years of the permit effective date. Structural BMPs shall be designed and constructed to ensure the permittee will comply with the 8 and 10 year phosphorus load milestones established in Table F-1. The Phase 1 plan shall be fully implemented as soon as possible, but no later than 10 years after the effective date of permit.

Estimated cost for implementing Phase 1 of the PCP – The permittee shall estimate the cost of implementing the Phase 1 non-structural and structural controls and associated Operation and Maintenance Program. This cost estimate can be used to assess the validity of the funding source assessment completed by year 3 after the permit effective date and to update funding sources as necessary to complete Phase 1.

Complete written Phase 1 Plan – The permittee must complete the written Phase 1 Plan of the PCP no later than 5 years after the permit effective date. The complete Phase 1 Plan shall include Phase 1 PCP item numbers 1-1 through 1-7 in Table F-1. The permittee shall make the Phase 1 Plan

available to the public for public comment during Phase 1 Plan development. EPA encourages the permittee to post the Phase I Plan online to facilitate public involvement.

**Performance Evaluation** –The permittee shall evaluate the effectiveness of the PCP by tracking the phosphorus reductions achieved through implementation of structural and non-structural BMPs<sup>6</sup> and tracking increases resulting from development. Phosphorus reductions shall be calculated consistent with Attachment 2 to Appendix F (non-structural BMP performance) and Attachment 3 to Appendix F (structural BMP performance) for all BMPs implemented to date. Phosphorus export increases since 2005 due to development shall be calculated consistent with Attachment 1 to Appendix F. Phosphorus loading increases and reductions in unit of mass/yr shall be added or subtracted from the applicable Baseline Phosphorus Load given in Table F-2 or Table F-3 depending on the Scope of PCP chosen to estimate the yearly phosphorous export rate from the PCP Area. The permittee shall also include all information required in part I.2 of this Appendix in each performance evaluation. Performance evaluations will be included as part of each permittee’s annual report as required by part 4.4 of the Permit.

| <b>Community Annual Stormwater Phosphorus Load Reduction by Permittee, Charles River Watershed</b> |                                        |                                                               |                                         |                                                            |
|----------------------------------------------------------------------------------------------------|----------------------------------------|---------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------|
| <b>Community</b>                                                                                   | <b>Baseline Phosphorus Load, kg/yr</b> | <b>Stormwater Phosphorus Load Reduction Requirement kg/yr</b> | <b>Allowable Phosphorus Load, kg/yr</b> | <b>Stormwater Percent Reduction in Phosphorus Load (%)</b> |
| Arlington                                                                                          | 106                                    | 57                                                            | 49                                      | 53%                                                        |
| Ashland                                                                                            | 67                                     | 23                                                            | 44                                      | 34%                                                        |
| Bellingham                                                                                         | 947                                    | 331                                                           | 616                                     | 35%                                                        |
| Belmont                                                                                            | 202                                    | 86                                                            | 116                                     | 42%                                                        |
| Brookline                                                                                          | 1,635                                  | 789                                                           | 846                                     | 48%                                                        |
| Cambridge                                                                                          | 512                                    | 263                                                           | 249                                     | 51%                                                        |
| Dedham                                                                                             | 805                                    | 325                                                           | 480                                     | 40%                                                        |
| Dover                                                                                              | 831                                    | 137                                                           | 694                                     | 17%                                                        |
| Foxborough                                                                                         | 2                                      | 0                                                             | 2                                       | 0%                                                         |
| Franklin                                                                                           | 2,344                                  | 818                                                           | 1,526                                   | 35%                                                        |

<sup>6</sup> In meeting its phosphorus reduction requirements a permittee may quantify phosphorus reductions by actions undertaken by another entity, except where those actions are credited to MassDOT or another permittee identified in Appendix F Table F-2 or F-3.

| <b>Community Annual Stormwater Phosphorus Load Reduction by Permittee, Charles River Watershed</b> |                                        |                                                               |                                         |                                                            |
|----------------------------------------------------------------------------------------------------|----------------------------------------|---------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------|
| <b>Community</b>                                                                                   | <b>Baseline Phosphorus Load, kg/yr</b> | <b>Stormwater Phosphorus Load Reduction Requirement kg/yr</b> | <b>Allowable Phosphorus Load, kg/yr</b> | <b>Stormwater Percent Reduction in Phosphorus Load (%)</b> |
| Holliston                                                                                          | 1,543                                  | 395                                                           | 1,148                                   | 26%                                                        |
| Hopedale                                                                                           | 107                                    | 37                                                            | 70                                      | 35%                                                        |
| Hopkinton                                                                                          | 292                                    | 66                                                            | 226                                     | 22%                                                        |
| Lexington                                                                                          | 530                                    | 194                                                           | 336                                     | 37%                                                        |
| Lincoln                                                                                            | 593                                    | 101                                                           | 492                                     | 17%                                                        |
| Medfield                                                                                           | 955                                    | 277                                                           | 678                                     | 29%                                                        |
| Medway                                                                                             | 1,063                                  | 314                                                           | 749                                     | 30%                                                        |
| Mendon                                                                                             | 29                                     | 9                                                             | 20                                      | 31%                                                        |
| Milford                                                                                            | 1,611                                  | 663                                                           | 948                                     | 41%                                                        |
| Millis                                                                                             | 969                                    | 248                                                           | 721                                     | 26%                                                        |
| Natick                                                                                             | 1,108                                  | 385                                                           | 723                                     | 35%                                                        |
| Needham                                                                                            | 1,772                                  | 796                                                           | 976                                     | 45%                                                        |
| Newton                                                                                             | 3,884                                  | 1,941                                                         | 1,943                                   | 50%                                                        |
| Norfolk                                                                                            | 1,004                                  | 232                                                           | 772                                     | 23%                                                        |
| Somerville                                                                                         | 646                                    | 331                                                           | 315                                     | 51%                                                        |
| Sherborn                                                                                           | 846                                    | 131                                                           | 715                                     | 16%                                                        |
| Walpole                                                                                            | 159                                    | 28                                                            | 131                                     | 18%                                                        |
| Waltham                                                                                            | 2,901                                  | 1,461                                                         | 1,400                                   | 50%                                                        |
| Watertown                                                                                          | 1,127                                  | 582                                                           | 545                                     | 52%                                                        |
| Wayland                                                                                            | 46                                     | 15                                                            | 31                                      | 33%                                                        |
| Wellesley                                                                                          | 1,431                                  | 661                                                           | 770                                     | 46%                                                        |
| Weston                                                                                             | 1,174                                  | 281                                                           | 893                                     | 24%                                                        |
| Westwood                                                                                           | 376                                    | 114                                                           | 262                                     | 30%                                                        |
| Wrentham                                                                                           | 618                                    | 171                                                           | 447                                     | 28%                                                        |
| Mass-DCR                                                                                           | 421                                    | 91                                                            | 330                                     | 22%                                                        |

**Table F-2: Baseline Phosphorus Load, Phosphorus Reduction Requirement, Allowable Phosphorus Load and Percent Reduction in Phosphorus Load from Charles River Watershed. For use when PCP Area is chosen to be the entire community within the Charles River Watershed.**

| <b>Urbanized Area Annual Stormwater Phosphorus Load Reduction by Permittee, Charles River Watershed</b> |                                                  |                                                                |                                         |                                                            |
|---------------------------------------------------------------------------------------------------------|--------------------------------------------------|----------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------|
| <b>Community</b>                                                                                        | <b>Baseline Watershed Phosphorus Load, kg/yr</b> | <b>Stormwater Phosphorus Load Reduction Requirement, kg/yr</b> | <b>Allowable Phosphorus Load, kg/yr</b> | <b>Stormwater Percent Reduction in Phosphorus Load (%)</b> |
| Arlington                                                                                               | 106                                              | 57                                                             | 49                                      | 53%                                                        |
| Ashland                                                                                                 | 67                                               | 23                                                             | 44                                      | 34%                                                        |
| Bellingham                                                                                              | 801                                              | 291                                                            | 510                                     | 36%                                                        |
| Belmont                                                                                                 | 202                                              | 86                                                             | 116                                     | 42%                                                        |
| Brookline                                                                                               | 1,635                                            | 789                                                            | 846                                     | 48%                                                        |
| Cambridge                                                                                               | 512                                              | 263                                                            | 249                                     | 51%                                                        |
| Dedham                                                                                                  | 805                                              | 325                                                            | 480                                     | 40%                                                        |
| Dover                                                                                                   | 282                                              | 54                                                             | 228                                     | 19%                                                        |
| Foxborough                                                                                              | 2                                                | 0                                                              | 2                                       | 0%                                                         |
| Franklin                                                                                                | 2,312                                            | 813                                                            | 1,499                                   | 35%                                                        |
| Holliston                                                                                               | 1,359                                            | 369                                                            | 990                                     | 27%                                                        |
| Hopedale                                                                                                | 107                                              | 37                                                             | 70                                      | 35%                                                        |
| Hopkinton                                                                                               | 280                                              | 65                                                             | 215                                     | 23%                                                        |
| Lexington                                                                                               | 525                                              | 193                                                            | 332                                     | 37%                                                        |
| Lincoln                                                                                                 | 366                                              | 63                                                             | 303                                     | 17%                                                        |
| Medfield                                                                                                | 827                                              | 267                                                            | 560                                     | 33%                                                        |
| Medway                                                                                                  | 1,037                                            | 305                                                            | 732                                     | 29%                                                        |
| Mendon                                                                                                  | 10                                               | 5                                                              | 5                                       | 50%                                                        |
| Milford                                                                                                 | 1,486                                            | 653                                                            | 833                                     | 44%                                                        |
| Millis                                                                                                  | 501                                              | 159                                                            | 342                                     | 32%                                                        |
| Natick                                                                                                  | 994                                              | 359                                                            | 635                                     | 36%                                                        |
| Needham                                                                                                 | 1,771                                            | 795                                                            | 976                                     | 45%                                                        |
| Newton                                                                                                  | 3,884                                            | 1,941                                                          | 1,943                                   | 50%                                                        |
| Norfolk                                                                                                 | 1,001                                            | 231                                                            | 770                                     | 23%                                                        |
| Somerville                                                                                              | 646                                              | 331                                                            | 315                                     | 51%                                                        |
| Sherborn                                                                                                | 203                                              | 38                                                             | 165                                     | 19%                                                        |
| Walpole                                                                                                 | 159                                              | 28                                                             | 131                                     | 18%                                                        |
| Waltham                                                                                                 | 2,901                                            | 1,461                                                          | 1,440                                   | 50%                                                        |
| Watertown                                                                                               | 1,127                                            | 582                                                            | 545                                     | 52%                                                        |
| Wayland                                                                                                 | 46                                               | 15                                                             | 31                                      | 33%                                                        |
| Wellesley                                                                                               | 1,431                                            | 661                                                            | 770                                     | 46%                                                        |

| <b>Urbanized Area Annual Stormwater Phosphorus Load Reduction by Permittee, Charles River Watershed</b> |                                                  |                                                                |                                         |                                                            |
|---------------------------------------------------------------------------------------------------------|--------------------------------------------------|----------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------|
| <b>Community</b>                                                                                        | <b>Baseline Watershed Phosphorus Load, kg/yr</b> | <b>Stormwater Phosphorus Load Reduction Requirement, kg/yr</b> | <b>Allowable Phosphorus Load, kg/yr</b> | <b>Stormwater Percent Reduction in Phosphorus Load (%)</b> |
| Weston                                                                                                  | 1,174                                            | 281                                                            | 893                                     | 24%                                                        |
| Westwood                                                                                                | 346                                              | 108                                                            | 238                                     | 31%                                                        |
| Wrentham                                                                                                | 556                                              | 159                                                            | 397                                     | 29%                                                        |
| Mass DCR                                                                                                | 396                                              | 89                                                             | 307                                     | 22%                                                        |

**Table F-3: Baseline Phosphorus Load, Phosphorus Reduction Requirement, Allowable Phosphorus Load and Percent Reduction in Phosphorus Load from Charles River Watershed. For use when PCP Area is chosen to be only the urbanized area portion of a permittee's jurisdiction within the Charles River Watershed.**

**b. Phase 2**

- 1) The permittee shall complete the Phase 2 Plan of the PCP 10 years after the permit effective date and fully implement the Phase 2 plan of the PCP as soon as possible but no longer than 15 years after the permit effective date.
- 2) The Phase 2 plan of the PCP shall be added to the Phase 1 Plan and contain the following elements and has the following required milestones:

| <b>Item Number</b> | <b>Phase 2 of the PCP Component and Milestones</b>       | <b>Completion Date</b>               |
|--------------------|----------------------------------------------------------|--------------------------------------|
| 2-1                | Update Legal analysis                                    | As necessary                         |
| 2-2                | Description of Phase 2 planned nonstructural controls    | 10 years after permit effective date |
| 2-3                | Description of Phase 2 planned structural controls       | 10 years after permit effective date |
| 2-4                | Updated description of Operation and Maintenance Program | 10 years after permit effective date |
| 2-5                | Phase 2 implementation schedule                          | 10 years after permit effective date |
| 2-6                | Estimated cost for implementing Phase 2 of the PCP       | 10 years after permit effective date |

|      |                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 2-7  | Complete written Phase 2 Plan                                                                                                                                                                                                                                                                                                                                                                                 | 10 years after permit effective date         |
| 2-8  | Performance Evaluation.                                                                                                                                                                                                                                                                                                                                                                                       | 11, and 12 years after permit effective date |
| 2-9  | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.65<br>$P_{exp} \leq P_{allow} + (P_{RR} \times 0.65)$ | 13 years after permit effective date         |
| 2-10 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                        | 14 years after permit effective date         |
| 2-11 | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.50<br>$P_{exp} \leq P_{allow} + (P_{RR} \times 0.50)$ | 15 years after permit effective date         |

**Table F-4: Phase 2 of the PCP components and Milestones**

## 3) Description of Phase 2 PCP Components

Updated Legal Analysis- The permittee shall update the legal analysis completed during Phase 1 of the PCP as necessary to include any new or augmented bylaws, ordinances or funding mechanisms the permittee has deemed necessary to implement the PCP. The permittee shall use experience gained during Phase 1 to inform the updated legal analysis. The permittee shall adopt necessary regulatory changes as soon as possible to implement the Phase 2 Plan.

Description of Phase 2 planned non-structural controls – The permittee shall describe the non-structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-4. The description of non-structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions that are expected to result from their implementation in units of mass/yr. Annual phosphorus reduction from non-structural BMPs shall be calculated consistent with Attachment 2 to Appendix F.

Description of planned Phase 2 structural controls – The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of phosphorus control practices during Phase 2. The ranking shall build upon the ranking developed for Phase 1. The permittee shall describe the structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-4. The description of structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions in units of mass/yr that are expected to result from their implementation. Structural measures to be implemented by a third party<sup>7</sup> may be included in a municipal PCP. Annual phosphorus reductions from structural BMPs shall be calculated consistent with Attachment 3 to Appendix F.

Updated description of Operation and Maintenance (O&M) Program for all planned and existing structural BMPs – The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit as part of Phase 1 and 2 of the PCP. This includes BMPs implemented to date as well as BMPs to be implemented during Phase 2 of the PCP. The Operation and Maintenance Program shall become part of the PCP and include: (1) inspection and maintenance schedule for each BMP according to BMP design or manufacturer specification and (2) program or department responsible for BMP maintenance.

Phase 2 Implementation Schedule – A schedule for implementation of all planned Phase 2 BMPs, including, as appropriate: funding, training, purchasing, construction, inspections, monitoring, O&M activities and other assessment and evaluation components of implementation. Implementation of planned BMPs must begin upon completion of the Phase 2 Plan. Structural BMPs shall be designed and constructed to ensure the permittee will comply with the 13 and 15 year milestones established in Table F-4. The Phase 2 plan shall be fully implemented as soon as possible, but no later than 15 years after the effective date of permit.

Estimated cost for implementing Phase 2 of the PCP – The permittee shall estimate the cost of implementing the Phase 2 non-structural and structural controls and associated Operation and Maintenance Program. This cost estimate can be used to plan for the full implementation of Phase 2.

Complete written Phase 2 Plan – The permittee must complete a written Phase 2 Plan of the PCP no later than 10 years after the permit effective date. The complete Phase 2 Plan shall include Phase 2 PCP item numbers 2-1 through 2-6 in Table F-4. The permittee shall make the Phase 2 Plan available to the public for public comment during Phase 2 plan development. EPA encourages the permittee to post the Phase 2 Plan online to facilitate public involvement.

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<sup>7</sup> See footnote 6

**Performance Evaluation** – The permittee shall evaluate the effectiveness of the PCP by tracking the phosphorus reductions achieved through implementation of structural and non-structural BMPs<sup>8</sup> and tracking increases resulting from development. Phosphorus reductions shall be calculated consistent with Attachment 2 to Appendix F (non-structural BMP performance) and Attachment 3 to Appendix F (structural BMP performance) for all BMPs implemented to date. Phosphorus export increases due to development shall be calculated consistent with Attachment 1 to Appendix F. Phosphorus loading increases and reductions in unit of mass/yr shall be added or subtracted from the applicable Baseline Phosphorus Load given in Table F-2 or Table F-3 depending on the Scope of PCP chosen to estimate the yearly phosphorous export rate from the PCP Area. The permittee shall also include all information required in part I.2 of this Appendix in each performance evaluation. Performance evaluations will be included as part of each permittee's annual report as required by part 4.4 of the Permit.

**c. Phase 3**

- 1) The permittee shall complete the Phase 3 Plan of the PCP 15 years after the permit effective date and fully implement the Phase 3 plan of the PCP as soon as possible but no longer than 20 years after the permit effective date.
- 2) The Phase 3 plan of the PCP shall be added to the Phase 1 Plan and the Phase 2 Plan to create the comprehensive PCP and contain the following elements and has the following required milestones:

| <b>Item Number</b> | <b>Phase 3 of the PCP Component and Milestones</b>             | <b>Completion Date</b>               |
|--------------------|----------------------------------------------------------------|--------------------------------------|
| 3-1                | Update Legal analysis                                          | As necessary                         |
| 3-2                | Description of Phase 3 planned nonstructural controls          | 15 years after permit effective date |
| 3-3                | Description of Phase 3 planned structural controls             | 15 years after permit effective date |
| 3-4                | Updated description of Operation and Maintenance (O&M) Program | 15 years after permit effective date |
| 3-5                | Phase 3 implementation schedule                                | 15 years after permit effective date |
| 3-6                | Estimated cost for implementing Phase 3 of the PCP             | 15 years after permit effective date |
| 3-7                | Complete written Phase 3 Plan                                  | 15 years after permit effective date |

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<sup>8</sup> See footnote 9

|      |                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 3-8  | Performance Evaluation.                                                                                                                                                                                                                                                                                                                                                                                        | 16, and 17 years after permit effective date |
| 3-9  | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load ( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.30<br>$P_{exp} \leq P_{allow} + (P_{RR} \times 0.30)$ | 18 years after permit effective date         |
| 3-10 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                         | 19 years after permit effective date         |
| 3-11 | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the PCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load ( $P_{allow}$ )<br>$P_{exp} \leq P_{allow}$                                                                                                             | 20 years after permit effective date         |

**Table F-5: Phase 3 of the PCP components and Milestones**

## 3) Description of Phase 3 PCP Components

Updated Legal Analysis- The permittee shall update the legal analysis completed during Phase 1 and Phase 2 of the PCP as necessary to include any new or augmented bylaws, ordinances or funding mechanisms the permittee has deemed necessary to implement the PCP. The permittee shall use experience gained during Phase 1 and Phase 2 to inform the updated legal analysis. The permittee shall adopt necessary regulatory changes as soon as possible to implement the Phase 3 Plan.

Description of Phase 3 planned non-structural controls – The permittee shall describe the non-structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-5. The description of non-structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions that are expected to result from their implementation in units of mass/yr. Annual phosphorus reduction from non-structural BMPs shall be calculated consistent with Attachment 2 to Appendix F.

Description of planned Phase 3 structural controls – The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of phosphorus control practices during Phase 3. The ranking shall build upon the ranking developed for

Phase 1 and 2. The permittee shall describe the structural stormwater control measures necessary to support achievement of the phosphorus export milestones in Table F-5. The description of structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions in units of mass/yr that are expected to result from their implementation. Structural measures to be implemented by a third party may be included in a municipal PCP. Annual phosphorus reduction from structural BMPs shall be calculated consistent with Attachment 3 to Appendix F.

Updated description of Operation and Maintenance (O&M) Program for all planned and existing structural BMPs – The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit as part of Phase 1, 2 and 3 of the PCP. This includes BMPs implemented to date as well as BMPs to be implemented during Phase 3 of the PCP. The Operation and Maintenance Program shall become part of the PCP and include: (1) inspection and maintenance schedule for each BMP according to BMP design or manufacturer specification and (2) program or department responsible for BMP maintenance.

Phase 3 Implementation Schedule – A schedule for implementation of all planned Phase 3 BMPs, including, as appropriate: funding, training, purchasing, construction, inspections, monitoring, O&M activities and other assessment and evaluation components of implementation. Implementation of planned BMPs must begin upon completion of the Phase 3 Plan. Structural BMPs shall be designed and constructed to ensure the permittee will comply with the 18 and 20 year milestones established in Table F-5. The Phase 3 plan shall be fully implemented as soon as possible, but no later than 20 years after the effective date of permit.

Estimated cost for implementing Phase 3 of the PCP – The permittee shall estimate the cost of implementing the Phase 3 non-structural and structural controls and associated Operation and Maintenance Program. This cost estimate can be used to plan for the full implementation of Phase 3.

Complete written Phase 3 Plan – The permittee must complete the written Phase 3 Plan of the PCP no later than 15 years after the permit effective date. The complete Phase 3 Plan shall include Phase 3 PCP item numbers 3-1 through 3-6 in Table F-5. The permittee shall make the Phase 3 Plan available to the public for public comment during Phase 3 Plan development. EPA encourages the permittee to post the Phase 3 Plan online to facilitate public involvement.

Performance Evaluation – The permittee shall evaluate the effectiveness of the PCP by tracking the phosphorus reductions achieved through implementation of structural and non-structural BMPs<sup>9</sup> and tracking increases resulting from development. Phosphorus reductions shall be calculated consistent with Attachment 2 to Appendix F (non-structural BMP

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<sup>9</sup> See footnote 9

performance) and Attachment 3 to Appendix F (structural BMP performance) for all BMPs implemented to date. Phosphorus export increases due to development shall be calculated consistent with Attachment 1 to Appendix F. Phosphorus loading increases and reductions in unit of mass/yr shall be added or subtracted from the applicable Baseline Phosphorus Load given in Table F-2 or Table F-3 depending on the Scope of PCP chosen to estimate the yearly phosphorous export rate from the PCP Area. The permittee shall also include all information required in part I.2 of this Appendix in each performance evaluation. Performance evaluations will be included as part of each permittee's annual report as required by part 4.4 of the Permit.

## 2. Reporting

Beginning 1 year after the permit effective date, the permittee shall include a progress report in each annual report on the planning and implementation of the PCP.

Beginning five (5) years after the permit effective date, the permittee shall include the following in each annual report submitted pursuant to part 4.4 of the Permit:

- a. All non-structural control measures implemented during the reporting year along with the phosphorus reduction in mass/yr ( $P_{NSred}$ ) calculated consistent with Attachment 2 to Appendix F
- b. Structural controls implemented during the reporting year and all previous years including:
  - a. Location information of structural BMPs (GPS coordinates or street address)
  - b. Phosphorus reduction from all structural BMPs implemented to date in mass/yr ( $P_{Sred}$ ) calculated consistent with Attachment 3 to Appendix F
  - c. Date of last completed maintenance and inspection for each Structural control
- c. Phosphorus load increases due to development over the previous reporting period and incurred since 2005 ( $P_{DEVinc}$ ) calculated consistent with Attachment 1 to Appendix F.
- d. Estimated yearly phosphorus export rate ( $P_{exp}$ ) from the PCP Area calculated using Equation 2. Equation 2 calculates the yearly phosphorus export rate by subtracting yearly phosphorus reductions through implemented nonstructural controls and structural controls to date from the Baseline Phosphorus Load and adding loading increases incurred through development to date. This equation shall be used to demonstrate compliance with the phosphorus reduction milestones required as part of each phase of the PCP.

$$P_{exp}\left(\frac{mass}{yr}\right) = P_{base}\left(\frac{mass}{yr}\right) - \left(P_{Sred}\left(\frac{mass}{yr}\right) + P_{NSred}\left(\frac{mass}{yr}\right)\right) + P_{DEVinc}\left(\frac{mass}{yr}\right)$$

**Equation 1. Equation used to calculate yearly phosphorus export rate from the chosen PCP Area.  $P_{exp}$ =Current phosphorus export rate from the PCP Area in mass/year.  $P_{base}$ =baseline phosphorus export rate from LPCP Area in mass/year.  $P_{Sred}$ = yearly phosphorus reduction from implemented structural controls in the PCP Area in mass/year.  $P_{NSred}$ = yearly phosphorus reduction from implemented non-structural controls in the PCP Area in mass/year.  $P_{DEVinc}$ = yearly phosphorus increase resulting from development since 2005 in the PCP Area in mass/year.**

- e. Certification that all structural BMPs are being inspected and maintained according to the O&M program specified as part of the PCP. The certification statement shall be:

*I certify under penalty of law that all source control and treatment Best Management Practices being claimed for phosphorus reduction credit have been inspected, maintained and repaired in accordance with manufacturer or design specification. I certify that, to the best of my knowledge, all Best Management Practices being claimed for a phosphorus reduction credit are performing as originally designed.*

- f. Certification that all municipally owned and maintained turf grass areas are being managed in accordance with Massachusetts Regulation 331 CMR 31 pertaining to proper use of fertilizers on turf grasses (see <http://www.mass.gov/courts/docs/lawlib/300-399cmr/330cmr31.pdf> ).

3. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part A.I.1. as follows.

- a. The permittee is relieved of its additional requirements as of the date when the following conditions are met:
  - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of phosphorus are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
- b. When the criteria in Appendix F part A.I.3.a. are met, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part A.I.1 as of that date and the permittee shall comply with the following:
  - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part A.I.1 to date to reduce phosphorus in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
  - ii. The permittee shall continue to implement all requirements of Appendix F part A.I.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications, and the reporting requirements of Appendix F part I.2. remain in place.

## II. Lake and Pond Phosphorus TMDL Requirements

Between 1999 and 2010 EPA has approved 13 Lake TMDLs<sup>10</sup> completed by MassDEP covering 78 lakes and ponds within the Commonwealth of Massachusetts. Any permittee (traditional or non-traditional) that discharges to a waterbody segment in Table F-6 is subject to the requirements of this part.

1. Permittees that operate regulated MS4s (traditional and non-traditional) that discharge to the identified impaired waters or their tributaries must reduce phosphorus discharges to support achievement of phosphorus load reductions identified in the TMDLs. To address phosphorus, all permittees with a phosphorus reduction requirement greater than 0% shall develop a Lake Phosphorus Control Plan (LPCP) designed to reduce the amount of phosphorus in stormwater discharges from its MS4 to the impaired waterbody or its tributaries in accordance with the phosphorus load reduction requirements set forth in Table F-6 below. Permittees discharging to waterbodies in Table F-6 with an associated 0% Phosphorus Required Percent Reduction are subject to Appendix F part II.2.f and are relieved of the requirements of Appendix F part II.1.i through Appendix F part II.2.e Table F-6 identifies the primary municipalities<sup>11</sup> located within the watershed of the respective lake or pond and the percent phosphorus reductions necessary from urban stormwater sources. Any permittee (traditional or non-traditional) that discharges to a lake or pond listed in Table F-6 or its tributaries is subject to the same phosphorus percent reduction requirements associated with that lake or pond.

| Primary Municipality | Waterbody Name        | Required Percent Reduction |
|----------------------|-----------------------|----------------------------|
| Auburn               | Leesville Pond        | 31%                        |
|                      | Auburn Pond           | 24%                        |
|                      | Eddy Pond             | 0%                         |
|                      | Pondville Pond        | 8%                         |
|                      | Stoneville Pond       | 3%                         |
| Charlton             | Buffumville Lake      | 28%                        |
|                      | Dresser Hill Pond     | 17%                        |
|                      | Gore Pond             | 14%                        |
|                      | Granite Reservoir     | 11%                        |
|                      | Jones Pond            | 13%                        |
|                      | Pierpoint Meadow Pond | 27%                        |
|                      | Pikes Pond            | 38%                        |
| Dudley               | Gore Pond             | 14%                        |

<sup>10</sup> Final TMDLs for lakes and ponds in the Northern Blackstone River Watershed, Chicopee Basin, Connecticut Basin, French Basin, Millers Basin and Bare Hill Pond, Flint Pond, Indian Lake, Lake Boon, Leesville Pond, Salisbury Pond, White Island Pond, Quaboag Pond and Quacumquasit Pond can be found here: <http://www.mass.gov/eea/agencies/massdep/water/watersheds/total-maximum-daily-loads-tmdls.html>

<sup>11</sup> Primary municipalities indicate the municipality in which the majority of the lake or pond is located but does not necessarily indicate each municipality that has urbanized area that discharges to the lake or pond or its tributaries.

| <b>Primary Municipality</b> | <b>Waterbody Name</b>        | <b>Required Percent Reduction</b> |
|-----------------------------|------------------------------|-----------------------------------|
|                             | Larner Pond                  | 55%                               |
|                             | New Pond                     | 56%                               |
|                             | Pierpoint Meadow Pond        | 27%                               |
|                             | Shepherd Pond                | 25%                               |
|                             | Tobins Pond                  | 62%                               |
|                             | Wallis Pond                  | 54%                               |
| Gardner                     | Hilchey Pond                 | 27%                               |
|                             | Parker Pond                  | 47%                               |
|                             | Bents Pond                   | 52%                               |
|                             | Ramsdall Pond                | 49%                               |
| Grafton                     | Flint Pond/Lake Quinsigamond | 59%                               |
| Granby                      | Aldrich Lake East            | 0%                                |
| Hadley                      | Lake Warner                  | 24%                               |
| Harvard                     | Bare Hill Pond               | 2%                                |
| Hudson                      | Lake Boon                    | 28%                               |
| Leicester                   | Smiths Pond                  | 30%                               |
|                             | Southwick Pond               | 64%                               |
|                             | Cedar Meadow Pond            | 17%                               |
|                             | Dutton Pond                  | 23%                               |
|                             | Greenville Pond              | 14%                               |
|                             | Rochdale Pond                | 8%                                |
| Ludlow                      | Minechoag Pond               | 48%                               |
| Millbury                    | Brierly Pond                 | 14%                               |
|                             | Dorothy Pond                 | 1%                                |
|                             | Howe Reservoir               | 48%                               |
| Oxford                      | Buffumville Lake             | 28%                               |
|                             | Hudson Pond                  | 37%                               |
|                             | Lowes Pond                   | 51%                               |
|                             | McKinstry Pond               | 79%                               |
|                             | Robinson Pond                | 8%                                |
|                             | Texas Pond                   | 21%                               |
| Shrewsbury                  | Flint Pond/Lake Quinsigamond | 49%                               |
|                             | Jordan Pond                  | 60%                               |
|                             | Mill Pond                    | 43%                               |
|                             | Newton Pond                  | 19%                               |
|                             | Shirley Street Pond          | 30%                               |
| Spencer                     | Quaboag Pond                 | 29%                               |

| Primary Municipality | Waterbody Name    | Required Percent Reduction |
|----------------------|-------------------|----------------------------|
|                      | Quacumquasit Pond | 2%                         |
|                      | Jones Pond        | 13%                        |
|                      | Sugden Reservoir  | 31%                        |
| Springfield          | Loon Pond         | 10%                        |
|                      | Long Pond         | 56%                        |
|                      | Mona Lake         | 57%                        |
| Stow                 | Lake Boon         | 28%                        |
| Templeton            | Brazell Pond      | 62%                        |
|                      | Depot Pond        | 50%                        |
|                      | Bourn-Hadley Pond | 49%                        |
|                      | Greenwood Pond 2  | 56%                        |
| Wilbraham            | Spectacle Pond    | 45%                        |
| Winchendon           | Lake Denison      | 22%                        |
|                      | Stoddard Pond     | 24%                        |
|                      | Whitney Pond      | 16%                        |
|                      | Whites Mill Pond  | 21%                        |

**Table F-6: Phosphorus impaired Lakes or Ponds subject to a TMDL along with primary municipality and required percent reduction of phosphorus from urban stormwater sources**

- i. The LPCP shall be implemented in accordance with the following schedule and contain the following elements:
  - a. LPCP Implementation Schedule – The permittee shall complete its LPCP and fully implement all of the control measures in its LPCP as soon as possible but no later than 15 years after the effective date of the permit.
  - b. The LPCP shall be implemented in accordance with the following schedule and contain the following elements:

| Number | LPCP Component and Milestones                                                                 | Completion Date                     |
|--------|-----------------------------------------------------------------------------------------------|-------------------------------------|
| 1      | Legal Analysis                                                                                | 2 years after permit effective date |
| 2      | Funding source assessment                                                                     | 3 years after permit effective date |
| 3      | Define LPCP scope (LPCP Area)                                                                 | 4 years after permit effective date |
| 4      | Calculate Baseline Phosphorus, Allowable Phosphorus Load and Phosphorus Reduction Requirement | 4 years after permit effective date |

|    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|
| 5  | Description of planned nonstructural and structural controls                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 5 years after permit effective date         |
| 6  | Description of Operation and Maintenance (O&M) Program                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 5 years after permit effective date         |
| 7  | Implementation schedule                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 5 years after permit effective date         |
| 8  | Cost and Funding Source Assessment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 years after permit effective date         |
| 9  | Complete written LPCP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 5 years after permit effective date         |
| 10 | Full implementation of nonstructural controls.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 6 years after permit effective date         |
| 11 | Performance Evaluation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 6 and 7 years after permit effective date   |
| 12 | <ol style="list-style-type: none"> <li>1. Performance Evaluation.</li> <li>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate (<math>P_{exp}</math>) from the LPCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load(<math>P_{allow}</math>) plus the applicable Phosphorus Reduction Requirement (<math>P_{RR}</math>) multiplied by 0.80<br/> <math display="block">P_{exp} \leq P_{allow} + (P_{RR} \times 0.80)</math> </li> </ol>                                                                                                                                                                                      | 8 years after permit effective date         |
| 13 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 9 years after permit effective date         |
| 14 | <ol style="list-style-type: none"> <li>1. Performance Evaluation.</li> <li>2. Update LPCP</li> <li>3. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate (<math>P_{exp}</math>) from the LPCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load(<math>P_{allow}</math>) plus the applicable Phosphorus Reduction Requirement (<math>P_{RR}</math>) multiplied by 0.60<br/> <math display="block">P_{exp} \leq P_{allow} + (P_{RR} \times 0.60)</math> OR that the permittee has reduced their phosphorus export rate by 30kg/year (whichever is greater, unless full Phosphorus Reduction Requirement has been met)</li> </ol> | 10years after permit effective date         |
| 15 | Performance Evaluation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 11 and 12 years after permit effective date |
| 16 | <ol style="list-style-type: none"> <li>1. Performance Evaluation.</li> <li>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate (<math>P_{exp}</math>) from the LPCP Area in mass/yr is equal to or less than the applicable Allowable</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                             | 13years after permit effective date         |

|    |                                                                                                                                                                                                                                                                                                    |                                      |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
|    | Phosphorus Load( $P_{allow}$ ) plus the applicable Phosphorus Reduction Requirement ( $P_{RR}$ ) multiplied by 0.30<br>$P_{exp} \leq P_{allow} + (P_{RR} \times 0.30)$                                                                                                                             |                                      |
| 17 | Performance Evaluation                                                                                                                                                                                                                                                                             | 14 years after permit effective date |
| 18 | 1. Performance Evaluation.<br>2. Full implementation of all structural controls used to demonstrate that the total phosphorus export rate ( $P_{exp}$ ) from the LPCP Area in mass/yr is equal to or less than the applicable Allowable Phosphorus Load( $P_{allow}$ )<br>$P_{exp} \leq P_{allow}$ | 15 years after permit effective date |

**Table F-7: LPCP components and milestones**

## c. Description of LPCP Components:

Legal Analysis- The permittee shall develop and implement an analysis that identifies existing regulatory mechanisms available to the MS4 such as by-laws and ordinances and describes any changes to these regulatory mechanisms that may be necessary to effectively implement the LPCP. This may include the creation or amendment of financial and regulatory authorities. The permittee shall adopt necessary regulatory changes by the end of the permit term.

Scope of the LPCP (LPCP Area) - The permittee shall indicate the area in which the permittee plans to implement the LPCP, this area is known as the “LPCP Area”. The permittee must choose one of the following: 1) to implement its LPCP in the entire area within its jurisdiction discharging to the impaired waterbody (for a municipality this would be the municipal boundary) or 2) to implement its LPCP in only the urbanized area portion of its jurisdiction discharging to the impaired waterbody. If the permittee chooses to implement the LPCP in its entire jurisdiction discharging to the impaired waterbody, the permittee may demonstrate compliance with the Phosphorus Reduction Requirement and Allowable Phosphorus Load requirements applicable to it through structural and non-structural controls on discharges that occur both inside and outside the urbanized area. If the permittee chooses to implement the LPCP in its urbanized area only discharging to the impaired waterbody, the permittee must demonstrate compliance with the Phosphorus Reduction Requirement and Allowable Phosphorus Load requirements applicable to it through structural and non-structural controls on discharges that occur within the urbanized area only.

Calculate Baseline Phosphorus Load ( $P_{base}$ ), Phosphorus Reduction Requirement ( $P_{RR}$ ) and Allowable Phosphorus Load ( $P_{allow}$ ) –Permittees shall calculate their numerical Allowable Phosphorus Load and Phosphorus Reduction Requirement in mass/yr by first estimating their Baseline Phosphorus Load in mass/yr from its LPCP Area consistent with the methodology in Attachment 1 to Appendix F, the baseline shall only be estimated using land use phosphorus export coefficients in Attachment 1 to Appendix F and not account for phosphorus reductions resulting from implemented structural BMPs completed to date. Table F-6 contains the

percent phosphorus reduction required from urban stormwater consistent with the TMDL of each impaired waterbody. The permittee shall apply the applicable required percent reduction in Table F-6 to the calculated Baseline Phosphorus Load to obtain the permittee specific Allowable Phosphorus Load. The Allowable Phosphorus Load shall then be subtracted from the Baseline Phosphorus Load to obtain the permittee specific Phosphorus Reduction Requirement in mass/yr.

Description of planned non-structural controls – The permittee shall describe the non-structural stormwater control measures to be implemented to support the achievement of the milestones in Table F-7. The description of non-structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions that are expected to result from their implementation. Annual phosphorus reduction from non-structural BMPs shall be calculated consistent with Attachment 2 to Appendix F. The permittee shall update the description of planned non-structural controls as needed to support the achievement of the milestones in Table F-7, including an update in the updated written LPCP 10 years after the permit effective date.

Description of planned structural controls – The permittee shall develop a priority ranking of areas and infrastructure within the municipality for potential implementation of phosphorus control practices. The ranking shall be developed through the use of available screening and monitoring results collected during the permit term either by the permittee or another entity and the mapping required pursuant to part 2.3.4.6 of the Permit. The permittee shall also include in this prioritization a detailed assessment of site suitability for potential phosphorus control measures based on soil types and other factors. The permittee shall coordinate this activity with the requirements of part 2.3.6.8.b of the Permit. A description and the result of this priority ranking shall be included in the LPCP. The permittee shall describe the structural stormwater control measures necessary to support achievement of the milestones in Table F-7. The description of structural controls shall include the planned measures, the areas where the measures will be implemented, and the annual phosphorus reductions in units of mass/yr that are expected to result from their implementation. Structural measures to be implemented by a third party may be included in the LPCP. Annual phosphorus reduction from structural BMPs shall be calculated consistent with Attachment 3 to Appendix F. The permittee shall update the description of planned structural controls as needed to support the achievement of the milestones in Table F-7, including an update in the updated written LPCP 10 years after the permit effective date.

Description of Operation and Maintenance (O&M) Program for all planned and existing structural BMPs – The permittee shall establish an Operation and Maintenance Program for all structural BMPs being claimed for phosphorus reduction credit as part of Phase 1 and 2 of the PCP. This includes BMPs implemented to date as well as BMPs to be implemented during Phase 2 of the PCP. The Operation and Maintenance Program shall become part of the PCP and include: (1) inspection and maintenance schedule for each BMP according to BMP design or manufacturer specification and (2) program or department responsible for BMP maintenance.

Implementation Schedule – An initial schedule for implementing the BMPs, including, as appropriate: funding, training, purchasing, construction, inspections, monitoring, O&M and other assessment and evaluation components of implementation. Implementation of planned BMPs must begin upon completion of the LPCP, and all non-structural BMPs shall be fully implemented within six years of the permit effective date. Where planned structural BMP retrofits or major drainage infrastructure projects are expected to take additional time to construct, the permittee shall within four years of the effective date of the permit have a schedule for completion of construction consistent with the reduction requirements in Table F-7. The permittee shall complete the implementation of its LPCP as soon as possible or at a minimum in accordance with the milestones set forth in Table F-7. The implementation schedule shall be updated as needed to support the achievement of the milestones in Table F-7, including an update in the updated written LPCP 10 years after the permit effective date.

Cost and funding source assessment – The permittee shall estimate the cost for implementing its LPCP and describe known and anticipated funding mechanisms. The permittee shall describe the steps it will take to implement its funding plan. This may include but is not limited to conceptual development, outreach to affected parties, and development of legal authorities.

Complete written LPCP – The permittee must complete the written LPCP 5 years after permit effective date. The complete LPCP shall include item numbers 1-8 in Table F-7. The permittee shall make the LPCP available to the public for public comment during the LPCP development. EPA encourages the permittee to post the LPCP online to facilitate public involvement. The LPCP shall be updated as needed with an update 10 years after the permit effective date at a minimum to reflect changes in BMP implementation to support achievement of the phosphorus export milestones in Table F-7. The updated LPCP shall build upon the original LPCP and include additional or new BMPs the permittee will use to support the achievement of the milestones in Table F-7.

Performance Evaluation – The permittee shall evaluate the effectiveness of the LPCP by tracking the phosphorus reductions achieved through implementation of structural and non-structural BMPs<sup>12</sup> and tracking increases in phosphorus loading from the LPCP Area beginning six years after the effective date of the permit. Phosphorus reductions shall be calculated consistent with Attachment 2 (non-structural BMP performance), Attachment 3 (structural BMP performance) and Attachment 1 (reductions through land use change), to Appendix F for all BMPs implemented to date<sup>13</sup>. Phosphorus load increases resulting from development shall be calculated consistent with Attachment 1 to Appendix F. Phosphorus

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<sup>12</sup> In meeting its phosphorus reduction requirements a permittee may quantify phosphorus reductions by actions undertaken by another entity, except where those actions are credited to MassDOT or another permittee identified in Appendix F Table F-7

<sup>13</sup> Annual phosphorus reductions from structural BMPs installed in the LPCP Area prior to the effective date of this permit shall be calculated consistent with Attachment 3 to Appendix F. Phosphorus Reduction Credit for previously installed BMPs will only be given if the Permittee demonstrates that the BMP is performing up to design specifications and certifies that the BMP is properly maintained and inspected according to manufacturer design or specifications. This certification shall be part of the annual performance evaluation during the year credit is claimed for the previously installed BMP.

loading increases and reductions in units of mass/yr shall be added or subtracted from the calculated Baseline Phosphorus Load to estimate the yearly phosphorous export rate from the LPCP Area in mass/yr. The permittee shall also include all information required in part II.2 of this Appendix in each performance evaluation.

## 2. Reporting

Beginning 1 year after the permit effective date, the permittee shall include a progress report in each annual report on the planning and implementation of the LPCP.

Beginning five (5) years after the permit effective date, the permittee shall include the following in each annual report submitted pursuant to part 4.4 of the Permit:

- a. All non-structural control measures implemented during the reporting year along with the phosphorus reduction in mass/yr ( $P_{NSred}$ ) calculated consistent with Attachment 2 to Appendix F
- b. Structural controls implemented during the reporting year and all previous years including:
  - a. Location information of structural BMPs (GPS coordinates or street address)
  - b. Phosphorus reduction from all structural BMPs implemented to date in mass/yr ( $P_{Sred}$ ) calculated consistent with Attachment 3 to Appendix F
  - c. Date of last completed maintenance for each Structural control
- c. Phosphorus load increases due to development over the previous reporting period and incurred to date ( $P_{DEVinc}$ ) calculated consistent with Attachment 1 to Appendix F.
- d. Estimated yearly phosphorus export rate ( $P_{exp}$ ) from the LPCP Area calculated using Equation 2. Equation 2 calculates the yearly phosphorus export rate by subtracting yearly phosphorus reductions through implemented nonstructural controls and structural controls to date from the Baseline Phosphorus Load and adding loading increases incurred through development to date. This equation shall be used to demonstrate compliance with the phosphorus reduction milestones required as part of each phase of the LPCP.

$$P_{exp} \left( \frac{\text{mass}}{\text{yr}} \right) = P_{base} \left( \frac{\text{mass}}{\text{yr}} \right) - \left( P_{Sred} \left( \frac{\text{mass}}{\text{yr}} \right) + P_{NSred} \left( \frac{\text{mass}}{\text{yr}} \right) \right) + P_{DEVinc} \left( \frac{\text{mass}}{\text{yr}} \right)$$

**Equation 2. Equation used to calculate yearly phosphorus export rate from the chosen LPCP Area.  $P_{exp}$ =Current phosphorus export rate from the LPCP Area in mass/year.  $P_{base}$ =baseline phosphorus export rate from LPCP Area in mass/year.  $P_{Sred}$ = yearly phosphorus reduction from implemented structural controls in the LPCP Area in mass/year.  $P_{NSred}$ = yearly phosphorus reduction from implemented non-structural controls in the LPCP Area in mass/year. Area in mass/year.  $P_{DEVinc}$ = yearly phosphorus increase resulting from development since the year baseline loading was calculated in the LPCP Area in mass/year.**

- e. Certification that all structural BMPs are being inspected and maintained according to the O&M program specified as part of the PCP. The certification statement shall be:

*I certify under penalty of law that all source control and treatment Best Management Practices being claimed for phosphorus reduction credit have been inspected, maintained and repaired in accordance with manufacturer or design specification. I certify that, to the best of my knowledge, all Best Management*

*Practices being claimed for a phosphorus reduction credit are performing as originally designed.*

- f. Certification that all municipally owned and maintained turf grass areas are being managed in accordance with Massachusetts Regulation 331 CMR 31 pertaining to proper use of fertilizers on turf grasses (see <http://www.mass.gov/courts/docs/lawlib/300-399cmr/330cmr31.pdf> ).
3. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part A.II.1. as follows:
- a. The permittee is relieved of its additional requirements as of the date when the following conditions are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of phosphorus are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any additional remaining requirements of Appendix F part A.II.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part A.II.1 to date to reduce phosphorus in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part A.I.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications, and the reporting requirements of Appendix F part A.II.2. remain in place.

### III. Bacteria and Pathogen TMDL Requirements

There are currently approved 16 approved bacteria (fecal coliform bacteria) or mixed pathogen (fecal coliform, E. coli, and/or enterococcus bacteria) TMDLs for certain waterbodies in Massachusetts.<sup>14</sup> Any permittee (traditional or non-traditional) that discharges to a waterbody segment in Table F-8 is subject to the requirements of this part.

1. Traditional and non-traditional MS4s operating in the municipalities listed in Table F-8 and/or that discharge to a waterbody listed on Table F-8 shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.3. Public Education: The permittee shall supplement its Residential program with an annual message encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee or its agents shall disseminate educational materials to dog owners at the time of issuance or renewal of a dog license, or other appropriate time. Education materials shall describe the detrimental impacts of improper management of pet waste, requirements for waste collection and disposal, and penalties for non-compliance. The permittee shall also provide information to owners of septic systems about proper maintenance in any catchment that discharges to a water body impaired for bacteria or pathogens. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.IV, A.V, B.I, B.II and B.III where appropriate.
      2. part 2.3.4 Illicit Discharge: Catchments draining to any waterbody impaired for bacteria or pathogens shall be designated either Problem Catchments or HIGH priority in implementation of the IDDE program.

| Primary Municipality | Segment ID | Waterbody Name     | Indicator Organism         |
|----------------------|------------|--------------------|----------------------------|
| Abington             | MA62-09    | Beaver Brook       | Escherichia Coli (E. Coli) |
| Abington             | MA62-33    | Shumatuscant River | Escherichia Coli (E. Coli) |
| Acushnet             | MA95-31    | Acushnet River     | Escherichia Coli (E. Coli) |
| Acushnet             | MA95-32    | Acushnet River     | Escherichia Coli (E. Coli) |
| Acushnet             | MA95-33    | Acushnet River     | Fecal Coliform             |

<sup>14</sup> Final bacteria or pathogen TMDLs can be found here:

<http://www.mass.gov/eea/agencies/massdep/water/watersheds/total-maximum-daily-loads-tmdls.html>

|            |         |                      |                            |
|------------|---------|----------------------|----------------------------|
| Andover    | MA83-04 | Rogers Brook         | Fecal Coliform             |
| Andover    | MA83-15 | Unnamed Tributary    | Fecal Coliform             |
| Andover    | MA83-18 | Shawsheen River      | Fecal Coliform             |
| Andover    | MA83-19 | Shawsheen River      | Fecal Coliform             |
| Avon       | MA62-07 | Trout Brook          | Escherichia Coli (E. Coli) |
| Barnstable | MA96-01 | Barnstable Harbor    | Fecal Coliform             |
| Barnstable | MA96-02 | Bumps River          | Fecal Coliform             |
| Barnstable | MA96-04 | Centerville River    | Fecal Coliform             |
| Barnstable | MA96-05 | Hyannis Harbor       | Fecal Coliform             |
| Barnstable | MA96-06 | Maraspin Creek       | Fecal Coliform             |
| Barnstable | MA96-07 | Prince Cove          | Fecal Coliform             |
| Barnstable | MA96-08 | Shoestring Bay       | Fecal Coliform             |
| Barnstable | MA96-36 | Lewis Bay            | Fecal Coliform             |
| Barnstable | MA96-37 | Mill Creek           | Fecal Coliform             |
| Barnstable | MA96-63 | Cotuit Bay           | Fecal Coliform             |
| Barnstable | MA96-64 | Seapuit River        | Fecal Coliform             |
| Barnstable | MA96-66 | North Bay            | Fecal Coliform             |
| Barnstable | MA96-81 | Snows Creek          | Fecal Coliform             |
| Barnstable | MA96-82 | Hyannis Inner Harbor | Fecal Coliform             |
| Barnstable | MA96-92 | Santuit River        | Fecal Coliform             |
| Barnstable | MA96-93 | Halls Creek          | Fecal Coliform             |
| Barnstable | MA96-94 | Stewarts Creek       | Fecal Coliform             |
| Bedford    | MA83-01 | Shawsheen River      | Fecal Coliform             |
| Bedford    | MA83-05 | Elm Brook            | Fecal Coliform             |
| Bedford    | MA83-06 | Vine Brook           | Fecal Coliform             |
| Bedford    | MA83-08 | Shawsheen River      | Fecal Coliform             |
| Bedford    | MA83-10 | Kiln Brook           | Fecal Coliform             |
| Bedford    | MA83-14 | Spring Brook         | Fecal Coliform             |
| Bedford    | MA83-17 | Shawsheen River      | Fecal Coliform             |
| Bellingham | MA72-03 | Charles River        | Pathogens                  |
| Bellingham | MA72-04 | Charles River        | Pathogens                  |
| Belmont    | MA72-28 | Beaver Brook         | Pathogens                  |
| Berkley    | MA62-02 | Taunton River        | Fecal Coliform             |
| Berkley    | MA62-03 | Taunton River        | Fecal Coliform             |
| Berkley    | MA62-20 | Assonet River        | Fecal Coliform             |
| Beverly    | MA93-08 | Bass River           | Fecal Coliform             |
| Beverly    | MA93-09 | Danvers River        | Fecal Coliform             |
| Beverly    | MA93-20 | Beverly Harbor       | Fecal Coliform             |
| Beverly    | MA93-25 | Salem Sound          | Fecal Coliform             |
| Billerica  | MA83-14 | Spring Brook         | Fecal Coliform             |
| Billerica  | MA83-17 | Shawsheen River      | Fecal Coliform             |

|             |         |                       |                            |
|-------------|---------|-----------------------|----------------------------|
| Billerica   | MA83-18 | Shawsheen River       | Fecal Coliform             |
| Bourne      | MA95-01 | Buttermilk Bay        | Fecal Coliform             |
| Bourne      | MA95-14 | Cape Cod Canal        | Fecal Coliform             |
| Bourne      | MA95-15 | Phinneys Harbor       | Fecal Coliform             |
| Bourne      | MA95-16 | Pocasset River        | Fecal Coliform             |
| Bourne      | MA95-17 | Pocasset Harbor       | Fecal Coliform             |
| Bourne      | MA95-18 | Red Brook Harbor      | Fecal Coliform             |
| Bourne      | MA95-47 | Back River            | Fecal Coliform             |
| Bourne      | MA95-48 | Eel Pond              | Fecal Coliform             |
| Brewster    | MA96-09 | Quivett Creek         | Fecal Coliform             |
| Brewster    | MA96-27 | Namskaket Creek       | Fecal Coliform             |
| Bridgewater | MA62-32 | Matfield River        | Escherichia Coli (E. Coli) |
| Brockton    | MA62-05 | Salisbury Plain River | Escherichia Coli (E. Coli) |
| Brockton    | MA62-06 | Salisbury Plain River | Escherichia Coli (E. Coli) |
| Brockton    | MA62-07 | Trout Brook           | Escherichia Coli (E. Coli) |
| Brockton    | MA62-08 | Salisbury Brook       | Escherichia Coli (E. Coli) |
| Brockton    | MA62-09 | Beaver Brook          | Escherichia Coli (E. Coli) |
| Brookline   | MA72-11 | Muddy River           | Pathogens                  |
| Burlington  | MA83-06 | Vine Brook            | Fecal Coliform             |
| Burlington  | MA83-11 | Long Meadow Brook     | Fecal Coliform             |
| Burlington  | MA83-13 | Sandy Brook           | Fecal Coliform             |
| Cambridge   | MA72-36 | Charles River         | Pathogens                  |
| Cambridge   | MA72-38 | Charles River         | Pathogens                  |
| Canton      | MA73-01 | Neponset River        | Fecal Coliform             |
| Canton      | MA73-01 | Neponset River        | Escherichia Coli (E. Coli) |
| Canton      | MA73-02 | Neponset River        | Fecal Coliform             |
| Canton      | MA73-05 | East Branch           | Fecal Coliform             |
| Canton      | MA73-20 | Beaver Meadow Brook   | Fecal Coliform             |
| Canton      | MA73-22 | Pequid Brook          | Fecal Coliform             |
| Canton      | MA73-25 | Pecunit Brook         | Escherichia Coli (E. Coli) |
| Canton      | MA73-27 | Ponkapog Brook        | Fecal Coliform             |
| Chatham     | MA96-11 | Stage Harbor          | Fecal Coliform             |
| Chatham     | MA96-41 | Mill Creek            | Fecal Coliform             |
| Chatham     | MA96-42 | Taylors Pond          | Fecal Coliform             |
| Chatham     | MA96-43 | Harding Beach Pond    | Fecal Coliform             |
| Chatham     | MA96-44 | Bucks Creek           | Fecal Coliform             |
| Chatham     | MA96-45 | Oyster Pond           | Fecal Coliform             |
| Chatham     | MA96-46 | Oyster Pond River     | Fecal Coliform             |
| Chatham     | MA96-49 | Frost Fish Creek      | Pathogens                  |
| Chatham     | MA96-50 | Ryder Cove            | Fecal Coliform             |
| Chatham     | MA96-51 | Muddy Creek           | Pathogens                  |

|                  |         |                            |                            |
|------------------|---------|----------------------------|----------------------------|
| Chatham          | MA96-79 | Cockle Cove Creek          | Fecal Coliform             |
| Chatham          | MA96-79 | Cockle Cove Creek          | Enterococcus Bacteria      |
| Cohasset         | MA94-01 | Cohasset Harbor            | Fecal Coliform             |
| Cohasset         | MA94-19 | The Gulf                   | Fecal Coliform             |
| Cohasset         | MA94-20 | Little Harbor              | Fecal Coliform             |
| Cohasset         | MA94-32 | Cohasset Cove              | Fecal Coliform             |
| Concord          | MA83-05 | Elm Brook                  | Fecal Coliform             |
| Danvers          | MA93-01 | Waters River               | Fecal Coliform             |
| Danvers          | MA93-02 | Crane Brook                | Escherichia Coli (E. Coli) |
| Danvers          | MA93-04 | Porter River               | Fecal Coliform             |
| Danvers          | MA93-09 | Danvers River              | Fecal Coliform             |
| Danvers          | MA93-36 | Frost Fish Brook           | Escherichia Coli (E. Coli) |
| Danvers          | MA93-41 | Crane River                | Fecal Coliform             |
| Dartmouth        | MA95-13 | Buttonwood Brook           | Escherichia Coli (E. Coli) |
| Dartmouth        | MA95-34 | Slocums River              | Fecal Coliform             |
| Dartmouth        | MA95-38 | Clarks Cove                | Fecal Coliform             |
| Dartmouth        | MA95-39 | Apponagansett Bay          | Fecal Coliform             |
| Dartmouth        | MA95-40 | East Branch Westport River | Escherichia Coli (E. Coli) |
| Dartmouth        | MA95-62 | Buzzards Bay               | Fecal Coliform             |
| Dedham           | MA72-07 | Charles River              | Pathogens                  |
| Dedham           | MA72-21 | Rock Meadow Brook          | Pathogens                  |
| Dedham           | MA73-02 | Neponset River             | Fecal Coliform             |
| Dennis           | MA96-09 | Quivett Creek              | Fecal Coliform             |
| Dennis           | MA96-12 | Bass River                 | Fecal Coliform             |
| Dennis           | MA96-13 | Sesuit Creek               | Fecal Coliform             |
| Dennis           | MA96-14 | Swan Pond River            | Fecal Coliform             |
| Dennis           | MA96-35 | Chase Garden Creek         | Fecal Coliform             |
| Dighton          | MA62-02 | Taunton River              | Fecal Coliform             |
| Dighton          | MA62-03 | Taunton River              | Fecal Coliform             |
| Dighton          | MA62-50 | Broad Cove                 | Fecal Coliform             |
| Dighton          | MA62-51 | Muddy Cove Brook           | Fecal Coliform             |
| Dighton          | MA62-55 | Segreganset River          | Fecal Coliform             |
| Dighton          | MA62-56 | Three Mile River           | Escherichia Coli (E. Coli) |
| Dighton          | MA62-57 | Three Mile River           | Fecal Coliform             |
| Dover            | MA72-05 | Charles River              | Pathogens                  |
| Dover            | MA72-06 | Charles River              | Pathogens                  |
| Duxbury          | MA94-15 | Duxbury Bay                | Fecal Coliform             |
| Duxbury          | MA94-30 | Bluefish River             | Fecal Coliform             |
| East Bridgewater | MA62-06 | Salisbury Plain River      | Escherichia Coli (E. Coli) |
| East Bridgewater | MA62-09 | Beaver Brook               | Escherichia Coli (E. Coli) |
| East Bridgewater | MA62-32 | Matfield River             | Escherichia Coli (E. Coli) |

|                  |         |                          |                            |
|------------------|---------|--------------------------|----------------------------|
| East Bridgewater | MA62-33 | Shumatuscacant River     | Escherichia Coli (E. Coli) |
| East Bridgewater | MA62-38 | Meadow Brook             | Escherichia Coli (E. Coli) |
| Eastham          | MA96-15 | Boat Meadow River        | Fecal Coliform             |
| Eastham          | MA96-16 | Rock Harbor Creek        | Fecal Coliform             |
| Eastham          | MA96-34 | Wellfleet Harbor         | Fecal Coliform             |
| Eastham          | MA96-68 | Town Cove                | Fecal Coliform             |
| Essex            | MA93-11 | Essex River              | Fecal Coliform             |
| Essex            | MA93-16 | Essex Bay                | Fecal Coliform             |
| Essex            | MA93-45 | Alewife Brook            | Escherichia Coli (E. Coli) |
| Essex            | MA93-46 | Alewife Brook            | Fecal Coliform             |
| Everett          | MA93-51 | Unnamed Tributary        | Enterococcus Bacteria      |
| Fairhaven        | MA95-33 | Acushnet River           | Fecal Coliform             |
| Fairhaven        | MA95-42 | New Bedford Inner Harbor | Fecal Coliform             |
| Fairhaven        | MA95-62 | Buzzards Bay             | Fecal Coliform             |
| Fairhaven        | MA95-63 | Outer New Bedford Harbor | Fecal Coliform             |
| Fairhaven        | MA95-64 | Little Bay               | Fecal Coliform             |
| Fairhaven        | MA95-65 | Nasketucket Bay          | Fecal Coliform             |
| Fall River       | MA61-06 | Mount Hope Bay           | Fecal Coliform             |
| Fall River       | MA62-04 | Taunton River            | Fecal Coliform             |
| Falmouth         | MA95-20 | Wild Harbor              | Fecal Coliform             |
| Falmouth         | MA95-21 | Herring Brook            | Fecal Coliform             |
| Falmouth         | MA95-22 | West Falmouth Harbor     | Fecal Coliform             |
| Falmouth         | MA95-23 | Great Sippewisset Creek  | Fecal Coliform             |
| Falmouth         | MA95-24 | Little Sippewisset Marsh | Fecal Coliform             |
| Falmouth         | MA95-25 | Quissett Harbor          | Fecal Coliform             |
| Falmouth         | MA95-46 | Harbor Head              | Fecal Coliform             |
| Falmouth         | MA96-17 | Falmouth Inner Harbor    | Fecal Coliform             |
| Falmouth         | MA96-18 | Great Harbor             | Fecal Coliform             |
| Falmouth         | MA96-19 | Little Harbor            | Fecal Coliform             |
| Falmouth         | MA96-20 | Quashnet River           | Fecal Coliform             |
| Falmouth         | MA96-21 | Waquoit Bay              | Fecal Coliform             |
| Falmouth         | MA96-53 | Perch Pond               | Fecal Coliform             |
| Falmouth         | MA96-54 | Great Pond               | Fecal Coliform             |
| Falmouth         | MA96-55 | Green Pond               | Fecal Coliform             |
| Falmouth         | MA96-56 | Little Pond              | Fecal Coliform             |
| Falmouth         | MA96-57 | Bournes Pond             | Fecal Coliform             |
| Falmouth         | MA96-58 | Hamblin Pond             | Fecal Coliform             |
| Falmouth         | MA96-62 | Oyster Pond              | Fecal Coliform             |
| Foxborough       | MA62-39 | Rumford River            | Escherichia Coli (E. Coli) |
| Foxborough       | MA62-47 | Wading River             | Escherichia Coli (E. Coli) |
| Foxborough       | MA73-01 | Neponset River           | Fecal Coliform             |

|            |         |                     |                            |
|------------|---------|---------------------|----------------------------|
| Foxborough | MA73-01 | Neponset River      | Escherichia Coli (E. Coli) |
| Franklin   | MA72-04 | Charles River       | Pathogens                  |
| Freetown   | MA62-04 | Taunton River       | Fecal Coliform             |
| Freetown   | MA62-20 | Assonet River       | Fecal Coliform             |
| Gloucester | MA93-12 | Annisquam River     | Fecal Coliform             |
| Gloucester | MA93-16 | Essex Bay           | Fecal Coliform             |
| Gloucester | MA93-18 | Gloucester Harbor   | Fecal Coliform             |
| Gloucester | MA93-28 | Mill River          | Fecal Coliform             |
| Hanover    | MA94-05 | North River         | Fecal Coliform             |
| Hanover    | MA94-21 | Drinkwater River    | Escherichia Coli (E. Coli) |
| Hanover    | MA94-24 | Iron Mine Brook     | Escherichia Coli (E. Coli) |
| Hanover    | MA94-27 | Third Herring Brook | Escherichia Coli (E. Coli) |
| Hanson     | MA62-33 | Shumatuscant River  | Escherichia Coli (E. Coli) |
| Harwich    | MA96-22 | Herring River       | Fecal Coliform             |
| Harwich    | MA96-23 | Saquatucket Harbor  | Fecal Coliform             |
| Harwich    | MA96-51 | Muddy Creek         | Pathogens                  |
| Holliston  | MA72-16 | Bogastow Brook      | Pathogens                  |
| Hopedale   | MA72-03 | Charles River       | Pathogens                  |
| Hopkinton  | MA72-01 | Charles River       | Pathogens                  |
| Ipswich    | MA93-16 | Essex Bay           | Fecal Coliform             |
| Kingston   | MA94-14 | Jones River         | Fecal Coliform             |
| Kingston   | MA94-15 | Duxbury Bay         | Fecal Coliform             |
| Lawrence   | MA83-19 | Shawsheen River     | Fecal Coliform             |
| Lexington  | MA72-28 | Beaver Brook        | Pathogens                  |
| Lexington  | MA83-06 | Vine Brook          | Fecal Coliform             |
| Lexington  | MA83-10 | Kiln Brook          | Fecal Coliform             |
| Lincoln    | MA83-05 | Elm Brook           | Fecal Coliform             |
| Lincoln    | MA83-08 | Shawsheen River     | Fecal Coliform             |
| Lynn       | MA93-24 | Nahant Bay          | Fecal Coliform             |
| Lynn       | MA93-44 | Saugus River        | Fecal Coliform             |
| Lynn       | MA93-52 | Lynn Harbor         | Fecal Coliform             |
| Lynnfield  | MA93-30 | Beaverdam Brook     | Escherichia Coli (E. Coli) |
| Lynnfield  | MA93-32 | Hawkes Brook        | Escherichia Coli (E. Coli) |
| Lynnfield  | MA93-34 | Saugus River        | Escherichia Coli (E. Coli) |
| Lynnfield  | MA93-35 | Saugus River        | Escherichia Coli (E. Coli) |
| Malden     | MA93-51 | Unnamed Tributary   | Enterococcus Bacteria      |
| Manchester | MA93-19 | Manchester Harbor   | Fecal Coliform             |
| Manchester | MA93-25 | Salem Sound         | Fecal Coliform             |
| Manchester | MA93-29 | Cat Brook           | Escherichia Coli (E. Coli) |
| Manchester | MA93-47 | Causeway Brook      | Escherichia Coli (E. Coli) |
| Mansfield  | MA62-39 | Rumford River       | Escherichia Coli (E. Coli) |

|               |         |                      |                            |
|---------------|---------|----------------------|----------------------------|
| Mansfield     | MA62-47 | Wading River         | Escherichia Coli (E. Coli) |
| Mansfield     | MA62-49 | Wading River         | Escherichia Coli (E. Coli) |
| Marblehead    | MA93-21 | Salem Harbor         | Fecal Coliform             |
| Marblehead    | MA93-22 | Marblehead Harbor    | Fecal Coliform             |
| Marblehead    | MA93-25 | Salem Sound          | Fecal Coliform             |
| Marion        | MA95-05 | Weweantic River      | Fecal Coliform             |
| Marion        | MA95-07 | Sippican River       | Fecal Coliform             |
| Marion        | MA95-08 | Sippican Harbor      | Fecal Coliform             |
| Marion        | MA95-09 | Aucoot Cove          | Fecal Coliform             |
| Marion        | MA95-56 | Hammett Cove         | Fecal Coliform             |
| Marshfield    | MA94-05 | North River          | Fecal Coliform             |
| Marshfield    | MA94-06 | North River          | Fecal Coliform             |
| Marshfield    | MA94-09 | South River          | Fecal Coliform             |
| Marshfield    | MA94-11 | Green Harbor         | Fecal Coliform             |
| Mashpee       | MA96-08 | Shoestring Bay       | Fecal Coliform             |
| Mashpee       | MA96-21 | Waquoit Bay          | Fecal Coliform             |
| Mashpee       | MA96-24 | Mashpee River        | Fecal Coliform             |
| Mashpee       | MA96-39 | Popponesset Creek    | Fecal Coliform             |
| Mashpee       | MA96-58 | Hamblin Pond         | Fecal Coliform             |
| Mashpee       | MA96-61 | Little River         | Fecal Coliform             |
| Mashpee       | MA96-92 | Santuit River        | Fecal Coliform             |
| Mattapoissett | MA95-09 | Aucoot Cove          | Fecal Coliform             |
| Mattapoissett | MA95-10 | Hiller Cove          | Fecal Coliform             |
| Mattapoissett | MA95-35 | Mattapoissett Harbor | Fecal Coliform             |
| Mattapoissett | MA95-60 | Mattapoissett River  | Fecal Coliform             |
| Mattapoissett | MA95-61 | Eel Pond             | Fecal Coliform             |
| Mattapoissett | MA95-65 | Nasketucket Bay      | Fecal Coliform             |
| Medfield      | MA72-05 | Charles River        | Pathogens                  |
| Medfield      | MA72-10 | Stop River           | Pathogens                  |
| Medfield      | MA73-09 | Mine Brook           | Fecal Coliform             |
| Medway        | MA72-04 | Charles River        | Pathogens                  |
| Medway        | MA72-05 | Charles River        | Pathogens                  |
| Melrose       | MA93-48 | Bennetts Pond Brook  | Escherichia Coli (E. Coli) |
| Mendon        | MA72-03 | Charles River        | Pathogens                  |
| Milford       | MA72-01 | Charles River        | Pathogens                  |
| Millis        | MA72-05 | Charles River        | Pathogens                  |
| Millis        | MA72-16 | Bogastow Brook       | Pathogens                  |
| Milton        | MA73-02 | Neponset River       | Fecal Coliform             |
| Milton        | MA73-03 | Neponset River       | Fecal Coliform             |
| Milton        | MA73-04 | Neponset River       | Fecal Coliform             |
| Milton        | MA73-26 | Unquity Brook        | Fecal Coliform             |

|               |         |                          |                            |
|---------------|---------|--------------------------|----------------------------|
| Milton        | MA73-29 | Pine Tree Brook          | Fecal Coliform             |
| Milton        | MA73-30 | Gulliver Creek           | Fecal Coliform             |
| Nahant        | MA93-24 | Nahant Bay               | Fecal Coliform             |
| Nahant        | MA93-52 | Lynn Harbor              | Fecal Coliform             |
| Nahant        | MA93-53 | Lynn Harbor              | Fecal Coliform             |
| Natick        | MA72-05 | Charles River            | Pathogens                  |
| Natick        | MA72-06 | Charles River            | Pathogens                  |
| Needham       | MA72-06 | Charles River            | Pathogens                  |
| Needham       | MA72-07 | Charles River            | Pathogens                  |
| Needham       | MA72-18 | Fuller Brook             | Pathogens                  |
| Needham       | MA72-21 | Rock Meadow Brook        | Pathogens                  |
| Needham       | MA72-25 | Rosemary Brook           | Pathogens                  |
| New Bedford   | MA95-13 | Buttonwood Brook         | Escherichia Coli (E. Coli) |
| New Bedford   | MA95-33 | Acushnet River           | Fecal Coliform             |
| New Bedford   | MA95-38 | Clarks Cove              | Fecal Coliform             |
| New Bedford   | MA95-42 | New Bedford Inner Harbor | Fecal Coliform             |
| New Bedford   | MA95-63 | Outer New Bedford Harbor | Fecal Coliform             |
| Newton        | MA72-07 | Charles River            | Pathogens                  |
| Newton        | MA72-23 | Sawmill Brook            | Pathogens                  |
| Newton        | MA72-24 | South Meadow Brook       | Pathogens                  |
| Newton        | MA72-29 | Cheese Cake Brook        | Pathogens                  |
| Newton        | MA72-36 | Charles River            | Pathogens                  |
| Norfolk       | MA72-05 | Charles River            | Pathogens                  |
| Norfolk       | MA72-10 | Stop River               | Pathogens                  |
| North Andover | MA83-19 | Shawsheen River          | Fecal Coliform             |
| Norton        | MA62-49 | Wading River             | Escherichia Coli (E. Coli) |
| Norton        | MA62-56 | Three Mile River         | Escherichia Coli (E. Coli) |
| Norwell       | MA94-05 | North River              | Fecal Coliform             |
| Norwell       | MA94-27 | Third Herring Brook      | Escherichia Coli (E. Coli) |
| Norwell       | MA94-31 | Second Herring Brook     | Fecal Coliform             |
| Norwood       | MA73-01 | Neponset River           | Fecal Coliform             |
| Norwood       | MA73-01 | Neponset River           | Escherichia Coli (E. Coli) |
| Norwood       | MA73-02 | Neponset River           | Fecal Coliform             |
| Norwood       | MA73-15 | Germany Brook            | Fecal Coliform             |
| Norwood       | MA73-16 | Hawes Brook              | Fecal Coliform             |
| Norwood       | MA73-17 | Traphole Brook           | Fecal Coliform             |
| Norwood       | MA73-24 | Purgatory Brook          | Fecal Coliform             |
| Norwood       | MA73-33 | Unnamed Tributary        | Escherichia Coli (E. Coli) |
| Orleans       | MA96-16 | Rock Harbor Creek        | Fecal Coliform             |
| Orleans       | MA96-26 | Little Namskaket Creek   | Fecal Coliform             |
| Orleans       | MA96-27 | Namskaket Creek          | Fecal Coliform             |

|          |         |                            |                            |
|----------|---------|----------------------------|----------------------------|
| Orleans  | MA96-68 | Town Cove                  | Fecal Coliform             |
| Orleans  | MA96-72 | Paw Wah Pond               | Fecal Coliform             |
| Orleans  | MA96-73 | Pochet Neck                | Fecal Coliform             |
| Orleans  | MA96-76 | The River                  | Fecal Coliform             |
| Orleans  | MA96-78 | Little Pleasant Bay        | Fecal Coliform             |
| Peabody  | MA93-01 | Waters River               | Fecal Coliform             |
| Peabody  | MA93-05 | Goldthwait Brook           | Escherichia Coli (E. Coli) |
| Peabody  | MA93-39 | Proctor Brook              | Escherichia Coli (E. Coli) |
| Pembroke | MA94-05 | North River                | Fecal Coliform             |
| Plymouth | MA94-15 | Duxbury Bay                | Fecal Coliform             |
| Plymouth | MA94-16 | Plymouth Harbor            | Fecal Coliform             |
| Plymouth | MA94-34 | Ellisville Harbor          | Fecal Coliform             |
| Raynham  | MA62-02 | Taunton River              | Fecal Coliform             |
| Rehoboth | MA53-03 | Palmer River               | Pathogens                  |
| Rehoboth | MA53-04 | Palmer River               | Pathogens                  |
| Rehoboth | MA53-05 | Palmer River               | Pathogens                  |
| Rehoboth | MA53-07 | Palmer River - West Branch | Pathogens                  |
| Rehoboth | MA53-08 | Palmer River - East Branch | Pathogens                  |
| Rehoboth | MA53-09 | Rumney Marsh Brook         | Pathogens                  |
| Rehoboth | MA53-10 | Beaver Dam Brook           | Pathogens                  |
| Rehoboth | MA53-11 | Bad Luck Brook             | Pathogens                  |
| Rehoboth | MA53-12 | Fullers Brook              | Pathogens                  |
| Rehoboth | MA53-13 | Clear Run Brook            | Pathogens                  |
| Rehoboth | MA53-14 | Torrey Creek               | Pathogens                  |
| Rehoboth | MA53-15 | Old Swamp Brook            | Pathogens                  |
| Rehoboth | MA53-16 | Rocky Run                  | Pathogens                  |
| Revere   | MA93-15 | Pines River                | Fecal Coliform             |
| Revere   | MA93-44 | Saugus River               | Fecal Coliform             |
| Revere   | MA93-51 | Unnamed Tributary          | Enterococcus Bacteria      |
| Revere   | MA93-52 | Lynn Harbor                | Fecal Coliform             |
| Revere   | MA93-53 | Lynn Harbor                | Fecal Coliform             |
| Rockland | MA94-03 | French Stream              | Escherichia Coli (E. Coli) |
| Rockport | MA93-17 | Rockport Harbor            | Fecal Coliform             |
| Salem    | MA93-09 | Danvers River              | Fecal Coliform             |
| Salem    | MA93-20 | Beverly Harbor             | Fecal Coliform             |
| Salem    | MA93-21 | Salem Harbor               | Fecal Coliform             |
| Salem    | MA93-25 | Salem Sound                | Fecal Coliform             |
| Salem    | MA93-39 | Proctor Brook              | Escherichia Coli (E. Coli) |
| Salem    | MA93-40 | Proctor Brook              | Enterococcus Bacteria      |
| Salem    | MA93-42 | North River                | Fecal Coliform             |
| Sandwich | MA95-14 | Cape Cod Canal             | Fecal Coliform             |

|            |         |                     |                            |
|------------|---------|---------------------|----------------------------|
| Sandwich   | MA96-30 | Scorton Creek       | Fecal Coliform             |
| Sandwich   | MA96-84 | Old Harbor Creek    | Fecal Coliform             |
| Sandwich   | MA96-85 | Mill Creek          | Fecal Coliform             |
| Sandwich   | MA96-86 | Dock Creek          | Fecal Coliform             |
| Sandwich   | MA96-87 | Springhill Creek    | Fecal Coliform             |
| Saugus     | MA93-15 | Pines River         | Fecal Coliform             |
| Saugus     | MA93-33 | Hawkes Brook        | Escherichia Coli (E. Coli) |
| Saugus     | MA93-35 | Saugus River        | Escherichia Coli (E. Coli) |
| Saugus     | MA93-43 | Saugus River        | Fecal Coliform             |
| Saugus     | MA93-44 | Saugus River        | Fecal Coliform             |
| Saugus     | MA93-48 | Bennetts Pond Brook | Escherichia Coli (E. Coli) |
| Saugus     | MA93-49 | Shute Brook         | Fecal Coliform             |
| Saugus     | MA93-50 | Shute Brook         | Escherichia Coli (E. Coli) |
| Scituate   | MA94-01 | Cohasset Harbor     | Fecal Coliform             |
| Scituate   | MA94-02 | Scituate Harbor     | Fecal Coliform             |
| Scituate   | MA94-05 | North River         | Fecal Coliform             |
| Scituate   | MA94-06 | North River         | Fecal Coliform             |
| Scituate   | MA94-07 | Herring River       | Fecal Coliform             |
| Scituate   | MA94-09 | South River         | Fecal Coliform             |
| Scituate   | MA94-19 | The Gulf            | Fecal Coliform             |
| Scituate   | MA94-32 | Cohasset Cove       | Fecal Coliform             |
| Scituate   | MA94-33 | Musquashcut Pond    | Fecal Coliform             |
| Seekonk    | MA53-01 | Runnins River       | Fecal Coliform             |
| Seekonk    | MA53-12 | Fullers Brook       | Pathogens                  |
| Seekonk    | MA53-13 | Clear Run Brook     | Pathogens                  |
| Seekonk    | MA53-14 | Torrey Creek        | Pathogens                  |
| Sharon     | MA62-39 | Rumford River       | Escherichia Coli (E. Coli) |
| Sharon     | MA73-17 | Traphole Brook      | Fecal Coliform             |
| Sharon     | MA73-31 | Unnamed Tributary   | Fecal Coliform             |
| Sherborn   | MA72-05 | Charles River       | Pathogens                  |
| Somerset   | MA61-01 | Lee River           | Fecal Coliform             |
| Somerset   | MA61-02 | Lee River           | Fecal Coliform             |
| Somerset   | MA61-06 | Mount Hope Bay      | Fecal Coliform             |
| Somerset   | MA62-03 | Taunton River       | Fecal Coliform             |
| Somerset   | MA62-04 | Taunton River       | Fecal Coliform             |
| Somerset   | MA62-50 | Broad Cove          | Fecal Coliform             |
| Stoughton  | MA73-20 | Beaver Meadow Brook | Fecal Coliform             |
| Stoughton  | MA73-32 | Unnamed Tributary   | Escherichia Coli (E. Coli) |
| Swampscott | MA93-24 | Nahant Bay          | Fecal Coliform             |
| Swansea    | MA53-03 | Palmer River        | Pathogens                  |
| Swansea    | MA53-06 | Warren River Pond   | Fecal Coliform             |

|           |         |                     |                            |
|-----------|---------|---------------------|----------------------------|
| Swansea   | MA53-16 | Rocky Run           | Pathogens                  |
| Swansea   | MA61-01 | Lee River           | Fecal Coliform             |
| Swansea   | MA61-02 | Lee River           | Fecal Coliform             |
| Swansea   | MA61-04 | Cole River          | Fecal Coliform             |
| Swansea   | MA61-07 | Mount Hope Bay      | Fecal Coliform             |
| Swansea   | MA61-08 | Kickemuit River     | Pathogens                  |
| Taunton   | MA62-02 | Taunton River       | Fecal Coliform             |
| Taunton   | MA62-56 | Three Mile River    | Escherichia Coli (E. Coli) |
| Taunton   | MA62-57 | Three Mile River    | Fecal Coliform             |
| Tewksbury | MA83-07 | Strong Water Brook  | Fecal Coliform             |
| Tewksbury | MA83-15 | Unnamed Tributary   | Fecal Coliform             |
| Tewksbury | MA83-18 | Shawsheen River     | Fecal Coliform             |
| Wakefield | MA93-31 | Mill River          | Escherichia Coli (E. Coli) |
| Wakefield | MA93-34 | Saugus River        | Escherichia Coli (E. Coli) |
| Wakefield | MA93-35 | Saugus River        | Escherichia Coli (E. Coli) |
| Walpole   | MA72-10 | Stop River          | Pathogens                  |
| Walpole   | MA73-01 | Neponset River      | Fecal Coliform             |
| Walpole   | MA73-01 | Neponset River      | Escherichia Coli (E. Coli) |
| Walpole   | MA73-06 | School Meadow Brook | Fecal Coliform             |
| Walpole   | MA73-09 | Mine Brook          | Fecal Coliform             |
| Walpole   | MA73-17 | Traphole Brook      | Fecal Coliform             |
| Waltham   | MA72-07 | Charles River       | Pathogens                  |
| Waltham   | MA72-28 | Beaver Brook        | Pathogens                  |
| Wareham   | MA95-01 | Buttermilk Bay      | Fecal Coliform             |
| Wareham   | MA95-02 | Onset Bay           | Fecal Coliform             |
| Wareham   | MA95-03 | Wareham River       | Fecal Coliform             |
| Wareham   | MA95-05 | Weweantic River     | Fecal Coliform             |
| Wareham   | MA95-07 | Sippican River      | Fecal Coliform             |
| Wareham   | MA95-29 | Agawam River        | Fecal Coliform             |
| Wareham   | MA95-49 | Broad Marsh River   | Fecal Coliform             |
| Wareham   | MA95-50 | Wankinco River      | Fecal Coliform             |
| Wareham   | MA95-51 | Crooked River       | Fecal Coliform             |
| Wareham   | MA95-52 | Cedar Island Creek  | Fecal Coliform             |
| Wareham   | MA95-53 | Beaverdam Creek     | Fecal Coliform             |
| Watertown | MA72-07 | Charles River       | Pathogens                  |
| Watertown | MA72-30 | Unnamed Tributary   | Pathogens                  |
| Watertown | MA72-32 | Unnamed Tributary   | Pathogens                  |
| Watertown | MA72-36 | Charles River       | Pathogens                  |
| Wellesley | MA72-06 | Charles River       | Pathogens                  |
| Wellesley | MA72-07 | Charles River       | Pathogens                  |
| Wellesley | MA72-18 | Fuller Brook        | Pathogens                  |

|                  |         |                            |                            |
|------------------|---------|----------------------------|----------------------------|
| Wellesley        | MA72-25 | Rosemary Brook             | Pathogens                  |
| Wellfleet        | MA96-32 | Duck Creek                 | Fecal Coliform             |
| Wellfleet        | MA96-33 | Herring River              | Fecal Coliform             |
| Wellfleet        | MA96-34 | Wellfleet Harbor           | Fecal Coliform             |
| West Bridgewater | MA62-06 | Salisbury Plain River      | Escherichia Coli (E. Coli) |
| Weston           | MA72-07 | Charles River              | Pathogens                  |
| Westport         | MA95-37 | West Branch Westport River | Fecal Coliform             |
| Westport         | MA95-40 | East Branch Westport River | Escherichia Coli (E. Coli) |
| Westport         | MA95-41 | East Branch Westport River | Fecal Coliform             |
| Westport         | MA95-44 | Snell Creek                | Escherichia Coli (E. Coli) |
| Westport         | MA95-45 | Snell Creek                | Escherichia Coli (E. Coli) |
| Westport         | MA95-54 | Westport River             | Fecal Coliform             |
| Westport         | MA95-58 | Bread And Cheese Brook     | Escherichia Coli (E. Coli) |
| Westport         | MA95-59 | Snell Creek                | Fecal Coliform             |
| Westwood         | MA72-21 | Rock Meadow Brook          | Pathogens                  |
| Westwood         | MA73-02 | Neponset River             | Fecal Coliform             |
| Westwood         | MA73-15 | Germany Brook              | Fecal Coliform             |
| Westwood         | MA73-24 | Purgatory Brook            | Fecal Coliform             |
| Westwood         | MA73-25 | Pecunit Brook              | Escherichia Coli (E. Coli) |
| Westwood         | MA73-27 | Ponkapog Brook             | Fecal Coliform             |
| Whitman          | MA62-09 | Beaver Brook               | Escherichia Coli (E. Coli) |
| Whitman          | MA62-33 | Shumatuscant River         | Escherichia Coli (E. Coli) |
| Whitman          | MA62-38 | Meadow Brook               | Escherichia Coli (E. Coli) |
| Wilmington       | MA83-18 | Shawsheen River            | Fecal Coliform             |
| Winthrop         | MA93-53 | Lynn Harbor                | Fecal Coliform             |
| Yarmouth         | MA96-12 | Bass River                 | Fecal Coliform             |
| Yarmouth         | MA96-35 | Chase Garden Creek         | Fecal Coliform             |
| Yarmouth         | MA96-36 | Lewis Bay                  | Fecal Coliform             |
| Yarmouth         | MA96-37 | Mill Creek                 | Fecal Coliform             |
| Yarmouth         | MA96-38 | Parkers River              | Fecal Coliform             |
| Yarmouth         | MA96-80 | Mill Creek                 | Fecal Coliform             |
| Yarmouth         | MA96-82 | Hyannis Inner Harbor       | Fecal Coliform             |

**Table F-8: Bacteria or pathogens impaired waterbody names and segment IDs along with primary municipality and indicator organism identified by the applicable TMDL. The term primary municipality indicates the municipality in which the majority of the segment is located, but does not necessarily indicate each municipality that has regulated discharges to the waterbody segment.**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part A.III.1. as follows:
  - a. The permittee is relieved of additional requirements as of the date when the following conditions are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable to the receiving water

- that indicates that no additional stormwater controls for bacteria/pathogens are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
- b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any additional remaining requirements of Appendix F part A.III.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part A.III.1 to date to reduce bacteria/pathogens in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part A.III.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

#### IV. Cape Cod Nitrogen TMDL Requirements

There are 19 approved TMDLs for nitrogen for various watersheds, ponds and bays on Cape Cod.<sup>15</sup> The following measures are needed to ensure that current nitrogen loads from MS4 stormwater discharged into the impaired waterbodies do not increase.

1. The operators of traditional and non-traditional MS4s located in municipalities listed in Table F-9 or any other MS4 (traditional and non-traditional) that discharges to any waterbody listed in Table F-9 or their tributaries shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.2, Public education and outreach: The permittee shall supplement its Residential and Business/Commercial/Institution program with annual timed messages on specific topics. The permittee shall distribute an annual message in the spring (April/May) timeframe that encourages the proper use and disposal of grass clippings and encourages the proper use of slow-release fertilizers. The permittee shall distribute an annual message in the summer (June/July) timeframe encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee shall distribute an annual message in the Fall (August/September/October) timeframe encouraging the proper disposal of leaf litter. The permittee shall deliver an annual message on each of these topics, unless the permittee determines that one or more of these issues is not a significant contributor of nitrogen to discharges from the MS4 and the permittee retains documentation of this finding in the SWMP. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.III, A.V, B.I, B.II and B.III where appropriate.
      2. part 2.3.6, Stormwater Management in New Development and Redevelopment: the requirement for adoption/amendment of the permittee's ordinance or other regulatory mechanism shall include a requirement that new development and redevelopment stormwater management BMPs be optimized for nitrogen removal; retrofit inventory and priority ranking under 2.3.6.1.b shall include consideration of BMPs to reduce nitrogen discharges.

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<sup>15</sup> Final nitrogen TMDLs for Cape Cod can be found here:

<http://www.mass.gov/eea/agencies/massdep/water/watersheds/total-maximum-daily-loads-tmdls.html>

3. part 2.3.7, Good House Keeping and Pollution Prevention for Permittee Owned Operations: establish requirements for use of slow release fertilizers on permittee owned property currently using fertilizer, in addition to reducing and managing fertilizer use as provided in in part 2.3.7.1; establish procedures to properly manage grass cuttings and leaf litter on permittee property, including prohibiting blowing organic waste materials onto adjacent impervious surfaces; increased street sweeping frequency of all municipal owned streets and parking lots subject to Permit part 2.3.7.a.iii.(c) to a minimum of two (2) times per year, once in the spring (following winter activities such as sanding) and at least once in the fall (Sept 1 – Dec 1; following leaf fall).

| <b>Municipality</b> | <b>Waterbody Name</b>      |
|---------------------|----------------------------|
| Barnstable          | Centerville River          |
| Barnstable          | Popponesset Bay            |
| Barnstable          | Shoestring Bay             |
| Barnstable          | Cotuit Bay                 |
| Barnstable          | North Bay                  |
| Barnstable          | Prince Cove                |
| Barnstable          | West Bay                   |
| Barnstable          | Hyannis Inner Harbor       |
| Barnstable          | Lewis Bay                  |
| Bourne              | Phinneys Harbor            |
| Chatham             | Crows Pond                 |
| Chatham             | Bucks Creek                |
| Chatham             | Harding Beach Pond         |
| Chatham             | Mill Creek                 |
| Chatham             | Mill Pond                  |
| Chatham             | Oyster Pond                |
| Chatham             | Oyster Pond River          |
| Chatham             | Stage Harbor               |
| Chatham             | Taylors Pond               |
| Chatham             | Frost Fish Creek           |
| Chatham             | Ryder Cove                 |
| Falmouth            | Bournes Pond               |
| Falmouth            | Great Pond                 |
| Falmouth            | Green Pond                 |
| Falmouth            | Perch Pond                 |
| Falmouth            | Little Pond                |
| Falmouth            | Oyster Pond                |
| Falmouth            | Quashnet River             |
| Falmouth            | Inner West Falmouth Harbor |

| <b>Municipality</b> | <b>Waterbody Name</b> |
|---------------------|-----------------------|
| Falmouth            | West Falmouth Harbor  |
| Falmouth            | Snug Harbor           |
| Falmouth            | Harbor Head           |
| Harwich             | Muddy Creek - Lower   |
| Harwich             | Muddy Creek - Upper   |
| Harwich             | Round Cove            |
| Mashpee             | Mashpee River         |
| Mashpee             | Great River           |
| Mashpee             | Hamblin Pond          |
| Mashpee             | Jehu Pond             |
| Mashpee             | Little River          |
| Orleans             | Areys Pond            |
| Orleans             | Little Pleasant Bay   |
| Orleans             | Namequoit River       |
| Orleans             | Paw Wah Pond          |
| Orleans             | Pleasant Bay          |
| Orleans             | Pochet Neck           |
| Orleans             | Quanset Pond          |
| Yarmouth            | Mill Creek            |
| Yarmouth            | Hyannis Inner Harbor  |
| Yarmouth            | Lewis Bay             |

**Table F-9: Waterbodies subject to a Cape Cod nitrogen TMDL and the primary municipalities**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part A.IV.1. applicable to it when in compliance with this part.
  - a. The permittee is relieved of its additional requirements as of the date when one of the following criteria are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of nitrogen are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part A.IV.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part A.IV.1 to date to reduce nitrogen in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part A.IV.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing

implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

## V. Assabet River Phosphorus TMDL Requirements

On September 23, 2004 EPA approved the *Assabet River Total Maximum Daily Load for Total Phosphorus*<sup>16</sup>. The following measures are needed to ensure that current phosphorus loads from MS4 stormwater discharged directly or indirectly via tributaries into the Assabet River do not increase.

1. The operators of traditional and non-traditional MS4s located in municipalities listed in Table F-10 within the Assabet River Watershed shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.2, Public education and outreach: The permittee shall supplement its Residential and Business/Commercial/Institution program with annual timed messages on specific topics. The permittee shall distribute an annual message in the spring (March/April) timeframe that encourages the proper use and disposal of grass clippings and encourages the proper use of slow-release and phosphorous-free fertilizers. The permittee shall distribute an annual message in the summer (June/July) timeframe encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee shall distribute an annual message in the fall (August/September/October) timeframe encouraging the proper disposal of leaf litter. The permittee shall deliver an annual message on each of these topics, unless the permittee determines that one or more of these issues is not a significant contributor of phosphorous to discharges from the MS4 and the permittee retains documentation of this finding in the SWMP. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.III, A.IV, B.I, B.II and B.III where appropriate.
      2. part 2.3.6, Stormwater Management in New Development and Redevelopment: the requirement for adoption/amendment of the permittee's ordinance or other regulatory mechanism shall include a requirement that new development and redevelopment stormwater management BMPs be optimized for phosphorus removal; retrofit inventory and priority ranking under 2.3.6.1.b shall include consideration of BMPs that infiltrate stormwater where feasible.
      3. part 2.3.7, Good House Keeping and Pollution Prevention for Permittee Owned Operations: Establish program to properly

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<sup>16</sup> Massachusetts Department of Environmental Protection, 2004. *Assabet River Total Maximum Daily Load for Total Phosphorus*. CN 201.0

manage grass cuttings and leaf litter on permittee property, including prohibiting blowing organic waste materials onto adjacent impervious surfaces; increased street sweeping frequency of all municipal owned streets and parking lots subject to Permit part 2.3.7.a.iii.(c) to a minimum of two times per year, once in the spring (following winter activities such as sanding) and at least once in the fall (Sept 1 – Dec 1; following leaf fall).

| <b>Municipality</b> |
|---------------------|
| Acton               |
| Berlin              |
| Bolton              |
| Boxborough          |
| Boylston            |
| Carlisle            |
| Clinton             |
| Concord             |
| Grafton             |
| Harvard             |
| Hudson              |
| Littleton           |
| Marlborough         |
| Maynard             |
| Northborough        |
| Shrewsbury          |
| Stow                |
| Westborough         |
| Westford            |

**Table F-10: Municipalities located in the Assabet River Watershed**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part A.V.1. as follows.
  - a. The permittee is relieved of its additional requirements as of the date when following conditions are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of phosphorus are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part A.V.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part A.V.1 to

- date to reduce phosphorus in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
- ii. The permittee shall continue to implement all requirements of Appendix F part A.V.1 required to be implemented prior to the date of the newly approved TMDL including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

**B. Requirements for Discharges to Impaired Waters with an Approved Out of State TMDL****I. Nitrogen TMDL Requirements**

Discharges from MS4s in Massachusetts to waters that are tributaries to the Long Island Sound, which has an approved TMDL for nitrogen<sup>17</sup>, are subject to the requirements of this part.

1. The operators of traditional and non-traditional MS4s located in municipalities listed in Table F-11 shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.2, Public education and outreach: The permittee shall supplement its Residential and Business/Commercial/Institution program with annual timed messages on specific topics. The permittee shall distribute an annual message in the spring (April/May) timeframe that encourages the proper use and disposal of grass clippings and encourages the proper use of slow-release fertilizers. The permittee shall distribute an annual message in the summer (June/July) timeframe encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee shall distribute an annual message in the Fall (August/September/October) timeframe encouraging the proper disposal of leaf litter. The permittee shall deliver an annual message on each of these topics, unless the permittee determines that one or more of these issues is not a significant contributor of nitrogen to discharges from the MS4 and the permittee retains documentation of this finding in the SWMP. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.III, A.IV, A.V, B.II and B.III where appropriate.
      2. part 2.3.6, Stormwater Management in New Development and Redevelopment: the requirement for adoption/amendment of the permittee's ordinance or other regulatory mechanism shall include a requirement that new development and redevelopment stormwater management BMPs be optimized for nitrogen removal; retrofit inventory and priority ranking under 2.3.6.1.b shall include consideration of BMPs to reduce nitrogen discharges.
      3. part 2.3.7, Good House Keeping and Pollution Prevention for Permittee Owned Operations: establish requirements for use of

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<sup>17</sup> Connecticut Department of Environmental Protection. 2000. *A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound*

slow release fertilizers on permittee owned property currently using fertilizer, in addition to reducing and managing fertilizer use as provided in in part 2.3.7.1; establish procedures to properly manage grass cuttings and leaf litter on permittee property, including prohibiting blowing organic waste materials onto adjacent impervious surfaces; increased street sweeping frequency of all municipal owned streets and parking lots subject to Permit part 2.3.7.a.iii.(c) to a minimum of two (2) times per year, once in the spring (following winter activities such as sanding) and at least once in the fall (Sept 1 – Dec 1; following leaf fall).

b. Nitrogen Source Identification Report

- i. Within four years of the permit effective date the permittee shall complete a Nitrogen Source Identification Report. The report shall include the following elements:
  1. Calculation of total urbanized area within the permittee's jurisdiction that is within the Connecticut River Watershed, the Housatonic River Watershed, or the Thames River Watershed, incorporating updated mapping of the MS4 and catchment delineations produced pursuant to part 2.3.4.6,
  2. All screening and monitoring results pursuant to part 2.3.4.7.d., targeting the receiving water segment(s)
  3. Impervious area and DCIA for the target catchment
  4. Identification, delineation and prioritization of potential catchments with high nitrogen loading
  5. Identification of potential retrofit opportunities or opportunities for the installation of structural BMPs during re-development
- ii. The final Nitrogen Source Identification Report shall be submitted to EPA as part of the year 4 annual report.

c. Structural BMPs

- i. Within five years of the permit effective date, the permittee shall evaluate all properties identified as presenting retrofit opportunities or areas for structural BMP installation under permit part 2.3.6.d.ii. or identified in the Nitrogen Source Identification Report. The evaluation shall include:
  1. The next planned infrastructure, resurfacing or redevelopment activity planned for the property (if applicable) OR planned retrofit date;
  2. The estimated cost of redevelopment or retrofit BMPs; and
  3. The engineering and regulatory feasibility of redevelopment or retrofit BMPs.
- ii. The permittee shall provide a listing of planned structural BMPs and a plan and schedule for implementation in the year 5 annual

report. The permittee shall plan and install a minimum of one structural BMP as a demonstration project within six years of the permit effective date. The demonstration project shall be installed targeting a catchment with high nitrogen load potential. The permittee shall install the remainder of the structural BMPs in accordance with the plan and schedule provided in the year 5 annual report.

- iii. Any structural BMPs listed in Table 4-3 of Attachment 1 to Appendix H installed in the urbanized area by the permittee or its agents shall be tracked and the permittee shall estimate the nitrogen removal by the BMP consistent with Attachment 1 to Appendix H. The permittee shall document the BMP type, total area treated by the BMP, the design storage volume of the BMP and the estimated nitrogen removed in mass per year by the BMP in each annual report.

|                 |                  |
|-----------------|------------------|
| Adams           | North Adams      |
| Agawam          | Northampton      |
| Amherst         | Oxford           |
| Ashburnham      | Palmer           |
| Ashby           | Paxton           |
| Auburn          | Pelham           |
| Belchertown     | Pittsfield       |
| Charlton        | Richmond         |
| Cheshire        | Russell          |
| Chicopee        | Rutland          |
| Dalton          | South Hadley     |
| Douglas         | Southampton      |
| Dudley          | Southbridge      |
| East Longmeadow | Southwick        |
| Easthampton     | Spencer          |
| Gardner         | Springfield      |
| Granby          | Sturbridge       |
| Hadley          | Sutton           |
| Hampden         | Templeton        |
| Hatfield        | Ware             |
| Hinsdale        | Webster          |
| Holyoke         | West Springfield |
| Lanesborough    | Westfield        |
| Leicester       | Westhampton      |
| Lenox           | Westminster      |
| Longmeadow      | Wilbraham        |
| Ludlow          | Williamsburg     |
| Millbury        | Winchendon       |

|        |  |
|--------|--|
| Monson |  |
|--------|--|

**Table F-11: Massachusetts municipalities in which MS4 discharges are within the Connecticut River Watershed, the Housatonic River Watershed, or the Thames River Watershed.**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part B.I.1. as follows:
  - a. The permittee is relieved of its additional requirements as of the date when the following conditions are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of nitrogen are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part B.I.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part B.I.1 to date to reduce nitrogen in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part B.I.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

## II. Phosphorus TMDL Requirements

There are currently eight approved phosphorus TMDLs for certain waterbody segments in Rhode Island that identify urban stormwater discharges in Massachusetts as sources that are contributing phosphorus to the impaired segments. The TMDLs include the Kickemuit Reservoir, Upper Kickemuit River, Kickemuit River, Ten Mile River, Central Pond, Turner Reservoir, Lower Ten Mile River, and Omega Pond TMDLs<sup>18</sup>. Table F-12 lists municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing phosphorus to the impaired waterbody segments in Rhode Island, the impaired receiving water, and the approved TMDL name. Any permittee (traditional or non-traditional) that operates an MS4 in a municipality listed in Table F-12 and that discharges to a waterbody or tributary of a waterbody listed on Table F-12 is subject to the requirements of this part.

1. The operators of traditional and non-traditional MS4s located in municipalities listed in Table F-12 and that discharge to a waterbody or a tributary of a waterbody identified on Table F-12 shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.2, Public education and outreach: The permittee shall supplement its Residential and Business/Commercial/Institution program with annual timed messages on specific topics. The permittee shall distribute an annual message in the spring (March/April) timeframe that encourages the proper use and disposal of grass clippings and encourages the proper use of slow-release and phosphorous-free fertilizers. The permittee shall distribute an annual message in the summer (June/July) timeframe encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee shall distribute an annual message in the fall (August/September/October) timeframe encouraging the proper disposal of leaf litter. The permittee shall deliver an annual message on each of these topics, unless the permittee determines that one or more of these issues is not a significant contributor of phosphorous to discharges from the MS4 and the permittee retains documentation of this finding in the SWMP. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.III, A.IV, A.V, B.I, and B.III where appropriate.
      2. part 2.3.6, Stormwater Management in New Development and Redevelopment: the requirement for

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<sup>18</sup> See <http://www.dem.ri.gov/programs/benviron/water/quality/rest/reports.htm> for all RI TMDL documents. (retrieved 6/30/2014)

adoption/amendment of the permittee's ordinance or other regulatory mechanism shall include a requirement that new development and redevelopment stormwater management BMPs be optimized for phosphorus removal; retrofit inventory and priority ranking under 2.3.6.1.b shall include consideration of BMPs that infiltrate stormwater where feasible.

3. part 2.3.7, Good House Keeping and Pollution Prevention for Permittee Owned Operations: Establish program to properly manage grass cuttings and leaf litter on permittee property, including prohibiting blowing organic waste materials onto adjacent impervious surfaces; increased street sweeping frequency of all municipal owned streets and parking lots subject to Permit part 2.3.7.a.iii.(c) to a minimum of two times per year, once in the spring (following winter activities such as sanding) and at least once in the fall (Sept 1 – Dec 1; following leaf fall).

b. Phosphorus Source Identification Report

- i. Within four years of the permit effective date the permittee shall complete a Phosphorus Source Identification Report. The report shall include the following elements:
  1. Calculation of total urbanized area draining to the water quality limited receiving water segments or their tributaries, incorporating updated mapping of the MS4 and catchment delineations produced pursuant to part 2.3.4.6,
  2. All screening and monitoring results pursuant to part 2.3.4.7.d., targeting the receiving water segment(s)
  3. Impervious area and DCIA for the target catchment
  4. Identification, delineation and prioritization of potential catchments with high phosphorus loading
  5. Identification of potential retrofit opportunities or opportunities for the installation of structural BMPs during re development, including the removal of impervious area of permittee owned properties
- ii. The phosphorus source identification report shall be submitted to EPA as part of the year 4 annual report.

c. Structural BMPs

- i. Within five years of the permit effective date, the permittee shall evaluate all permittee owned properties identified as presenting retrofit opportunities or areas for structural BMP installation under permit part 2.3.6.d.ii or identified in the Phosphorus Source Identification Report that are within the drainage area of the water quality limited water or its tributaries. The evaluation shall include:

1. The next planned infrastructure, resurfacing or redevelopment activity planned for the property (if applicable) OR planned retrofit date;
  2. The estimated cost of redevelopment or retrofit BMPs; and
  3. The engineering and regulatory feasibility of redevelopment or retrofit BMPs.
- ii. The permittee shall provide a listing of planned structural BMPs and a plan and schedule for implementation in the year 5 annual report. The permittee shall plan and install a minimum of one structural BMP as a demonstration project within the drainage area of the water quality limited water or its tributaries within six years of the permit effective date. The demonstration project shall be installed targeting a catchment with high phosphorus load potential. The permittee shall install the remainder of the structural BMPs in accordance with the plan and schedule provided in the year 5 annual report.
- iii. Any structural BMPs installed in the urbanized area by the permittee or its agents shall be tracked and the permittee shall estimate the phosphorus removal by the BMP consistent with Attachment 3 to Appendix F. The permittee shall document the BMP type, total area treated by the BMP, the design storage volume of the BMP and the estimated phosphorus removed in mass per year by the BMP in each annual report.

| <b>Municipality</b> | <b>Receiving Water</b>                                                                    | <b>TMDL Name</b>                                                   |
|---------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Attleboro           | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Omega Pond and Turner Reservoir | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| North Attleborough  | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Omega Pond and Turner Reservoir | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| Plainville          | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Omega Pond and Turner Reservoir | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| Rehoboth            | Upper Kikemuit River, Kickemuit River, Kickemuit Reservoir                                | Fecal Coliform and Total Phosphorus TMDLs:                         |

| <b>Municipality</b> | <b>Receiving Water</b>                                                                    | <b>TMDL Name</b>                                                                                                                                                             |
|---------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                     |                                                                                           | Kickemuit Reservoir, Rhode Island (RI0007034L-01)<br>Upper Kickemuit River (RI 0007034R-01)<br>Kickemuit River (MA 61-08 2004)                                               |
| Seekonk             | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Omega Pond and Turner Reservoir | Total Maximum Daily Load Analysis For The Ten Mile River Watershed                                                                                                           |
| Swansea             | Upper Kikemuit River, Kickemuit River, Kickemuit Reservoir                                | Fecal Coliform and Total Phosphorus TMDLs:<br>Kickemuit Reservoir, Rhode Island (RI0007034L-01)<br>Upper Kickemuit River (RI 0007034R-01)<br>Kickemuit River (MA 61-08 2004) |

Table F-12: Municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing phosphorus to the impaired waterbody segments in Rhode Island, the impaired receiving water, and the approved TMDL name.

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part B.II.1. as follows:
  - a. The permittee is relieved of its additional requirements as of the date when one of the following criteria are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of phosphorus are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part B.II.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part B.II.1 to date to reduce phosphorus in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part B.II.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

### III. Bacteria and Pathogen TMDL Requirements

There are currently six approved bacteria (fecal coliform bacteria) or pathogen (fecal coliform and/or enterococcus bacteria) TMDLs for certain waterbody segments in Rhode Island that identify urban stormwater discharges in Massachusetts as sources that are contributing bacteria or pathogens to the impaired segments. The TMDLs include the Kickemuit Reservoir, Upper Kickemuit River, Ten Mile River, Lower Ten Mile River and Omega Pond TMDLs<sup>19</sup>. Table F-13 lists municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing bacteria or pathogens to the impaired waterbody segments in Rhode Island, the impaired receiving water, and the approved TMDL name. Any permittee (traditional or non-traditional) that operates an MS4 in a municipality listed in Table F-13 and that discharges to a waterbody or a tributary of a waterbody listed on Table F-13 is subject to the requirements of this part.

- 1) Traditional and non-traditional MS4s operating in the municipalities identified in Table F-13 and that discharge to a waterbody or a tributary of a waterbody identified on Table F-13 shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below::
  - a. Enhanced BMPs
    - i. Enhancement of BMPs required by part 2.3 of the permit that shall be implemented during this permit term:
      1. part 2.3.3. Public Education: The permittee shall supplement its Residential program with an annual message encouraging the proper management of pet waste, including noting any existing ordinances where appropriate. The permittee or its agents shall disseminate educational materials to dog owners at the time of issuance or renewal of a dog license, or other appropriate time. Education materials shall describe the detrimental impacts of improper management of pet waste, requirements for waste collection and disposal, and penalties for non-compliance. The permittee shall also provide information to owners of septic systems about proper maintenance in any catchment that discharges to a water body impaired for bacteria or pathogens. All public education messages can be combined with requirements of Appendix H part I, II and III as well as Appendix F part A.III, A.IV, A.V, B.I, and B.II where appropriate.
      2. part 2.3.4 Illicit Discharge: Catchments draining to any waterbody impaired for bacteria or pathogens shall be designated either Problem Catchments or HIGH priority in implementation of the IDDE program.

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<sup>19</sup> See <http://www.dem.ri.gov/programs/benviron/water/quality/rest/reports.htm> for all RI TMDL documents. (retrieved 6/30/2014)

| <b>Municipality</b> | <b>Receiving Water</b>                                 | <b>TMDL Name</b>                                                                                                                                                             |
|---------------------|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Attleboro           | Upper Ten Mile River, Lower Ten Mile River, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed                                                                                                           |
| North Attleborough  | Upper Ten Mile River, Lower Ten Mile River, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed                                                                                                           |
| Plainville          | Upper Ten Mile River, Lower Ten Mile River, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed                                                                                                           |
| Rehoboth            | Upper Kikemuit River, Kickemuit Reservoir              | Fecal Coliform and Total Phosphorus TMDLs:<br>Kickemuit Reservoir, Rhode Island (RI0007034L-01)<br>Upper Kickemuit River (RI 0007034R-01)<br>Kickemuit River (MA 61-08 2004) |
| Seekonk             | Upper Ten Mile River, Lower Ten Mile River, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed                                                                                                           |

**Table F-13: Municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing bacteria or pathogens to the impaired waterbody segments in Rhode Island,, the impaired receiving water, and the approved TMDL name**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part B.III.1. applicable to it when in compliance with this part.
  - a. The permittee is relieved of its additional requirements as of the date when one of the following criteria are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of bacteria/pathogens are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL
  - b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part B.III.1 as of that date and the permittee shall comply with the following:
    - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part B.III.1 to date to reduce bacteria/pathogens in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
    - ii. The permittee shall continue to implement all requirements of Appendix F part B.III.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation

of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

#### IV. Metals TMDL Requirements

There are currently five approved metals TMDL for a waterbody segment in Rhode Island that identifies urban stormwater discharges in Massachusetts as sources that are contributing metals (Cadmium, Lead, Aluminum, Iron) to the impaired segment. The TMDLs include the Upper Ten Mile River, Lower Ten Mile River, Central Pond, Turner Reservoir and Omega Pond TMDLs.<sup>20</sup> Table F-14 lists municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing metals to the impaired waterbody segments in Rhode Island, the impaired receiving water, the approved TMDL name, and the pollutant of concern. Any permittee (traditional or non-traditional) that operates an MS4 in a municipality listed in Table F-14 and the discharge is to a waterbody or tributary of a waterbody listed on Table F-14 is subject to the requirements of this part.

- 1) Traditional and non-traditional MS4s operating in the municipalities identified in Table F-14 and that discharge to a waterbody or a tributary of a waterbody identified on Table F-14 shall identify and implement BMPs designed to reduce metals discharges from its MS4. To address metals discharges, each permittee shall comply with the following BMPs in addition to the requirements of part 2.3 of the Permit, as described below:
  - a. Enhanced BMPs
    - i. The permittee remains subject to the requirements of part 2.3. of the permit and shall include the following enhancements to the BMPs required by part 2.3 of the permit:
      1. part 2.3.6, Stormwater Management in New Development and Redevelopment: stormwater management systems designed on commercial and industrial land use area draining to the water quality limited waterbody shall incorporate designs that allow for shutdown and containment where appropriate to isolate the system in the event of an emergency spill or other unexpected event. EPA also encourages the permittee to require any stormwater management system designed to infiltrate stormwater on commercial or industrial sites to provide the level of pollutant removal equal to or greater than the level of pollutant removal provided through the use of biofiltration of the same volume of runoff to be infiltrated, prior to infiltration.
      2. part 2.3.7, Good House Keeping and Pollution Prevention for Permittee Owned Operations: increased street sweeping frequency of all municipal owned streets and parking lots to a schedule determined by the permittee to target areas with potential for high pollutant loads. This may include, but is not limited to, increased street sweeping frequency in commercial areas and high density residential areas, or

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<sup>20</sup> See <http://www.dem.ri.gov/programs/benviron/water/quality/rest/reports.htm> for all RI TMDL documents. (retrieved 6/30/2014)

drainage areas with a large amount of impervious area. Prioritize inspection and maintenance for catch basins to ensure that no sump shall be more than 50 percent full. Clean catch basins more frequently if inspection and maintenance activities indicate excessive sediment or debris loadings. Each annual report shall include the street sweeping schedule determined by the permittee to target high pollutant loads.

| <b>Municipality</b> | <b>Receiving Water</b>                                                                 | <b>TMDL Name</b>                                                   |
|---------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Attleboro           | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Turner Reservoir, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| North Attleborough  | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Turner Reservoir, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| Plainville          | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Turner Reservoir, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |
| Seekonk             | Upper Ten Mile River, Lower Ten Mile River, Central Pond, Turner Reservoir, Omega Pond | Total Maximum Daily Load Analysis For The Ten Mile River Watershed |

**Table F-14: Municipalities in Massachusetts identified in the TMDLs as containing MS4s contributing metals to the impaired waterbody segments in Rhode Island, the impaired receiving water, the approved TMDL name, and the pollutant of concern.**

2. At any time during the permit term the permittee may be relieved of additional requirements in Appendix F part B.IV.1. applicable to it when in compliance with this part.
  - a. The permittee is relieved of its additional requirements as of the date when one of the following criteria are met:
    - i. The applicable TMDL has been modified, revised or withdrawn and EPA has approved a new TMDL applicable for the receiving water that indicates that no additional stormwater controls for the control of metals (Cadmium, Lead, Aluminum, Iron) are necessary for the permittee's discharge based on wasteload allocations in the newly approved TMDL

- b. In such a case, the permittee shall document the date of the approved TMDL in its SWMP and is relieved of any remaining requirements of Appendix F part B.IV.1 as of that date and the permittee shall comply with the following:
  - i. The permittee shall identify in its SWMP all activities implemented in accordance with the requirements of Appendix F part B.IV.1 to date to reduce metals (Cadmium, Lead, Aluminum, Iron) in their discharges including implementation schedules for non-structural BMPs and any maintenance requirements for structural BMPs
  - ii. The permittee shall continue to implement all requirements of Appendix F part B.IV.1 required to be implemented prior to the date of the newly approved TMDL, including ongoing implementation of identified non-structural BMPs and routine maintenance and replacement of all structural BMPs in accordance with manufacturer or design specifications.

**C. Requirements for Discharges to Impaired Waters with a Regional TMDL****I. The “Northeast Regional Mercury TMDL (2007)”**

The Northeast Regional Mercury TMDL does not specify a wasteload allocation or other requirements either individually or categorically for the MS4 discharges and specifies that load reductions are to be achieved through reduction in atmospheric deposition sources. No requirements related to this TMDL are imposed on MS4 discharges under this part. However, if the permittee becomes aware, or EPA or MassDEP determines, that an MS4 discharge is causing or contributing to such impairment to an extent that cannot be explained by atmospheric deposition (e.g. chemical spill, acid landfill leachate or other sources), the permittee shall comply with the requirements of part 2.1.1.d and 2.3.4 of the permit.

## **ATTACHMENT 1 TO APPENDIX F**

### **Method to Calculate Baseline Phosphorus Load (Baseline), Phosphorus Reduction Requirements and Phosphorus load increases due to development ( $P_{DEVinc}$ )**

The methods and annual phosphorus load export rates presented in Attachments 1, 2 and 3 are for the purpose of measuring load reductions for various stormwater BMPs treating runoff from different site conditions (i.e. impervious or pervious) and land uses (e.g. commercial, industrial, residential). The estimates of annual phosphorus load and load reductions due to BMPs are intended for use by the permittee to measure compliance with its Phosphorus Reduction Requirement under the permit.

This attachment provides the method to calculate a baseline phosphorus load discharging in stormwater for the impaired municipalities subject to Lakes and Ponds TMDL. A complete list of municipalities subject to these TMDLs is presented in Appendix F, Table F-6. This method shall be used to calculate the following annual phosphorus loads:

- 1) Baseline Phosphorus Load for Permittees
- 2) Phosphorus Reduction Requirement

This attachment also provides the method to calculate stormwater phosphorus load increases due to development for the municipalities subject to the Charles River TMDL requirements and the Lakes & Ponds TMDL requirements:

- 3) Phosphorus Load Increases due to Development

The **Baseline Phosphorus Load** is a measure of the annual phosphorus load discharging in stormwater from the impervious and pervious areas of the impaired Lake Phosphorus Control Plan (LPCP) Area.

The **Baseline Phosphorus Pounds Reduction** referred to as the permittee's **Phosphorus Reduction Requirement** represents the required reduction in annual phosphorus load in stormwater to meet the WLA for the impaired watershed. The percent phosphorus reduction for each watershed (identified in Appendix F, Table F-6) is applied to the Baseline Phosphorus Load to calculate the Phosphorus Pounds Reduction.

The **Phosphorus load increases due to development ( $P_{DEVinc}$ )** is the stormwater phosphorus load increases due to development over the previous reporting period and incurred to date. Increases in stormwater phosphorus load from development will increase the permittee's baseline phosphorus load and therefore, the phosphorus reduction requirement.

Examples are provided to illustrate use of the methods. Table 1-1 below provides annual composite phosphorus load export rates (PLERs) by land use category for the Baseline Load and Phosphorus Reduction Requirement calculations. The permittee shall select the land use category that most closely represents the actual use of the watershed. For watersheds with institutional type uses, such as government properties, hospitals, and schools, the permittee shall use the commercial land use category for the purpose of calculating phosphorus loads. Table 1-2 provides annual PLERs by land use category for impervious and pervious areas. The permittee shall select the land use category that most closely represents the actual use of the watershed. For pervious areas, if the hydrologic soil group (HSG) is known, use the appropriate value. If the HSG is not known, assume HSG C conditions for the phosphorus load export rate. For watersheds with

institutional type uses, such as government properties, hospitals, and schools, the permittee shall use the commercial/industrial land use category for the purpose of calculating phosphorus loads. Table 1-3 provides a crosswalk table of land use codes between Tables 1-1 and 1-2 and the codes used by MassGIS.

The composite PLERs in Table 1-1 to be used for calculating Baseline Phosphorus Load are based on the specified directly connected impervious area (DCIA). If the permittee determines through mapping and site investigations that the overall DCIA for the collective area for each land use category is different than the corresponding values in Table 1-1, then the permittee is encouraged to submit this information in its annual report and request EPA to recalculate the composite PLERs for the permittees to use in refining the Baseline Phosphorus Load calculation for the LPCP.

**(1) Baseline Phosphorus Load:** The permittee shall calculate the **Baseline Phosphorus Load** by the following procedure:

- 1) Determine the total area (acre) associated with the impaired watershed;
- 2) Sort the total area associated with the watershed into land use categories;
- 3) Calculate the annual phosphorus load associated with each land use category by multiplying the total area of land use by the appropriate land use-based composite phosphorus load export rate provided in Table 1-1; and
- 4) Determine the Baseline Phosphorus Load by summing the land use loads.

**Example 1-1 to determine Baseline Phosphorus Load:**

Watershed A is 18.0 acres, with 11.0 acres of industrial area (e.g. access drives, buildings, and parking lots), 3.0 acres of medium-density residential and 4.0 acres of unmanaged wooded area.

The **Baseline Phosphorus Load** = (Baseline P Load<sub>IND</sub>) + (Baseline P Load<sub>MDR</sub>) + (Baseline P Load<sub>FOR</sub>)

**Where:**

$$\begin{aligned}\text{Baseline P Load}_{\text{IND}} &= (\text{TA}_{\text{IND}}) \times (\text{PLER for industrial use (Table 1-1)}) \\ &= 11.0 \text{ acre} \times 1.27 \text{ lbs/acre/year} \\ &= 14.0 \text{ lbs P/year}\end{aligned}$$

$$\begin{aligned}\text{Baseline P Load}_{\text{MDR}} &= (\text{TA}_{\text{MDR}}) \times (\text{PLER for medium density residential (Table 1-1)}) \\ &= 3.0 \text{ acre} \times 0.49 \text{ lbs/acre/year} \\ &= 1.5 \text{ lbs P/year}\end{aligned}$$

$$\begin{aligned}\text{Baseline P Load}_{\text{FOR}} &= (\text{TA}_{\text{FOR}}) \times (\text{PLER for forest (Table 1-1)}) \\ &= 4.0 \text{ acre} \times 0.12 \text{ lbs/acre/year} \\ &= 0.5 \text{ lbs P/year}\end{aligned}$$

$$\begin{aligned}\text{Baseline Phosphorus Load} &= 14.0 \text{ lbs P/year} + 1.5 \text{ lbs P/year} + 0.5 \text{ lbs P/year} \\ &= \mathbf{16.0 \text{ lbs P/year}}\end{aligned}$$

**(2) Baseline Phosphorus Pounds Reduction (Phosphorus Reduction Requirement):** The Baselines Phosphorus Reduction requirement is the amount of reduction in annual phosphorus load (in pounds) that the permittee is required to achieve in the Watershed. The permittee shall calculate the **Phosphorus Reduction Requirement** by multiplying the **Baseline Phosphorus Load** by the applicable percent phosphorus reduction for that watershed specified in Table F-6 (Appendix F).

**Example 1-2 to determine Watershed Phosphorus Reduction Requirement:**

Table F-6 identifies Watershed A's percent phosphorus reduction as 45%; therefore the Watershed Phosphorus Reduction Requirement is:

$$\begin{aligned}\text{Phosphorus Reduction Requirement} &= (\text{Baseline Phosphorus Load}) \times (0.45) \\ &= (16.0 \text{ lbs P/year}) \times (0.45) \\ &= \mathbf{7.2 \text{ lbs P/year}}\end{aligned}$$

**(3) Phosphorus load increases due to development ( $P_{DEVinc}$ ):** To estimate the increases in stormwater phosphorus load due to development in the Watershed (either PCP or LPCP Area), the permittee will use the following procedure:

- 1) Determine the total area of development by land use category and calculate the baseline load from that area using the composite PLERs in Table 1-1;
- 2) Distribute the total development area into impervious and pervious subareas by land use category;
- 3) Calculate the phosphorus load due to development ( $P_{DEV}$ ) for each land use-based impervious and pervious subarea by multiplying the subarea by the appropriate phosphorus load export rate provided in Table 1-2; and
- 4) Determine the phosphorus load increase ( $P_{DEVinc}$ ) by subtracting the baseline phosphorus load from the increased phosphorus load due to development.

Note: If structural BMPs are installed as part of new development, the  $P_{DEVinc}$  will be reduced by the amount of BMP load treated by that BMP as calculated in Attachment 3.

**Example 1-3 to determine Phosphorus Load Increases:** For the same 15.11 acre Watershed A as specified in Example 1-1, a permittee has tracked development in the LPCP Area in the last year that resulted in 1.5 acres of medium density residential area and 0.5 acres of forest land being converted to high density residential impervious area as detailed below. The undeveloped MDR area is pervious area, HSG C soil and the undeveloped forest area is pervious, HSG B soil.

| Land Use Category | Baseline Area (acres) | P export rate (lbs P/acre/yr)* | Baseline area unchanged (acres) | P export rate (lbs P/acre/yr)** | Developed Area converted to HDR IA (acres) | P export rate (lbs P/acre/yr)** |
|-------------------|-----------------------|--------------------------------|---------------------------------|---------------------------------|--------------------------------------------|---------------------------------|
| Industrial        | 11.0                  | 1.27                           | No change                       | --                              | No change                                  | --                              |
| MDR               | 3.0                   | 0.49                           | 1.5                             | 0.21                            | 1.5                                        | 2.32                            |

|        |     |      |     |      |     |      |
|--------|-----|------|-----|------|-----|------|
| Forest | 4.0 | 0.12 | 3.5 | 0.12 | 0.5 | 2.32 |
|--------|-----|------|-----|------|-----|------|

\*From Table 1-1; \*\* From Table 1-2

The phosphorus load increase is calculated as:

$$\begin{aligned}
 \text{Baseline Load} &= (\text{Baseline P Load}_{\text{IND}}) + \\
 &\quad (\text{Baseline P Load}_{\text{MDR}}) + \\
 &\quad (\text{Baseline P Load}_{\text{FOR}}) \\
 &= \mathbf{16.0 \text{ lb/year}} \text{ (determined in Example 1-1)}
 \end{aligned}$$

$$\begin{aligned}
 P_{\text{DEV}} &= (TA_{\text{IND}} \times \text{PLER}_{\text{IND}}) + (IA_{\text{HDR}} \times \text{PLER}_{\text{HDR}}) + (PA_{\text{MDR}} \times \text{PLER}_{\text{MDR}}) + (PA_{\text{FOR}} \times \text{PLER}_{\text{FOR}}) \\
 &= (11.0 \text{ acres} \times 1.27) + (2.0 \text{ acres} \times 2.32) + (1.5 \text{ acres} \times 0.21) + (3.5 \times 0.12) \\
 &= \mathbf{19.0 \text{ lbs P/year}}
 \end{aligned}$$

$$\begin{aligned}
 P_{\text{DEVinc}} &= P_{\text{DEV}} - \text{Baseline Load} \\
 &= 19.0 - 16.0 \\
 &= \mathbf{3.0 \text{ lbs/year}}
 \end{aligned}$$

**Table 1-1. Annual composite phosphorus load export rates**

| Land Cover                 | Representative DCIA, % | Composite PLERs, lb/ac/yr | Composite PLERs, kg/ha/yr |
|----------------------------|------------------------|---------------------------|---------------------------|
| Commercial                 | 57                     | 1.13                      | 1.27                      |
| Industrial                 | 67                     | 1.27                      | 1.42                      |
| High Density Residential   | 36                     | 1.04                      | 1.16                      |
| Medium Density Residential | 16                     | 0.49                      | 0.55                      |
| Low Density Residential    | 11                     | 0.30                      | 0.34                      |
| Freeway                    | 44                     | 0.73                      | 0.82                      |
| Open Space                 | 8                      | 0.26                      | 0.29                      |
| Agriculture                | 0.4                    | 0.45                      | 0.50                      |
| Forest                     | 0.1                    | 0.12                      | 0.13                      |

**Table 1-2: Proposed average annual distinct P Load export rates for use in estimating P Load reduction credits the MA MS4 Permit**

| <b>Phosphorus Source Category by Land Use</b>                  | <b>Land Surface Cover</b>     | <b>P Load Export Rate, lbs/acre/year</b> | <b>P Load Export Rate, kg/ha/yr</b> |
|----------------------------------------------------------------|-------------------------------|------------------------------------------|-------------------------------------|
| Commercial (Com) and Industrial (Ind)                          | Directly connected impervious | 1.78                                     | 2.0                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Multi-Family (MFR) and High-Density Residential (HDR)          | Directly connected impervious | 2.32                                     | 2.6                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Medium -Density Residential (MDR)                              | Directly connected impervious | 1.96                                     | 2.2                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Low Density Residential (LDR) - "Rural"                        | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Highway (HWY)                                                  | Directly connected impervious | 1.34                                     | 1.5                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Forest (For)                                                   | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | 0.13                                     | 0.13                                |
| Open Land (Open)                                               | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Agriculture (Ag)                                               | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | 0.45                                     | 0.5                                 |
| *Developed Land Pervious (DevPERV)- Hydrologic Soil Group A    | Pervious                      | 0.03                                     | 0.03                                |
| *Developed Land Pervious (DevPERV)- Hydrologic Soil Group B    | Pervious                      | 0.12                                     | 0.13                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group C   | Pervious                      | 0.21                                     | 0.24                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group C/D | Pervious                      | 0.29                                     | 0.33                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group D   | Pervious                      | 0.37                                     | 0.41                                |

**Table 1-3: Crosswalk of MassGIS land-use categories to land-use groups for P Load Calculations**

| <b>Mass GIS<br/>Land Use<br/>LU_CODE</b> | <b>Description</b>                  | <b>Land Use group for<br/>calculating P Load -<br/>2013/14 MA MS4</b> |
|------------------------------------------|-------------------------------------|-----------------------------------------------------------------------|
| 1                                        | Crop Land                           | Agriculture                                                           |
| 2                                        | Pasture (active)                    | Agriculture                                                           |
| 3                                        | Forest                              | Forest                                                                |
| 4                                        | Wetland                             | Forest                                                                |
| 5                                        | Mining                              | Industrial                                                            |
| 6                                        | Open Land includes inactive pasture | open land                                                             |
| 7                                        | Participation Recreation            | open land                                                             |
| 8                                        | spectator recreation                | open land                                                             |
| 9                                        | Water Based Recreation              | open land                                                             |
| 10                                       | Multi-Family Residential            | High Density Residential                                              |
| 11                                       | High Density Residential            | High Density Residential                                              |
| 12                                       | Medium Density Residential          | Medium Density Residential                                            |
| 13                                       | Low Density Residential             | Low Density Residential                                               |
| 14                                       | Saltwater Wetland                   | Water                                                                 |
| 15                                       | Commercial                          | Commercial                                                            |
| 16                                       | Industrial                          | Industrial                                                            |
| 17                                       | Urban Open                          | open land                                                             |
| 18                                       | Transportation                      | Highway                                                               |
| 19                                       | Waste Disposal                      | Industrial                                                            |
| 20                                       | Water                               | Water                                                                 |
| 23                                       | cranberry bog                       | Agriculture                                                           |
| 24                                       | Powerline                           | open land                                                             |
| 25                                       | Saltwater Sandy Beach               | open land                                                             |
| 26                                       | Golf Course                         | Agriculture                                                           |
| 29                                       | Marina                              | Commercial                                                            |
| 31                                       | Urban Public                        | Commercial                                                            |
| 34                                       | Cemetery                            | open land                                                             |
| 35                                       | Orchard                             | Forest                                                                |
| 36                                       | Nursery                             | Agriculture                                                           |
| 37                                       | Forested Wetland                    | Forest                                                                |
| 38                                       | Very Low Density residential        | Low Density Residential                                               |
| 39                                       | Junkyards                           | Industrial                                                            |
| 40                                       | Brush land/Successional             | Forest                                                                |

## **ATTACHMENT 2 TO APPENDIX F**

### **Phosphorus Reduction Credits for Selected Enhanced Non-Structural BMPs**

The permittee shall use the following methods to calculate phosphorus load reduction credits for the following enhanced non-structural control practices implemented in the Watershed:

- 1) Enhanced Sweeping Program;
- 2) Catch Basin Cleaning;  
and
- 3) Organic Waste and Leaf Litter Collection program

The methods include the use of default phosphorus reduction factors that EPA has determined are acceptable for calculating phosphorus load reduction credits for these practices.

The methods and annual phosphorus load export rates presented in this attachment are for the purpose of counting load reductions for various BMPs treating storm water runoff from varying site conditions (i.e., impervious or pervious surfaces) and different land uses (e.g. industrial and commercial) within the impaired watershed. Table 2-1 below provides annual phosphorus load export rates by land use category for impervious and pervious areas. The estimates of annual phosphorus load and load reductions resulting from BMP implementation are intended for use by the permittee to measure compliance with its Phosphorus Reduction Requirement under the permit.

Examples are provided to illustrate use of the methods. In calculating phosphorus export rates, the permittee shall select the land use category that most closely represents the actual use for the area in question. For watersheds with institutional type uses, such as government properties, hospitals, and schools, the permittee shall use the commercial land use category for the purpose of calculating phosphorus loads. Table 2-2 provides a crosswalk table of land use codes between land use groups in Table 2-1 and the codes used by Mass GIS. For pervious areas, permittees should use the appropriate value for the hydrologic soil group (HSG) if known, otherwise, assume HSG C conditions.

**Alternative Methods and/or Phosphorus Reduction Factors:** A permittee may propose alternative methods and/or phosphorus reduction factors for calculating phosphorus load reduction credits for these non-structural practices. EPA will consider alternative methods and/or phosphorus reduction factors, provided that the permittee submits adequate supporting documentation to EPA. At a minimum, supporting documentation shall consist of a description of the proposed method, the technical basis of the method, identification of alternative phosphorus reduction factors, supporting calculations, and identification of references and sources of information that support the use of the alternative method and/or factors in the Watershed. If EPA determines that the alternative methods and/or factors are not adequately supported, EPA will notify the permittee and the permittee may receive no phosphorus reduction credit other than a reduction credit calculated by the permittee following the methods in this attachment for the identified practices.

**Table 2-1: Proposed average annual distinct P Load export rates for use in estimating P Load reduction credits in the MA MS4 Permit**

| Phosphorus Source Category by Land Use                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Land Surface Cover            | P Load Export Rate, lbs/acre/year | P Load Export Rate, kg/ha/yr |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------|------------------------------|
| Commercial (Com) and Industrial (Ind)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Directly connected impervious | 1.78                              | 2.0                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Multi-Family (MFR) and High-Density Residential (HDR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Directly connected impervious | 2.32                              | 2.6                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Medium -Density Residential (MDR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Directly connected impervious | 1.96                              | 2.2                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Low Density Residential (LDR) - "Rural"                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Directly connected impervious | 1.52                              | 1.7                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Highway (HWY)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Directly connected impervious | 1.34                              | 1.5                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Forest (For)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Directly connected impervious | 1.52                              | 1.7                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | 0.13                              | 0.13                         |
| Open Land (Open)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Directly connected impervious | 1.52                              | 1.7                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | See* DevPERV                      | See* DevPERV                 |
| Agriculture (Ag)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Directly connected impervious | 1.52                              | 1.7                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Pervious                      | 0.45                              | 0.5                          |
| *Developed Land Pervious (DevPERV) – HSG A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Pervious                      | 0.03                              | 0.03                         |
| *Developed Land Pervious (DevPERV) – HSG B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Pervious                      | 0.12                              | 0.13                         |
| *Developed Land Pervious (DevPERV) – HSG C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Pervious                      | 0.21                              | 0.24                         |
| *Developed Land Pervious (DevPERV) – HSG C/D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Pervious                      | 0.29                              | 0.33                         |
| *Developed Land Pervious (DevPERV) – HSG D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Pervious                      | 0.37                              | 0.41                         |
| <b>Notes:</b> <ul style="list-style-type: none"> <li>For pervious areas, if the hydrologic soil group (HSG) is known, use the appropriate value from this table. If the HSG is not known, assume HSG C conditions for the phosphorus load export rate.</li> <li>Agriculture includes row crops. Actively managed hay fields and pasture lands. Institutional land uses such as government properties, hospitals and schools are to be included in the commercial and industrial land use grouping for the purpose of calculating phosphorus loading.</li> <li>Impervious surfaces within the forest land use category are typically roadways adjacent to forested pervious areas.</li> </ul> |                               |                                   |                              |

**Table 2-2: Crosswalk of Mass GIS land use categories  
to land use groups for P load calculations**

| Mass GIS<br>Land Use<br>LU_CODE | Description                         | Land Use group for calculating<br>P Load - 2013/14 MA MS4 |
|---------------------------------|-------------------------------------|-----------------------------------------------------------|
| 1                               | Crop Land                           | Agriculture                                               |
| 2                               | Pasture (active)                    | Agriculture                                               |
| 3                               | Forest                              | Forest                                                    |
| 4                               | Wetland                             | Forest                                                    |
| 5                               | Mining                              | Industrial                                                |
| 6                               | Open Land includes inactive pasture | open land                                                 |
| 7                               | Participation Recreation            | open land                                                 |
| 8                               | spectator recreation                | open land                                                 |
| 9                               | Water Based Recreation              | open land                                                 |
| 10                              | Multi-Family Residential            | High Density Residential                                  |
| 11                              | High Density Residential            | High Density Residential                                  |
| 12                              | Medium Density Residential          | Medium Density Residential                                |
| 13                              | Low Density Residential             | Low Density Residential                                   |
| 14                              | Saltwater Wetland                   | Water                                                     |
| 15                              | Commercial                          | Commercial                                                |
| 16                              | Industrial                          | Industrial                                                |
| 17                              | Urban Open                          | open land                                                 |
| 18                              | Transportation                      | Highway                                                   |
| 19                              | Waste Disposal                      | Industrial                                                |
| 20                              | Water                               | Water                                                     |
| 23                              | cranberry bog                       | Agriculture                                               |
| 24                              | Powerline                           | open land                                                 |
| 25                              | Saltwater Sandy Beach               | open land                                                 |
| 26                              | Golf Course                         | Agriculture                                               |
| 29                              | Marina                              | Commercial                                                |
| 31                              | Urban Public                        | Commercial                                                |
| 34                              | Cemetery                            | open land                                                 |
| 35                              | Orchard                             | Forest                                                    |
| 36                              | Nursery                             | Agriculture                                               |
| 37                              | Forested Wetland                    | Forest                                                    |
| 38                              | Very Low Density residential        | Low Density Residential                                   |
| 39                              | Junkyards                           | Industrial                                                |
| 40                              | Brush land/Successional             | Forest                                                    |

**(1) Enhanced Sweeping Program:** The permittee may earn a phosphorus reduction credit for conducting an enhanced sweeping program of impervious surfaces. Table 2-2 below outlines the default phosphorus removal factors for enhanced sweeping programs. The credit shall be calculated by using the following equation:

$$\text{Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{PLE}_{\text{IC-land use}} \times \text{PRF}_{\text{sweeping}} \times \text{AF} \quad (\text{Equation 2-1})$$

**Where:**

|                                   |   |                                                                                                                                                                         |
|-----------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\text{Credit}_{\text{sweeping}}$ | = | Amount of phosphorus load removed by enhanced sweeping program (lb/year)                                                                                                |
| $\text{IA}_{\text{swept}}$        | = | Area of impervious surface that is swept under the enhanced sweeping program (acres)                                                                                    |
| $\text{PLE}_{\text{IC-land use}}$ | = | Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)                                                                    |
| $\text{PRF}_{\text{sweeping}}$    | = | Phosphorus Reduction Factor for sweeping based on sweeper type and frequency (see Table 2-3).                                                                           |
| AF                                | = | Annual Frequency of sweeping. For example, if sweeping does not occur in Dec/Jan/Feb, the AF would be 9 mo./12 mo. = 0.75. For year-round sweeping, AF=1.0 <sup>1</sup> |

As an alternative, the permittee may apply a credible sweeping model of the Watershed and perform continuous simulations reflecting build-up and wash-off of phosphorus using long-term local rainfall data.

**Table 2-3: Phosphorus reduction efficiency factors  
( $\text{PRF}_{\text{sweeping}}$ ) for sweeping impervious areas**

| Frequency <sup>1</sup>                | Sweeper Technology                      | $\text{PRF}_{\text{sweeping}}$ |
|---------------------------------------|-----------------------------------------|--------------------------------|
| 2/year (spring and fall) <sup>2</sup> | Mechanical Broom                        | 0.01                           |
| 2/year (spring and fall) <sup>2</sup> | Vacuum Assisted                         | 0.02                           |
| 2/year (spring and fall) <sup>2</sup> | High-Efficiency Regenerative Air-Vacuum | 0.02                           |
|                                       |                                         |                                |
| Monthly                               | Mechanical Broom                        | 0.03                           |
| Monthly                               | Vacuum Assisted                         | 0.04                           |
| Monthly                               | High Efficiency Regenerative Air-Vacuum | 0.08                           |
|                                       |                                         |                                |
| Weekly                                | Mechanical Broom                        | 0.05                           |
| Weekly                                | Vacuum Assisted                         | 0.08                           |
| Weekly                                | High Efficiency Regenerative Air-Vacuum | 0.10                           |

<sup>1</sup>For full credit for monthly and weekly frequency, sweeping must be conducted year round. Otherwise, the credit should be adjusted proportionally based on the duration of the sweeping season (using AF factor).

<sup>2</sup> In order to earn credit for semi-annual sweeping the sweeping must occur in the spring following snow-melt and road sand applications to impervious surfaces and in the fall after leaf-fall and prior to the onset to the snow season.

**Example 2-1: Calculation of enhanced sweeping program credit (Credit<sub>sweeping</sub>):** A permittee proposes to implement an enhanced sweeping program and perform weekly sweeping from March 1 – December 1 (9 months) in their Watershed, using a vacuum assisted sweeper on 20.3 acres of parking lots and roadways in a high-density residential area of the Watershed. For this site the needed information is:

$$\begin{aligned}
 IA_{\text{swept}} &= 20.3 \text{ acres} \\
 PLE_{\text{IC-HDR}} &= 2.32 \text{ lb/acre/yr (from Table 2-1)} \\
 PRF_{\text{sweeping}} &= 0.08 \text{ (from Table 2-3)} \\
 AF &= (9 \text{ months} / 12 \text{ months}) = 0.75
 \end{aligned}$$

Substitution into equation 2-1 yields a Credit<sub>sweeping</sub> of 3.2 pounds of phosphorus removed per year.

$$\begin{aligned}
 \text{Credit}_{\text{sweeping}} &= IA_{\text{swept}} \times PLE_{\text{land use}} \times PRF_{\text{sweeping}} \times AF \\
 &= 20.3 \text{ acres} \times 2.32 \text{ lbs/acre/yr} \times 0.08 \times 0.75 \\
 &= \mathbf{2.8 \text{ lbs/yr}}
 \end{aligned}$$

**(2) Catch Basin Cleaning:** The permittee may earn a phosphorus reduction credit, Credit<sub>CB</sub>, by removing accumulated materials from catch basins (i.e., catch basin cleaning) in the Watershed such that a minimum sump storage capacity of 50% is maintained throughout the year. The credit shall be calculated by using the following equation:

$$\text{Credit}_{\text{CB}} = IA_{\text{CB}} \times PLE_{\text{IC-land use}} \times PRF_{\text{CB}} \quad \text{(Equation 2-2)}$$

**Where:**

$$\begin{aligned}
 \text{Credit}_{\text{CB}} &= \text{Amount of phosphorus load removed by catch basin cleaning (lb/year)} \\
 IA_{\text{CB}} &= \text{Impervious drainage area to catch basins (acres)} \\
 PLE_{\text{IC-land use}} &= \text{Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)} \\
 PRF_{\text{CB}} &= \text{Phosphorus Reduction Factor for catch basin cleaning (see Table 2-4)}
 \end{aligned}$$

**Table 2-4: Phosphorus reduction efficiency factor (PRF<sub>CB</sub>) for semi-annual catch basin cleaning**

| Frequency   | Practice             | PRF <sub>CB</sub> |
|-------------|----------------------|-------------------|
| Semi-annual | Catch Basin Cleaning | 0.02              |

**Example 2-2: Calculation for catch basin cleaning credit (Credit<sub>CB</sub>):**

A permittee proposes to clean catch basins in their Watershed (i.e., remove accumulated sediments and contaminants captured in the catch basins) that drain runoff from 15.3 acres of medium-density residential impervious area. For this site the needed information is:

|                       |                                     |
|-----------------------|-------------------------------------|
| IA <sub>CB</sub>      | = 15.3 acre                         |
| PLE <sub>IC-MDR</sub> | = 1.96 lbs/acre/yr (from Table 2-1) |
| PRF <sub>CB</sub>     | = 0.02 (from Table 2-4)             |

Substitution into equation 2-2 yields a Credit<sub>CB</sub> of 0.6 pounds of phosphorus removed per year:

$$\begin{aligned}
 \text{Credit}_{CB} &= \text{IA}_{CB} \times \text{PLE}_{IC-MDR} \times \text{PRF}_{CB} \\
 &= 15.3 \text{ acre} \times 1.96 \text{ lbs/acre/yr} \times 0.02 \\
 &= \mathbf{0.6 \text{ lbs/yr}}
 \end{aligned}$$

**(3) Enhanced Organic Waste and Leaf Litter Collection program:** The permittee may earn a phosphorus reduction credit by performing regular gathering, removal and disposal of landscaping wastes, organic debris, and leaf litter from impervious surfaces from which runoff discharges to the TMDL waterbody or its tributaries. In order to earn this credit (Credit<sub>leaf litter</sub>), the permittee must gather and remove all landscaping wastes, organic debris, and leaf litter from impervious roadways and parking lots at least once per week during the period of September 1 to December 1 of each year. Credit can only be earned for those impervious surfaces that are cleared of organic materials in accordance with the description above. The gathering and removal shall occur immediately following any landscaping activities in the Watershed and at additional times when necessary to achieve a weekly cleaning frequency. The permittee must ensure that the disposal of these materials will not contribute pollutants to any surface water discharges. The permittee may use an enhanced sweeping program (e.g., weekly frequency) as part of earning this credit provided that the sweeping is effective at removing leaf litter and organic materials. The Credit<sub>leaf litter</sub> shall be determined by the following equation:

$$\text{Credit}_{\text{leaf litter}} = (\text{Watershed Area}) \times (\text{PLE}_{IC\text{-land use}}) \times (0.05) \quad \textbf{(Equation 2-3)}$$

**Where:**

|                               |                                                                                                                     |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Credit <sub>leaf litter</sub> | = Amount of phosphorus load reduction credit for organic waste and leaf litter collection program (lb/year)         |
| Watershed Area                | = All impervious area (acre) from which runoff discharges to the TMDL waterbody or its tributaries in the Watershed |
| PLE <sub>IC-land use</sub>    | = Phosphorus Load Export Rate for impervious cover and specified land use (lbs/acre/yr) (see Table 2-1)             |
| 0.05                          | = 5% phosphorus reduction factor for organic waste and leaf litter collection program in the Watershed              |

**Example 2-3: Calculation for organic waste and leaf litter collection program credit**

**(Credit<sub>leaf litter</sub>):** A permittee proposes to implement an organic waste and leaf litter collection program by sweeping the parking lots and access drives at a minimum of once per week using a mechanical broom sweeper for the period of September 1 to December 1 over 12.5 acres of impervious roadways and parking lots in an industrial/commercial area of the Watershed. Also, the permittee will ensure that organic materials are removed from impervious areas immediately following all landscaping activities at the site. For this site the needed information to calculate the Credit<sub>leaf litter</sub> is:

$$\begin{aligned}\text{Watershed Area} &= 12.5 \text{ acres; and} \\ \text{PLE}_{\text{IC-commercial}} &= 1.78 \text{ lbs/acre/yr (from Table 2-1)}\end{aligned}$$

Substitution into equation 2-4 yields a Credit<sub>leaf litter</sub> of 1.1 pounds of phosphorus removed per year:

$$\begin{aligned}\text{Credit}_{\text{leaf litter}} &= (12.5 \text{ acre}) \times (1.78 \text{ lbs/acre/yr}) \times (0.05) \\ &= 1.1 \text{ lbs/yr}\end{aligned}$$

The permittee also may earn a phosphorus reduction credit for enhanced sweeping of roads and parking lot areas (i.e., Credit<sub>sweeping</sub>) for the three months of use. Using equation 2-1, Credit<sub>sweeping</sub> is:

$$\begin{aligned}\text{Credit}_{\text{sweeping}} &= \text{IA}_{\text{swept}} \times \text{PLE}_{\text{IC-land use}} \times \text{PRF}_{\text{sweeping}} \times \text{AF} && \text{(Equation 2-1)} \\ \text{IA}_{\text{swept}} &= 12.5 \text{ acre} \\ \text{PLE}_{\text{IC-commercial}} &= 1.78 \text{ lbs/acre/yr (from Table 2-1)} \\ \text{PRF}_{\text{sweeping}} &= 0.05 \text{ (from Table 2-3)} \\ \text{AF} &= 3 \text{ mo./12 mo.} = 0.25\end{aligned}$$

Substitution into equation 2-1 yields a Credit<sub>sweeping</sub> of 0.28 pounds of phosphorus removed per year.

$$\begin{aligned}\text{Credit}_{\text{sweeping}} &= \text{IA}_{\text{swept}} \times \text{PLE}_{\text{IC-commercial}} \times \text{PRF}_{\text{sweeping}} \times \text{AF} \\ &= 12.5 \text{ acre} \times 1.78 \text{ lbs/acre/yr} \times 0.05 \times 0.25 \\ &= \mathbf{0.3 \text{ lbs/yr}}\end{aligned}$$

## **ATTACHMENT 3 TO APPENDIX F**

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**Methods to Calculate Phosphorus Load Reductions for Structural Stormwater Best Management Practices in the Watershed**

This attachment provides methods to determine design storage volume capacities and to calculate phosphorus load reductions for the following structural Best Management Practices (structural BMPs) for a Watershed:

- 1) Infiltration Trench;
- 2) Infiltration Basin or other surface infiltration practice;
- 3) Bio-filtration Practice;
- 4) Gravel Wetland System;
- 5) Porous Pavement;
- 6) Wet Pond or wet detention basin;
- 7) Dry Pond or detention basin; and
- 8) Dry Water Quality Swale/ Grass Swale.

Additionally, this attachment provides methods to design and quantify associated phosphorus load reduction credits for the following four types of semi-structural/non-structural BMPs

- 9) Impervious Area Disconnection through Storage (e.g., rain barrels, cisterns, etc);
- 10) Impervious Area Disconnection;
- 11) Conversions of Impervious Area to Permeable Pervious Area; and
- 12) Soil Amendments to Enhance Permeability of Pervious Areas.

Methods and examples are provided in this Attachment to calculate phosphorus load reductions for structural BMPs for the four following purposes:

- 1) To determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious;
- 2) To determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious;
- 3) To determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces; and
- 4) To determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area has impervious and pervious surfaces.

Examples are also provided for estimating phosphorus load reductions associated with the four semi-structural/non-structural BMPs.

Also, this attachment provides the methodology for calculating the annual stormwater phosphorus load that will be delivered to BMPs for treatment (BMP Load) and to be used for quantifying phosphorus load reduction credits. The methods and annual phosphorus export load rates presented in this attachment are for the purpose of counting load reductions for various BMPs treating storm water runoff from varying site conditions (i.e., impervious or pervious surfaces) and different land uses (e.g. commercial and industrial). The estimates of annual phosphorus load and load reductions by BMPs are to demonstrate compliance with the permittee's Phosphorus Reduction Requirement under the permit.

## Appendix F Attachment 3

**Structural BMP performance credits:** For each structural BMP type identified above (BMPs 1-8), long-term cumulative performance information is provided to calculate phosphorus load reductions or to determine needed design storage volumes to achieve a specified reduction target (e.g., 65% phosphorus load reduction). The performance information is expressed as cumulative phosphorus load removed (% removed) depending on the physical storage capacity of the structural BMP (expressed as inches of runoff from impervious area) and is provided at the end of this Attachment (see Tables 3-1 through 3-18 and performance curves Figures 3-1 through 3-17). Multiple tables and performance curves are provided for the infiltration practices to represent cumulative phosphorus load reduction performance for six infiltration rates (IR), 0.17, 0.27, 0.53, 1.02, 2.41, and 8.27 inches/hour. These infiltration rates represent the saturated hydraulic conductivity of the soils. The permittee may use the performance curves provided in this attachment to interpolate phosphorus load removal reductions for field measured infiltration rates that are different than the infiltration rates used to develop the performance curves. Otherwise, the permittee shall use the performance curve for the IR that is nearest, but less than, the field measured rate. Physical storage capacity equals the total physical storage volume of the control structure to contain water at any instant in time. Typically, this storage capacity is comprised of the surface ponding storage volume prior to overflow and subsurface storage volumes in storage units and pore spaces of coarse filter media. Table 3-30 provides the formulae to calculate physical storage capacities for the structural control types for using the performance curves.

**Semi-Structural/Non-structural BMP performance credits:** For each semi-structural/non-structural BMP type identified above (BMPs 9-12), long-term cumulative performance information is provided to calculate phosphorus load reductions or to determine needed design specifications to achieve a desired reduction target (e.g., 50% phosphorus load reduction). The performance information is expressed as cumulative runoff volume reduction (% removed) depending on the design specifics and actual field conditions. Cumulative percent runoff volume reduction is being used to estimate the cumulative phosphorus load reduction credit for these BMPs. To represent a wide range of potential conditions for implementing these types of BMPs, numerous performance tables and curves have been developed to reflect a wide range of potential conditions and designs such as varying storage volumes (expressed in terms of varying ratios of storage volume to impervious area (0.1 to 2.0 inches)); varying ratios of impervious source area to receiving pervious area based on hydrologic soil groups (HSGs) A, B, C and D (8:1, 6:1, 4:1, 2: 1 and 1:1); and varying discharge time periods for temporary storage (1, 2 or 3 days) . The default credits are provided at the end of this Attachment (see Tables 3-19 through 3-26 and performance curves Figures 3-18 through 3-38).

EPA will consider phosphorus load reductions calculated using the methods provided below to be valid for the purpose of complying with the terms of this permit for BMPs that have not been explicitly modeled if the desired BMP has functionality that is similar to one of the simulated BMP types. Please note that only the surface infiltration and the infiltration trench BMP types were simulated to direct storm water runoff into the ground (i.e., infiltration). All of the other simulated BMPs represent practices that have either under-drains or impermeable liners and therefore, are not hydraulically connected to the sub-surface soils (i.e., no infiltration). Following are some simple guidelines for selecting the BMP type and/or determining whether the results of any of the BMP types provided are appropriate for another BMP of interest.

**Infiltration Trench** is a practice that provides temporary storage of runoff using the void spaces within the soil/sand/gravel mixture that is used to backfill the trench for subsequent infiltration into the surrounding sub-soils. Performance results for the infiltration trench can be used for all subsurface infiltration practices including systems that include pipes and/or chambers that provide temporary storage. Also, the results for this BMP type can be used for bio-retention systems that rely on infiltration when the majority of the temporary storage capacity is provided in the void spaces of the soil filter media and porous pavements that allow infiltration to occur.

**Surface Infiltration** represents a practice that provides temporary surface storage of runoff (e.g., ponding) for subsequent infiltration into the ground. Appropriate practices for use of the surface infiltration performance estimates include infiltration basins, infiltration swales, rain gardens and bio-retention systems that rely on infiltration and provide the majority of storage capacity through surface-ponding. If an infiltration system includes both surface storage through ponding and a lesser storage volume within the void spaces of a coarse filter media, then the physical storage volume capacity used to determine the long-term cumulative phosphorus removal efficiency from the infiltration basin performance curves would be equal to the sum of the surface storage volume and the void space storage volume. General design specifications for various surface infiltration systems are provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>).

**Bio-filtration** is a practice that provides temporary storage of runoff for filtering through an engineered soil media. The storage capacity is typically made of void spaces in the filter media and temporary ponding at the surface of the practice. Once the runoff has passed through the filter media it is collected by an under-drain pipe for discharge. The performance curve for this control practice assumes zero infiltration. If a filtration system has subsurface soils that are suitable for infiltration, then user should use the either performance curves for the infiltration trench or the infiltration basin depending on the predominance of storage volume made up by free standing storage or void space storage. Depending on the design of the filter media manufactured or packaged bio-filter systems such as tree box filters may be suitable for using the bio-filtration performance results. Design specifications for bio-filtration systems are provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>).

**Gravel Wetland** performance results should be used for practices that have been designed in accordance or share similar features with the design specifications for gravel wetland systems provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>).

**Porous Pavement** performance results represent systems with an impermeable under-liner and an under-drain. *If porous pavement systems do not have an impermeable under-liner so that filtered runoff can infiltrate into sub-soils then the performance results for an infiltration trench may be used for these systems.* Design specifications for porous pavement systems are provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>).

**Extended Dry Detention Pond** performance results should only be used for practices that have been designed in accordance with the design specifications for extended dry detention ponds provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>)

**Dry Water Quality Swale/ Grass Swale** performance results should only be used for practices that have been designed in accordance with the design specifications for a water quality dry swale provided in the most recent version of *the Massachusetts Stormwater Handbook, Volume 2/Chapter2* (<http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf>)

**Impervious Area Disconnection using Storage (e.g., rain barrels, cistern, etc)** performance results are for collecting runoff volumes from impervious areas such as roof tops, providing temporary storage of runoff volume using rain barrels, cisterns or other storage containers, and discharging stored volume to adjacent permeable pervious surfaces over an extended period of time.

**Impervious Area Disconnection** performance results are for diverting runoff volumes from impervious areas such as roadways, parking lots and roof tops, and discharging it to adjacent vegetated permeable surfaces that are of sufficient size with adequate soils to receive the runoff without causing negative impacts to adjacent down-gradient properties. Careful consideration must be given to the ratio of impervious area to the pervious area that will receive the discharge. Also, devices such as level spreaders to disperse the discharge and provide sheet flow should be employed whenever needed to increase recharge and avoid flow concentration and short circuiting through the pervious area. Soil testing is needed to classify the permeability of the receiving pervious area in terms of HSG.

**Conversion of Impervious Area to Permeable Pervious Area** phosphorus load reduction credits are for replacing existing impervious surfaces (such as traditional pavements and buildings with roof tops) with permeable surfaces. To be eligible for credit, it is essential that the area previously covered with impervious surface be restored to provide natural or enhanced hydrologic functioning so that the surface is permeable. Sub-soils beneath pavements are typically highly compacted and will require reworking to loosen the soil and the possible addition of soil amendments to restore permeability. Soil testing is needed to classify the permeability (in terms of HSG) of the restored pervious area.

**Soil Amendments to Increase Permeability of Pervious Areas** performance results are for the practice of improving the permeability of pervious areas through incorporation of soil amendments, tilling and establishing dense vegetation. This practice may be used to compliment other practices such as impervious area disconnection to improve overall performance and increase reduction credits earned. Soil testing is needed to classify the permeability (in terms of HSG) of the restored pervious area.

**Alternative Methods:**

## Appendix F Attachment 3

A permittee may propose alternative long-term cumulative performance information or alternative methods to calculate phosphorus load reductions for the structural BMPs identified above or for other structural BMPs not identified in this Attachment.

EPA will consider alternative long-term cumulative performance information and alternative methods to calculate phosphorus load reductions for structural BMPs provided that the permittee provides EPA with adequate supporting documentation. At a minimum, the supporting documentation shall include:

- 1) Results of continuous BMP model simulations representing the structural BMP, using a verified BMP model and representative long-term (i.e., 10 years) climatic data including hourly rainfall data;
- 2) Supporting calculations and model documentation that justify use of the model, model input parameters, and the resulting cumulative phosphorus load reduction estimate;
- 3) If pollutant removal performance data are available for the specific BMP, model calibration results should be provided; and
- 4) Identification of references and sources of information that support the use of the alternative information and method.

If EPA determines that the long-term cumulative phosphorus load reductions developed based on alternative information are not adequately supported, EPA will notify the permittee in writing, and the permittee may receive no phosphorus reduction credit other than a reduction credit calculated by the permittee using the default phosphorus reduction factors provided in this attachment for the identified practices. The permittee is required to submit to EPA valid phosphorus load reductions for structural BMPs in the watershed in accordance with the submission schedule requirements specified in the permit and Appendix F.

### **Method to Calculate Annual Phosphorus Load Delivered to BMPs (BMP Load)**

The **BMP Load** is the annual phosphorus load from the drainage area to each proposed or existing BMP used by permittee to claim credit against its stormwater phosphorus load reduction requirement (i.e., Phosphorus Reduction Requirement). The BMP Load is the starting point from which the permittee calculates the reduction in phosphorus load achieved by each existing and proposed BMP.

Examples are provided to illustrate use of the methods. Table 3-1 below provides annual phosphorus load export rates (PLERs) by land use category for impervious and pervious areas. The permittee shall select the land use category that most closely represents the actual use of the watershed. For pervious areas, if the hydrologic soil group (HSG) is known, use the appropriate value. If the HSG is not known, assume HSG C conditions for the phosphorus load export rate. For watersheds with institutional type uses, such as government properties, hospitals, and schools, the permittee shall use the commercial/industrial land use category for the purpose of calculating phosphorus loads. Table 3-2 provides a crosswalk table of land use codes between land use groups in Table 3-1 and the codes used by MassGIS.

## Appendix F Attachment 3

**BMP Load:** To estimate the annual phosphorus load reduction that a storm water BMP can achieve, it is first necessary to estimate the amount of annual phosphorus load that the BMP will receive or treat (BMP Load).

For a given BMP:

- 1) Determine the total drainage area to the BMP;
- 2) Distribute the total drainage area into impervious and pervious subareas by land use category as defined by Tables 3-1 and 3-2;
- 3) Calculate the phosphorus load for each land use-based impervious and pervious subarea by multiplying the subarea by the appropriate phosphorus load export rate provided in Table 3-1; and
- 4) Determine the total annual phosphorus load to the BMP by summing the calculated impervious and pervious subarea phosphorus loads.

**Example 3-1 to determine phosphorus load to a proposed BMP:** A permittee is proposing a surface stormwater infiltration system that will treat runoff from an industrial site with an area of 12.87 acres (5.21 hectares) and is made up of 10.13 acres of impervious cover (e.g., roadways, parking areas and rooftops), 1.85 acres of landscaped pervious area and 0.89 acres of wooded area both with HSG C soils. The drainage area information for the proposed BMP is:

| BMP Subarea ID | Land Use Category  | Cover Type | Area (acres) | P export rate (lb/acre/yr)* |
|----------------|--------------------|------------|--------------|-----------------------------|
| 1              | Industrial         | impervious | 10.13        | 1.78                        |
| 2              | Landscaped (HSG C) | pervious   | 1.85         | 0.21                        |
| 3              | Forest (HSG C)     | pervious   | 0.89         | 0.12                        |

\*From Table 3-1

The phosphorus load to the proposed BMP (BMP Load) is calculated as:

$$\begin{aligned}\text{BMP Load} &= (IA_{\text{Ind}} \times \text{PLER}_{\text{Ind}}) + (PA_{\text{Ind}} \times \text{PLER}_{\text{Ind}}) + (PA_{\text{FOREST}} \times \text{PLER}_{\text{For}}) \\ &= (10.13 \times 1.78) + (1.85 \times 0.21) + (0.89 \times 0.12) \\ &= \mathbf{18.53 \text{ lbs P/year}}\end{aligned}$$

**Table 3-1: Average annual distinct phosphorus load (P Load) export rates for use in estimating phosphorus load reduction credits the MA MS4 Permit**

| <b>Phosphorus Source Category by Land Use</b>                  | <b>Land Surface Cover</b>     | <b>P Load Export Rate, lbs/acre/year</b> | <b>P Load Export Rate, kg/ha/yr</b> |
|----------------------------------------------------------------|-------------------------------|------------------------------------------|-------------------------------------|
| Commercial (Com) and Industrial (Ind)                          | Directly connected impervious | 1.78                                     | 2.0                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Multi-Family (MFR) and High-Density Residential (HDR)          | Directly connected impervious | 2.32                                     | 2.6                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Medium -Density Residential (MDR)                              | Directly connected impervious | 1.96                                     | 2.2                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Low Density Residential (LDR) - "Rural"                        | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Highway (HWY)                                                  | Directly connected impervious | 1.34                                     | 1.5                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Forest (For)                                                   | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | 0.13                                     | 0.13                                |
| Open Land (Open)                                               | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | See* DevPERV                             | See* DevPERV                        |
| Agriculture (Ag)                                               | Directly connected impervious | 1.52                                     | 1.7                                 |
|                                                                | Pervious                      | 0.45                                     | 0.5                                 |
| *Developed Land Pervious (DevPERV)- Hydrologic Soil Group A    | Pervious                      | 0.03                                     | 0.03                                |
| *Developed Land Pervious (DevPERV)- Hydrologic Soil Group B    | Pervious                      | 0.12                                     | 0.13                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group C   | Pervious                      | 0.21                                     | 0.24                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group C/D | Pervious                      | 0.29                                     | 0.33                                |
| *Developed Land Pervious (DevPERV) - Hydrologic Soil Group D   | Pervious                      | 0.37                                     | 0.41                                |

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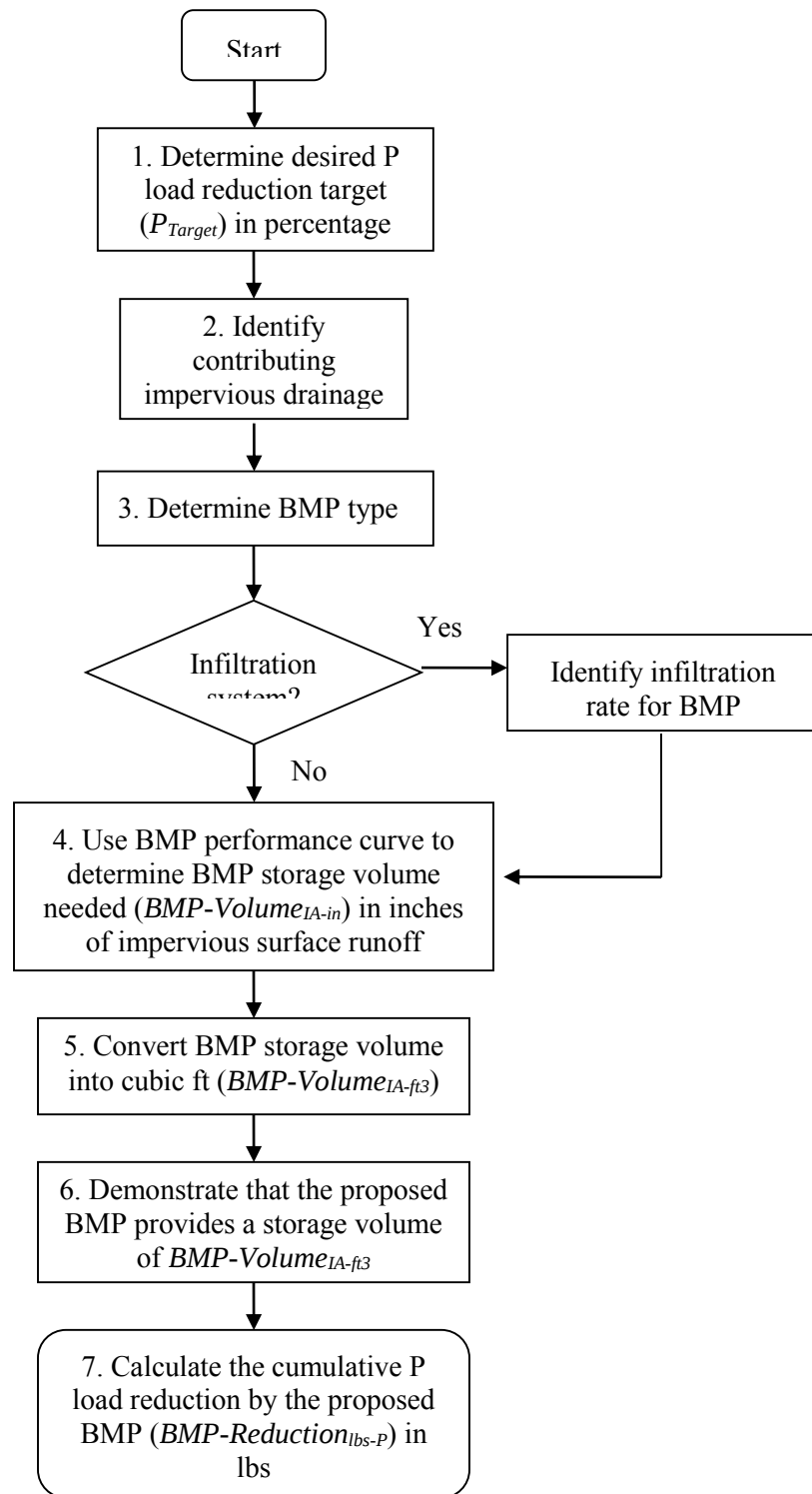
**Table 3- 2: MassGIS land-use categories with associated land-use groups for phosphorus load calculations**

| Mass GIS<br>Land Use<br>LU_CODE | Description                         | Land Use group for<br>calculating P Load - 2013/14<br>MA MS4 |
|---------------------------------|-------------------------------------|--------------------------------------------------------------|
| 1                               | Crop Land                           | Agriculture                                                  |
| 2                               | Pasture (active)                    | Agriculture                                                  |
| 3                               | Forest                              | Forest                                                       |
| 4                               | Wetland                             | Forest                                                       |
| 5                               | Mining                              | Industrial                                                   |
| 6                               | Open Land includes inactive pasture | open land                                                    |
| 7                               | Participation Recreation            | open land                                                    |
| 8                               | spectator recreation                | open land                                                    |
| 9                               | Water Based Recreation              | open land                                                    |
| 10                              | Multi-Family Residential            | High Density Residential                                     |
| 11                              | High Density Residential            | High Density Residential                                     |
| 12                              | Medium Density Residential          | Medium Density Residential                                   |
| 13                              | Low Density Residential             | Low Density Residential                                      |
| 14                              | Saltwater Wetland                   | Water                                                        |
| 15                              | Commercial                          | Commercial                                                   |
| 16                              | Industrial                          | Industrial                                                   |
| 17                              | Urban Open                          | open land                                                    |
| 18                              | Transportation                      | Highway                                                      |
| 19                              | Waste Disposal                      | Industrial                                                   |
| 20                              | Water                               | Water                                                        |
| 23                              | cranberry bog                       | Agriculture                                                  |
| 24                              | Powerline                           | open land                                                    |
| 25                              | Saltwater Sandy Beach               | open land                                                    |
| 26                              | Golf Course                         | Agriculture                                                  |
| 29                              | Marina                              | Commercial                                                   |
| 31                              | Urban Public                        | Commercial                                                   |
| 34                              | Cemetery                            | open land                                                    |
| 35                              | Orchard                             | Forest                                                       |
| 36                              | Nursery                             | Agriculture                                                  |
| 37                              | Forested Wetland                    | Forest                                                       |
| 38                              | Very Low Density residential        | Low Density Residential                                      |
| 39                              | Junkyards                           | Industrial                                                   |
| 40                              | Brush land/Successional             | Forest                                                       |

**(1) Method to determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious:**

## Appendix F Attachment 3

Flow Chart 1 illustrates the steps to determine the design volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area is 100% impervious.



**Flow Chart 1: Method to determine BMP design volume to achieve a known phosphorous load reduction when contributing drainage area is 100% impervious.**

- 1) Determine the desired cumulative phosphorus load reduction target ( $P_{\text{target}}$ ) in percentage for the structural BMP;
- 2) Determine the contributing impervious drainage area (IA) in acres to the structural BMP;
- 3) Determine the structural BMP type (e.g., infiltration trench, gravel wetland). For infiltration systems, determine the appropriate infiltration rate for the location of the BMP in the Watershed;
- 4) Using the cumulative phosphorus removal performance curve for the selected structural BMP (Figures 3-1 through 3-18), determine the storage volume for the BMP (BMP-Volume  $_{\text{IA-in}}$ ), in inches of runoff, needed to treat runoff from the contributing IA to achieve the reduction target;
- 5) Calculate the corresponding BMP storage volume in cubic feet (BMP-Volume  $_{\text{IA-ft}^3}$ ) using BMP-Volume  $_{\text{IA-in}}$  determined from step 4 and equation 3-1:

$$\text{BMP-Volume}_{\text{IA-ft}^3} = \text{IA (acre)} \times \text{BMP-Volume}_{\text{IA-in}} \times 3630 \text{ ft}^3/\text{ac-in} \quad \text{(Equation 3-1)}$$

- 6) Provide supporting calculations using the dimensions and specifications of the proposed structural BMP showing that the necessary storage volume, BMP-Volume  $_{\text{IA-ft}^3}$ , determined from step 5 will be provided to achieve the  $P_{\text{Target}}$ ; and
- 7) Calculate the cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction  $_{\text{lbs-P}}$ ) for the structural BMP using the BMP Load (as calculated from the procedure in Attachment 1 to Appendix F) and  $P_{\text{target}}$  by using equation 3-2:

$$\text{BMP-Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (P_{\text{target}} / 100) \quad \text{(Equation 3-2)}$$

**Example 3-2 to determine design volume of a structural BMP with a 100% impervious drainage area to achieve a known phosphorus load reduction target:**

A permittee is considering a surface infiltration practice to capture and treat runoff from 2.57 acres (1.04 ha) of commercial impervious area that will achieve a 70% reduction in annual phosphorus load. The infiltration practice would be located adjacent to the impervious area. The permittee has measured an infiltration rate (IR) of 0.39 inches per hour (in/hr) in the vicinity of the proposed infiltration practice. Determine the:

- A) Design storage volume needed for an surface infiltration practice to achieve a 70% reduction in annual phosphorus load from the contributing drainage area (BMP-Volume  $_{\text{IA-ft}^3}$ ); and
- B) Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction  $_{\text{lbs-P}}$ )

**Solution:**

- 1) Contributing impervious drainages area (IA) = 2.57 acres

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BMP type is a surface infiltration practice (i.e., basin) with an infiltration rate (IR) of 0.39 in/hr

### **Solution continued:**

3) Phosphorus load reduction target ( $P_{\text{target}}$ ) = 70%

4) The performance curve for the infiltration basin (i.e., surface infiltration practice), Figure 3-8, IR = 0.27 in/hr is used to determine the design storage volume of the BMP (BMP-Volume<sub>IA-in</sub>) needed to treat runoff from the contributing IA and achieve a  $P_{\text{target}}$  = 70%. The curve for an infiltration rate of 0.27 in/hr is chosen because 0.27 in/hr is the nearest simulated IR that is less than the field measured IR of 0.39 in/hr. From Figure 3-8, the BMP-Volume<sub>IA-in</sub> for a  $P_{\text{target}}$  = 70% is 0.36 in.

5) The BMP-Volume<sub>IA-in</sub> is converted to cubic feet (BMP-Volume<sub>IA-ft<sup>3</sup></sub>) using Equation 3-1:

$$\begin{aligned}\text{BMP-Volume}_{\text{IA-ft}^3} &= \text{IA (acre)} \times \text{BMP-Volume}_{\text{IA-in}} \times 3,630 \text{ ft}^3/\text{acre-in} \\ \text{BMP-Volume}_{\text{IA-ft}^3} &= 2.57 \text{ acre} \times 0.36 \text{ in} \times 3,630 \text{ ft}^3/\text{acre-in} \\ &= \mathbf{3,359 \text{ ft}^3}\end{aligned}$$

6) A narrow trapezoidal infiltration basin with the following characteristics is proposed to achieve the  $P_{\text{Target}}$  of 70%:

| Length (ft) | Design Depth (ft) | Side Slopes | Bottom area (ft <sup>2</sup> ) | Pond surface area (ft <sup>2</sup> ) | Design Storage Volume (ft <sup>3</sup> ) |
|-------------|-------------------|-------------|--------------------------------|--------------------------------------|------------------------------------------|
| 355         | 1.25              | 3:1         | 1,387                          | 4,059                                | 3,404                                    |

The volume of the proposed infiltration practice, 3,404 ft<sup>3</sup>, exceeds the BMP-Volume<sub>IA-ft<sup>3</sup></sub> needed, 3,359 ft<sup>3</sup> and is sufficient to achieve the  $P_{\text{Target}}$  of 70%.

7) The cumulative phosphorus load reduction in pounds of phosphorus for the infiltration practice (BMP-Reduction<sub>lbs-P</sub>) is calculated using Equation 3-2. The BMP Load is first determined using the method described above.

$$\begin{aligned}\text{BMP Load} &= \text{IA} \times \text{impervious cover phosphorus export loading rate for commercial use (see Table 3-1)} \\ &= 2.57 \text{ acres} \times 1.78 \text{ lbs/acre/yr} \\ &= 4.58 \text{ lbs/yr}\end{aligned}$$

$$\begin{aligned}\text{BMP-Reduction}_{\text{lbs-P}} &= \text{BMP Load} \times (P_{\text{target}}/100) \\ \text{BMP-Reduction}_{\text{lbs-P}} &= 4.58 \text{ lbs/yr} \times (70/100) \\ &= \mathbf{3.21 \text{ lbs/yr}}\end{aligned}$$

**Alternate Solution:** Alternatively, the permittee could determine the design storage volume needed for an IR = 0.39 in/hr by performing interpolation of the results from the surface

## Appendix F Attachment 3

infiltration performance curves for IR = 0.27 in/hr and IR = 0.52 in/hr as follows (replacing steps 3 and 4 on the previous page):

### **Alternate solution continued:**

Using the performance curves for the infiltration basin (i.e., surface infiltration practice), Figures 3-8, IR = 0.27 in/hr and 3-9, IR = 0.52 in/hr, interpolate between the curves to determine the design storage volume of the BMP (BMP-Volume<sub>IA-in</sub>) needed to treat runoff from the contributing IA and achieve a  $P_{\text{target}} = 70\%$ .

First calculate the interpolation adjustment factor (IAF) to interpolate between the infiltration basin performance curves for infiltration rates of 0.27 and 0.52 in/hr:

$$\text{IAF} = (0.39 - 0.27) / (0.52 - 0.27) = 0.48$$

From the two performance curves, develop the following table to estimate the general magnitude of the needed storage volume for an infiltration swale with an IR = 0.39 in/hr and a  $P_{\text{target}}$  of 70%.

**Table Example 3-1-1: Interpolation Table for determining design storage volume of infiltration basin with IR = 0.39 in/hr and a phosphorus load reduction target of 70%**

| BMP Storage Volume | % Phosphorus Load Reduction IR = 0.27 in/hr (PR <sub>IR=0.27</sub> ) | % Phosphorus Load Reduction IR = 0.52 in/hr (PR <sub>IR=0.52</sub> ) | Interpolated % Phosphorus Load Reduction IR = 0.39 in/hr (PR <sub>IR=0.39</sub> )<br>$\text{PR}_{\text{IR}=0.39} = \text{IAF}(\text{PR}_{\text{IR}=0.52} - \text{PR}_{\text{IR}=0.27}) + \text{PR}_{\text{IR}=0.27}$ |
|--------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.3                | 64%                                                                  | 67%                                                                  | 65%                                                                                                                                                                                                                  |
| 0.4                | 74%                                                                  | 77%                                                                  | 75%                                                                                                                                                                                                                  |
| 0.5                | 79%                                                                  | 82%                                                                  | 80%                                                                                                                                                                                                                  |

As indicated from Table Example 3-1, the BMP-Volume<sub>IA-in</sub> for PR<sub>IR=0.39</sub> of 70% is between 0.3 and 0.4 inches and can be determined by interpolation:

$$\begin{aligned} \text{BMP-Volume}_{\text{IA-in}} &= (70\% - 65\%) / (75\% - 65\%) \times (0.4 \text{ in} - 0.3 \text{ in}) + 0.3 \text{ in} \\ &= 0.35 \text{ inches} \end{aligned}$$

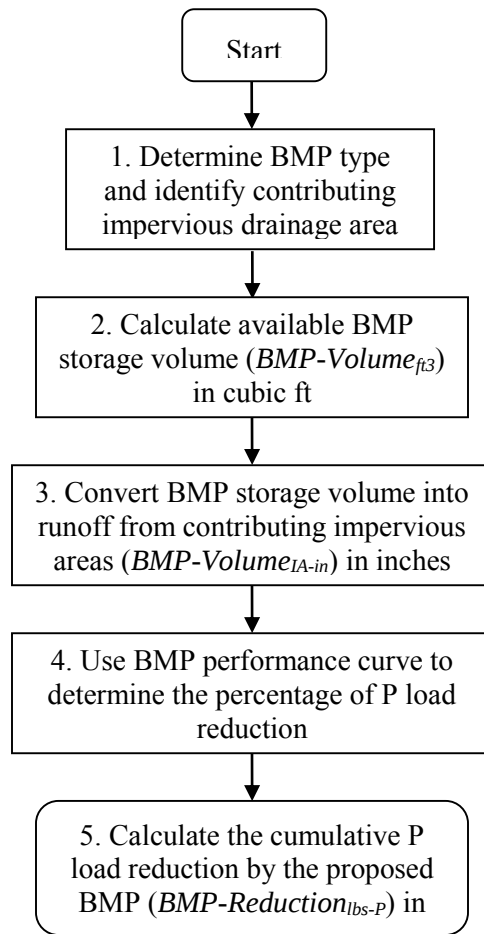
**5 alternative)** Convert the resulting BMP-Volume<sub>IA-in</sub> to cubic feet (BMP-Volume<sub>IA-ft<sup>3</sup></sub>) using equation 3-1:

$$\begin{aligned} \text{BMP-Volume}_{\text{IA-ft}^3} &= 2.57 \text{ acre} \times 0.35 \text{ in} \times 3,630 \text{ ft}^3/\text{acre-in} \\ &= 3,265 \text{ ft}^3 \end{aligned}$$

### **(2) Method to determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious:**

Flow Chart 2 illustrates the steps to determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area is 100% impervious.

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**Flow Chart 2: Method to determine the phosphorus load reduction for a BMP with a known design volume when contributing drainage area is 100% impervious.**

- 1) Identify the structural BMP type and contributing impervious drainage area (IA);
- 2) Document the available storage volume (ft<sup>3</sup>) of the structural BMP (BMP-Volume<sub>ft<sup>3</sup></sub>) using the BMP dimensions and design specifications (e.g., maximum storage depth, filter media porosity);
- 3) Convert BMP-Volume<sub>ft<sup>3</sup></sub> into inches of runoff from the contributing impervious area (BMP-Volume<sub>IA-in</sub>) using equation 3-3:

$$\text{BMP-Volume}_{\text{IA-in}} = \text{BMP-Volume}_{\text{ft}^3} / \text{IA (acre)} \times 12 \text{ in/ft} \times 1 \text{ acre}/43560 \text{ ft}^2 \text{ (Equation 3-3)}$$

- 4) Determine the % phosphorus load reduction for the structural BMP (BMP Reduction<sub>%-P</sub>) using the appropriate BMP performance curve (Figures 3-1 through 3-18) and the BMP-Volume<sub>IA-in</sub> calculated in step 3; and

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- 5) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the structural BMP (BMP Reduction<sub>lbs-P</sub>) using the BMP Load as calculated from the procedure described above and the percent phosphorus load reduction determined in step 4 by using equation 3-4:

$$\text{BMP Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{BMP Reduction}_{\%-\text{P}}/100) \quad \text{(Equation 3-4)}$$

**Example 3-2: Determine the phosphorus load reduction for a structural BMP with a known storage volume capacity when the contributing drainage area is 100% impervious:**

A permittee is considering a bio-filtration system to treat runoff from 1.49 acres of high density residential (HDR) impervious area. Site constraints would limit the bio-filtration system to have a surface area of 1200 ft<sup>2</sup> and the system would have to be located next to the impervious drainage area to be treated. The design parameters for the bio-filtration system are presented in Table Example 3-2-1.

**Table Example 3-2-1: Design parameters for bio-filtration system for Example 3-2**

| Components of representation | Parameters                        | Value                |
|------------------------------|-----------------------------------|----------------------|
| Ponding                      | Maximum depth                     | 0.5 ft               |
|                              | Surface area                      | 1200 ft <sup>2</sup> |
|                              | Vegetative parameter <sup>a</sup> | 85-95%               |
| Soil mix                     | Depth                             | 2.5 ft               |
|                              | Porosity                          | 0.40                 |
|                              | Hydraulic conductivity            | 4 inches/hour        |
| Gravel layer                 | Depth                             | 0.67 ft              |
|                              | Porosity                          | 0.40                 |
|                              | Hydraulic conductivity            | 14 inches/hour       |
| Orifice #1                   | Diameter                          | 0.5 ft               |

<sup>a</sup> Refers to the percentage of surface covered with vegetation

Determine the:

- A) Percent phosphorus load reduction (BMP Reduction<sub>%-P</sub>) for the specified bio-filtration system and contributing impervious drainage area; and
- B) Cumulative phosphorus reduction in pounds that would be accomplished by the bio-filtration system (BMP-Reduction<sub>lbs-P</sub>)

**Solution:**

- 1) The BMP is a bio-filtration system that will treat runoff from 1.49 acres of impervious area (IA = 1.49 acre);
- 2) The available storage volume capacity (ft<sup>3</sup>) of the bio-filtration system (BMP-Volume<sub>BMP-ft<sup>3</sup></sub>) is determined using the surface area of the system, depth of ponding, and the porosity of the filter media:

$$\begin{aligned}
 \text{BMP-Volume}_{\text{BMP-ft}^3} &= (\text{surface area} \times \text{pond maximum depth}) + ((\text{soil mix depth} + \text{gravel layer depth})/12 \text{ in/ft}) \times \text{surface area} \times \text{gravel layer porosity}) \\
 &= (1,200 \text{ ft}^2 \times 0.5 \text{ ft}) + ((38/12) \times 1,200 \text{ ft}^2 \times 0.4) \\
 &= 2,120 \text{ ft}^3
 \end{aligned}$$

**Solution continued:**

- 3) The available storage volume capacity of the bio-filtration system in inches of runoff from the contributing impervious area (BMP-Volume<sub>IA-in</sub>) is calculated using equation 3-3:

$$\begin{aligned}\text{BMP-Volume}_{\text{IA-in}} &= (\text{BMP-Volume}_{\text{ft}^3} / \text{IA (acre)} \times 12 \text{ in/ft} \times 1 \text{ acre} / 43560 \text{ ft}^2 \\ \text{BMP-Volume}_{\text{IA-in}} &= (2120 \text{ ft}^3 / 1.49 \text{ acre}) \times 12 \text{ in/ft} \times 1 \text{ acre} / 43560 \text{ ft}^2 \\ &= 0.39 \text{ in}\end{aligned}$$

- 4) Using the bio-filtration performance curve shown in Figure 3-13, a **51%** phosphorus load reduction (BMP Reduction %-P) is determined for a bio-filtration system sized for 0.39 in of runoff from 1.49 acres of impervious area; and
- 5) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the bio-filtration system (BMP Reduction<sub>lbs-P</sub>) using the BMP Load as calculated from the procedure described above and the BMP Reduction %-P determined in step 4 by using equation 3-4. First, the BMP Load is determined as specified above:

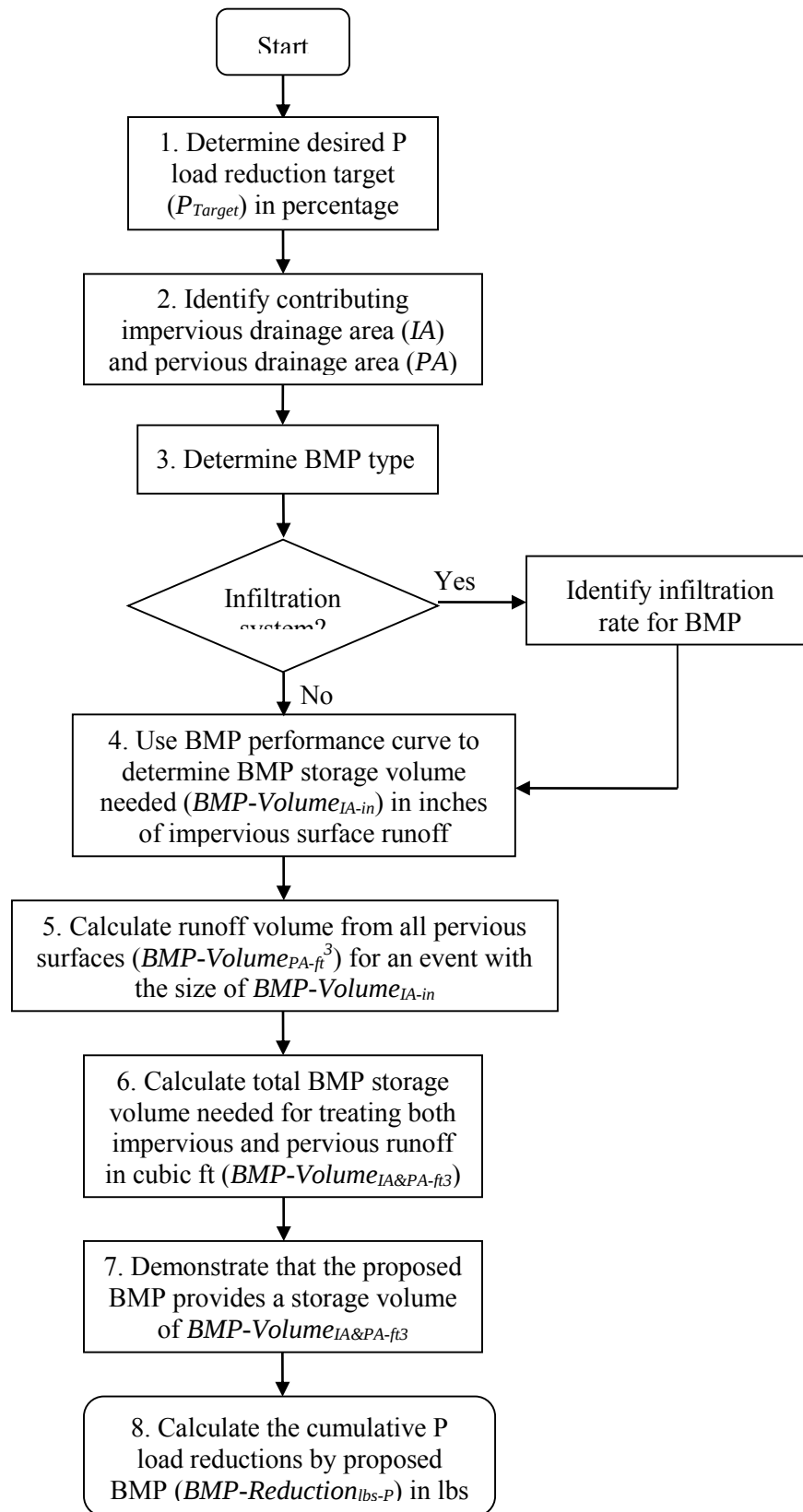
$$\begin{aligned}\text{BMP Load} &= \text{IA} \times \text{impervious cover phosphorus export loading rate for HDR (see Table 3-1)} \\ &= 1.49 \text{ acres} \times 2.32 \text{ lbs/acre/yr} \\ &= 3.46 \text{ lbs/yr}\end{aligned}$$

$$\begin{aligned}\text{BMP Reduction}_{\text{lbs-P}} &= \text{BMP Load} \times (\text{BMP Reduction \% - P} / 100) \\ \text{BMP Reduction}_{\text{lbs-P}} &= 3.46 \text{ lbs/yr} \times (51 / 100) \\ &= \mathbf{1.76 \text{ lbs/yr}}\end{aligned}$$

**(3) Method to determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces:**

Flow Chart 3 illustrates the steps to determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces.

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**Flow Chart 3: Method to determine the design storage volume of a BMP to reach a known P load reduction when both impervious and pervious drainage areas are present.**

- 1) Determine the desired cumulative phosphorus load reduction target ( $P_{\text{target}}$ ) in percentage for the structural BMP;
- 2) Characterize the contributing drainage area to the structural BMP by identifying the following information for the impervious and pervious surfaces:  
**Impervious area (IA)** - Area (acre) and land use (e.g., commercial)

**Pervious area (PA)** – Area (acre) and runoff depths based on hydrologic soil group (HSG) and rainfall depth. Table 3-3 provides values of runoff depth from pervious areas for various rainfall depths and HSGs. Soils are assigned to an HSG on the basis of their permeability. HSG A is the most permeable, and HSG D is the least permeable. HSG categories for pervious areas in the drainage area shall be estimated by consulting local soil surveys prepared by the National Resource Conservation Service (NRCS) or by a storm water professional evaluating soil testing results from the drainage area. If the HSG condition is not known, a HSG D soil condition should be assumed.

**Table 3- 3: Developed Land Pervious Area Runoff Depths based on Precipitation depth and Hydrological Soil Groups (HSGs)**

| Developed Land Pervious Area Runoff Depths based on Precipitation depth and Hydrological Soil Groups                                                                                                                                                                                                                                                   |                      |                |                |                  |                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------|----------------|------------------|----------------|
| Rainfall Depth, Inches                                                                                                                                                                                                                                                                                                                                 | Runoff Depth, inches |                |                |                  |                |
|                                                                                                                                                                                                                                                                                                                                                        | Pervious HSG A       | Pervious HSG B | Pervious HSG C | Pervious HSG C/D | Pervious HSG D |
| 0.10                                                                                                                                                                                                                                                                                                                                                   | 0.00                 | 0.00           | 0.00           | 0.00             | 0.00           |
| 0.20                                                                                                                                                                                                                                                                                                                                                   | 0.00                 | 0.00           | 0.01           | 0.02             | 0.02           |
| 0.40                                                                                                                                                                                                                                                                                                                                                   | 0.00                 | 0.00           | 0.03           | 0.05             | 0.06           |
| 0.50                                                                                                                                                                                                                                                                                                                                                   | 0.00                 | 0.01           | 0.05           | 0.07             | 0.09           |
| 0.60                                                                                                                                                                                                                                                                                                                                                   | 0.01                 | 0.02           | 0.06           | 0.09             | 0.11           |
| 0.80                                                                                                                                                                                                                                                                                                                                                   | 0.02                 | 0.03           | 0.09           | 0.13             | 0.16           |
| 1.00                                                                                                                                                                                                                                                                                                                                                   | 0.03                 | 0.04           | 0.12           | 0.17             | 0.21           |
| 1.20                                                                                                                                                                                                                                                                                                                                                   | 0.04                 | 0.05           | 0.14           | 0.27             | 0.39           |
| 1.50                                                                                                                                                                                                                                                                                                                                                   | 0.08                 | 0.11           | 0.39           | 0.55             | 0.72           |
| 2.00                                                                                                                                                                                                                                                                                                                                                   | 0.14                 | 0.22           | 0.69           | 0.89             | 1.08           |
| Notes: Runoff depths derived from combination of volumetric runoff coefficients from Table 5 of <i>Small Storm Hydrology and Why it is Important for the Design of Stormwater Control Practices</i> , (Pitt, 1999), and using the Stormwater Management Model (SWMM) in continuous model mode for hourly precipitation data for Boston, MA, 1998-2002. |                      |                |                |                  |                |

- 3) Determine the structural BMP type (e.g., infiltration trench, gravel wetland). For infiltration systems, determine the appropriate infiltration rate for the location of the BMP in the Watershed;
- 4) Using the cumulative phosphorus removal performance curve for the selected structural BMP, determine the storage volume capacity of the BMP in inches needed to treat runoff from the contributing impervious area (BMP-Volume<sub>IA-in</sub>);

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- 5) Using Equation 3-5 below and the pervious area runoff depth information from Table 3-3-1, determine the total volume of runoff from the contributing pervious drainage area in cubic feet (BMP Volume  $_{PA-ft^3}$ ) for a rainfall size equal to the sum of BMP Volume  $_{IA-in}$ , determined in step 4. The runoff volume for each distinct pervious area must be determined;

$$\text{BMP-Volume}_{PA-ft^3} = \sum (PA \times (\text{runoff depth}) \times 3,630 \text{ ft}^3/\text{acre-in}) \quad (PA1, \dots, PAn) \quad \text{(Equation 3-5)}$$

- 6) Using equation 3-6 below, calculate the BMP storage volume in cubic feet (BMP-Volume  $_{IA\&PA-ft^3}$ ) needed to treat the runoff depth from the contributing impervious (IA) and pervious areas (PA);

$$\text{BMP-Volume}_{IA\&PA-ft^3} = \text{BMP Volume}_{PA-ft^3} + (\text{BMP Volume}_{IA-in} \times IA \text{ (acre)}) \times 3,630 \text{ ft}^3/\text{acre-in} \quad \text{(Equation 3-6)}$$

- 7) Provide supporting calculations using the dimensions and specifications of the proposed structural BMP showing that the necessary storage volume determined in step 6, BMP-Volume  $_{IA\&PA-ft^3}$ , will be provided to achieve the  $P_{\text{Target}}$ ; and
- 8) Calculate the cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction  $_{lbs-P}$ ) for the structural BMP using the BMP Load (as calculated from the procedure in Attachment 1 to Appendix F) and the  $P_{\text{target}}$  by using equation 3-2:

$$\text{BMP-Reduction}_{lbs-P} = \text{BMP Load} \times (P_{\text{target}} / 100) \quad \text{(Equation 3-2)}$$

### **Example 3-3: Determine the design storage volume of a structural BMP to achieve a known phosphorus load reduction target when the contributing drainage area has impervious and pervious surfaces**

A permittee is considering a gravel wetland system to treat runoff from a high-density residential (HDR) site. The site is 7.50 acres of which 4.00 acres are impervious surfaces and 3.50 acres are pervious surfaces. The pervious area is made up of 2.5 acres of lawns in good condition surrounding cluster housing units and 1.00 acre of stable unmanaged woodland. Soils information indicates that all of the woodland and 0.50 acres of the lawn is hydrologic soil group (HSG) B and the other 2.00 acres of lawn are HSG C. The permittee wants to size the gravel wetland system to achieve a cumulative phosphorus load reduction ( $P_{\text{Target}}$ ) of 55% from the entire 7.50 acres.

Determine the:

- A)** Design storage volume needed for a gravel wetland system to achieve a 55% reduction in annual phosphorus load from the contributing drainage area (BMP-Volume  $_{IA\&PA-ft^3}$ ); and
- B)** Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction  $_{lbs-P}$ )

**Example 3-3 continued:****Solution:**

1) The BMP type is gravel wetland system.

2) The phosphorus load reduction target ( $P_{\text{Target}}$ ) = 55%.

3) Using the cumulative phosphorus removal performance curve for the gravel wetland system shown in Figure 3-14, the storage volume capacity in inches needed to treat runoff from the contributing impervious area (BMP Volume<sub>IA-in</sub>) is 0.71 in;

Using equation 3-5 and the pervious runoff depth information from Table 3-3, the volume of runoff from the contributing pervious drainage area in cubic feet (BMP Volume<sub>PA-ft<sup>3</sup></sub>) for a rainfall size equal to 0.71 in is summarized in Table Example 3-3-A. As indicated from Table 3-3, the runoff depth for a rainfall size equal to 0.71 inches is between 0.6 and 0.8 inches and can be determined by interpolation (example shown for runoff depth of HSG C):

$$\begin{aligned}\text{Runoff depth (HSG C)} &= (0.71 - 0.6)/(0.8 - 0.6) \times (0.09 \text{ in} - 0.06 \text{ in}) + 0.06 \text{ in} \\ &= 0.07 \text{ inches}\end{aligned}$$

**Table Example 3-3-A: Runoff contributions from pervious areas for HDR site**

| ID           | Type  | Pervious Area (acre) | HSG   | Runoff (in) | Runoff = (runoff) x PA (acre-in) | Runoff = Runoff (acre-in) x 3630 ft <sup>3</sup> /acre-in (ft <sup>3</sup> ) |
|--------------|-------|----------------------|-------|-------------|----------------------------------|------------------------------------------------------------------------------|
| PA1          | Grass | 2.00                 | C     | 0.07        | 0.14                             | 508                                                                          |
| PA2          | Grass | 0.50                 | B     | 0.01        | 0.0                              | 0.0                                                                          |
| PA3          | Woods | 1.00                 | B     | 0.01        | 0.0                              | 0.0                                                                          |
| <b>Total</b> | ----- | <b>3.50</b>          | ----- | -----       | <b>0.14</b>                      | <b>508</b>                                                                   |

4) Using equation 3-6, determine the BMP storage volume in cubic feet (BMP-Volume<sub>IA&PA-ft<sup>3</sup></sub>) needed to treat 0.71 inches of runoff from the contributing impervious area (IA) and the runoff of 0.14 acre-in from the contributing pervious areas, determined in step 5 is:

$$\text{BMP Volume}_{\text{IA\&PA-ft}^3} = \text{BMP Volume}_{\text{PA ac-in}} + (\text{BMP Volume}_{\text{IA-in}} \times \text{IA (acre)}) \times 3,630 \text{ ft}^3/\text{acre-in}$$

$$\begin{aligned}\text{BMP Volume}_{\text{IA\&PA-ft}^3} &= (508 \text{ ft}^3 + (0.71 \text{ in} \times 4.00 \text{ acre})) \times 3,630 \text{ ft}^3/\text{acre-in} \\ &= 10,817 \text{ ft}^3\end{aligned}$$

5) Table Example 3-3-B provides design details for of a potential gravel wetland system

**Solution continued:****Table Example 3-3-B: Design details for gravel wetland system**

| Gravel Wetland System Components | Design Detail                  | Depth (ft) | Surface Area (ft <sup>2</sup> ) | Volume (ft <sup>3</sup> ) |
|----------------------------------|--------------------------------|------------|---------------------------------|---------------------------|
| <b>Sediment Forebay</b>          | <b>10% of Treatment Volume</b> |            |                                 |                           |
| Pond area                        | ----                           | 1.33       | 896                             | 1,192                     |
| <b>Wetland Cell #1</b>           | <b>45% of Treatment Volume</b> | -----      | -----                           | -----                     |
| Pond area                        | ----                           | 2.00       | 1,914                           | 3,828                     |
| Gravel layer                     | porosity = 0.4                 | 2.00       | 1,914                           | 1,531                     |
| <b>Wetland Cell #2</b>           | <b>45% of Treatment Volume</b> | -----      | -----                           | -----                     |
| Pond area                        | ----                           | 2.00       | 1,914                           | 3,828                     |
| Gravel layer                     | porosity = 0.4                 | 2.00       | 1,914                           | 1,531                     |

The total design storage volume for the proposed gravel wetland system identified in Table Example 3-3-C is 11,910 ft<sup>3</sup>. This volume is greater than 11,834 ft<sup>3</sup> ((BMP-Volume<sub>IA&PA-ft</sub>)<sup>3</sup>), calculated in step 6) and is therefore sufficient to achieve a P<sub>Target</sub> of 55%.

- 6) The cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction<sub>lbs-P</sub>) for the proposed gravel wetland system is calculated by using equation 3-2 with the BMP Load and the P<sub>target</sub> = 55%.

$$\text{BMP-Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{P}_{\text{target}} / 100) \quad (\text{Equation 3-2})$$

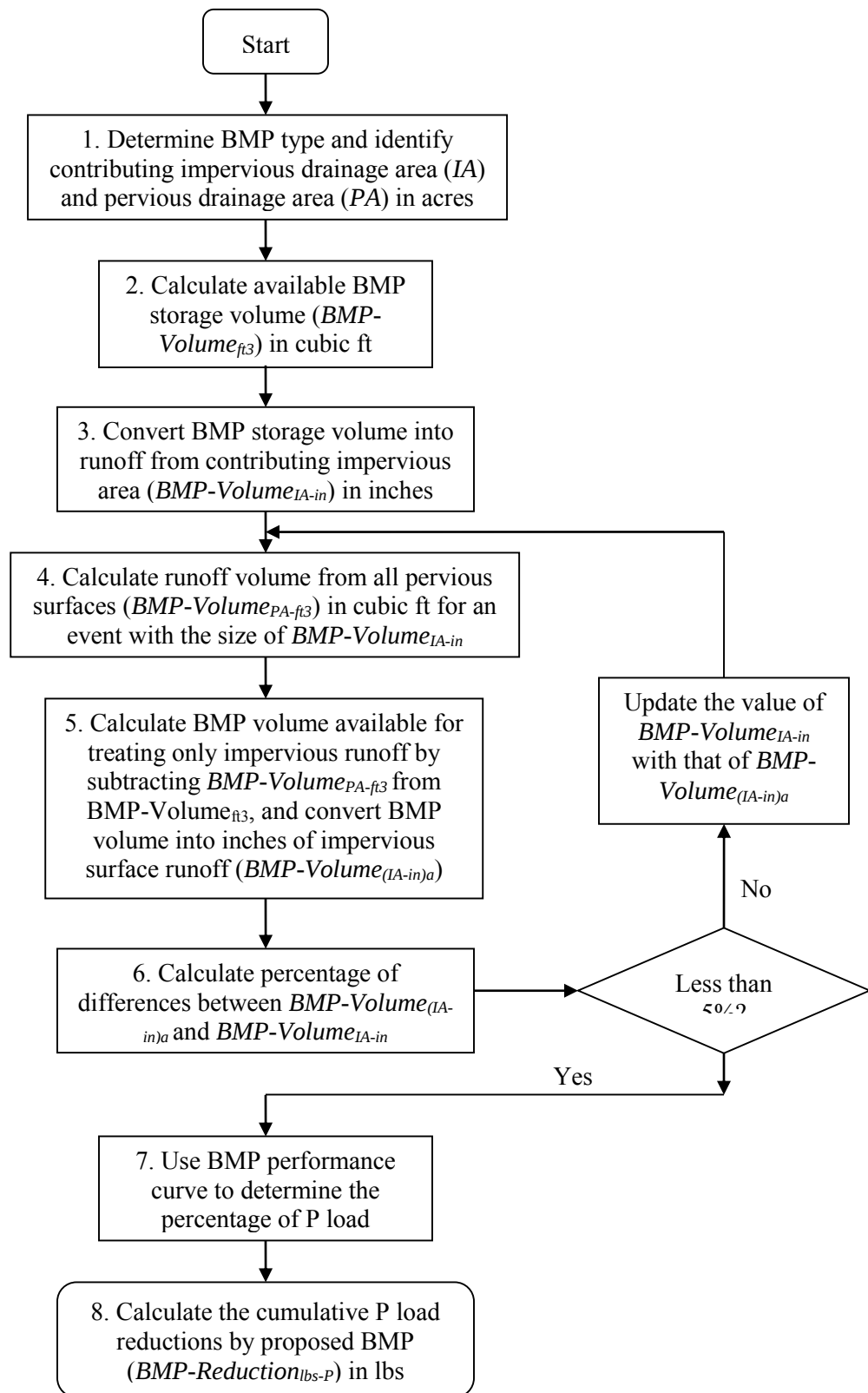
Using Table 3-1, the BMP Load is calculated:

$$\begin{aligned} \text{BMP Load} &= (\text{IA} \times \text{PLER}_{\text{HDR}}) + (\text{PA}_{\text{lawn HSG B}} \times \text{PLER}_{\text{HSG B}}) + (\text{PA}_{\text{lawn HSG C}} \times \text{PLER}_{\text{HSG C}}) + (\text{PA}_{\text{forest}} \times \text{PA}_{\text{PLER For}}) \\ &= (4.00 \text{ acre} \times 2.32 \text{ lbs/acre/yr}) + (0.50 \text{ acres} \times 0.12 \text{ lbs/acre/yr}) + (1.00 \text{ acre} \times 0.21 \text{ lbs/acre/yr}) + (1.00 \text{ acres} \times 0.13) \\ &= 9.68 \text{ lbs/yr} \\ \text{BMP-Reduction}_{\text{lbs-P}} &= \text{BMP Load} \times (\text{P}_{\text{target}} / 100) \\ \text{BMP-Reduction}_{\text{lbs-P}} &= 9.68 \text{ lbs/yr} \times 55/100 \\ &= \mathbf{5.32 \text{ lbs/yr}} \end{aligned}$$

**(4) Method to determine the phosphorus load reduction for a structural BMP with a known storage volume when the contributing drainage area has impervious and pervious surfaces:**

Flow Chart 4 illustrates the steps to determine the phosphorus load reduction for a structural BMP with a known storage volume when the contributing drainage area has impervious and pervious surfaces.

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**Flow Chart 4: Method to determine the phosphorus load reduction for a BMP with known storage volume when both pervious and impervious drainage areas are present.**

- 1) Identify the type of structural BMP and characterize the contributing drainage area to the structural BMP by identifying the following information for the impervious and pervious surfaces:

**Impervious area (IA)** – Area (acre) and land use (e.g., commercial)

**Pervious area (PA)** – Area (acre) and runoff depth based on hydrologic soil group (HSG) and size of rainfall event. Table 3-3 provides values of runoff depth for various rainfall depths and HSGs. Soils are assigned to an HSG based on their permeability. HSG categories for pervious areas in the Watershed shall be estimated by consulting local soil surveys prepared by the National Resource Conservation Service (NRCS) or by a storm water professional evaluating soil testing results from the Watershed. If the HSG condition is not known, a HSG C/D soil condition should be assumed.

- 2) Determine the available storage volume ( $\text{ft}^3$ ) of the structural BMP (BMP-Volume  $\text{ft}^3$ ) using the BMP dimensions and design specifications (e.g., maximum storage depth, filter media porosity);
- 3) To estimate the phosphorus load reduction of a BMP with a known storage volume capacity, it is first necessary to determine the portion of available BMP storage capacity (BMP-Volume  $\text{ft}^3$ ) that would treat the runoff volume generated from the contributing impervious area (IA) for a rainfall event with a depth of  $i$  inches (in). This will require knowing the corresponding amount of runoff volume that would be generated from the contributing pervious area (PA) for the same rainfall event (depth of  $i$  inches). Using equation 3-6a below, solve for the BMP capacity that would be available to treat runoff from the contributing impervious area for the unknown rainfall depth of  $i$  inches (see equation 3-6b):

$$\text{BMP-Volume}_{\text{ft}^3} = \text{BMP-Volume}_{(\text{IA-ft}^3)_i} + \text{BMP-Volume}_{(\text{PA-ft}^3)_i} \quad \text{(Equation 3-6a)}$$

Where:

BMP-Volume  $\text{ft}^3$  = the available storage volume of the BMP;

BMP-Volume  $(\text{IA-ft}^3)_i$  = the available storage volume of the BMP that would fully treat runoff generated from the contributing impervious area for a rainfall event of size  $i$  inches; and

BMP-Volume  $(\text{PA-ft}^3)_i$  = the available storage volume of the BMP that would fully treat runoff generated from the contributing pervious area for a rainfall event of size  $i$  inches

Solving for BMP-Volume  $(\text{IA-ft}^3)_i$ :

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$$\text{BMP-Volume}_{(IA-ft^3)_i} = \text{BMP-Volume}_{ft^3} - \text{BMP-Volume}_{(PA-ft^3)_i} \quad \text{(Equation 3-6b)}$$

To determine BMP-Volume  $_{(IA-ft^3)_i}$ , requires performing an iterative process of refining estimates of the rainfall depth used to calculate runoff volumes until the rainfall depth used results in the sum of runoff volumes from the contributing IA and PA equaling the available BMP storage capacity (BMP-Volume  $_{ft^3}$ ). For the purpose of estimating BMP performance, it will be considered adequate when the IA runoff depth (in) is within 5% IA runoff depth used in the previous iteration.

For the first iteration (1), convert the BMP-Volume  $_{ft^3}$  determined in step 2 into inches of runoff from the contributing impervious area (BMP Volume  $_{(IA-in)_1}$ ) using equation 3-7a.

$$\text{BMP-Volume}_{(IA-in)_1} = (\text{BMP-Volume}_{ft^3} / \text{IA (acre)}) \times (12 \text{ in/ft} / 43,560 \text{ ft}^2/\text{acre}) \quad \text{(Equation 3-7a)}$$

For iterations 2 through n (2...n), convert the BMP Volume  $_{(IA-ft^3)_{2...n}}$ , determined in step 5a below, into inches of runoff from the contributing impervious area (BMP Volume  $_{(IA-in)_{2...n}}$ ) using equation 3-7b.

$$\text{BMP-Volume}_{(IA-in)_{2...n}} = (\text{BMP-Volume}_{(IA-ft^3)_{2...n}} / \text{IA (acre)}) \times (12 \text{ in/ft} / 43,560 \text{ ft}^2/\text{acre}) \quad \text{(Equation 3-7b)}$$

- 4) For 1 to n iterations, use the pervious runoff depth information from Table 3-3 and equation 3-8 to determine the total volume of runoff ( $ft^3$ ) from the contributing PA (BMP Volume  $_{PA-ft^3}$ ) for a rainfall size equal to the sum of BMP-Volume  $_{(IA-in)_1}$ , determined in step 3. The runoff volume for each distinct pervious area must be determined.

$$\text{BMP Volume}_{(PA-ft^3)_{1...n}} = \sum ((PA \times (\text{runoff depth})_{(PA1, PA2...PAN)}) \times (3,630 \text{ ft}^3/\text{acre-in})) \quad \text{(Equation 3-8)}$$

- 5) For iteration 1, estimate the portion of BMP Volume that is available to treat runoff from only the IA by subtracting BMP-Volume  $_{PA-ft^3}$ , determined in step 4, from BMP-Volume  $_{ft^3}$ , determined in step 2, and convert to inches of runoff from IA (see equations 3-9a and 3-9b):

$$\text{BMP-Volume}_{(IA-ft^3)_2} = ((\text{BMP-Volume}_{ft^3} - \text{BMP Volume}_{(PA-ft^3)_1}) \quad \text{(Equation 3-9a)}$$

$$\text{BMP-Volume}_{(IA-in)_2} = (\text{BMP-Volume}_{(IA-ft^3)_2} / \text{IA (acre)}) \times (12 \text{ in/ft} \times 1 \text{ acre} / 43,560 \text{ ft}^2) \quad \text{(Equation 3-9b)}$$

If additional iterations (i.e., 2 through n) are needed, estimate the portion of BMP volume that is available to treat runoff from only the IA (BMP-Volume  $_{(IA-in)_{3..n+1}}$ ) by subtracting BMP Volume  $_{(PA-ft^3)_{2..n}}$ , determined in step 4, from BMP Volume  $_{(IA-ft^3)_{3..n+1}}$ , determined in step 5, and by converting to inches of runoff from IA using equation 3-9b):

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- 6) For iteration a (an iteration between 1 and n+1), compare BMP Volume  $(IA-in)_a$  to BMP Volume  $(IA-in)_{a-1}$  determined from the previous iteration (a-1). If the difference in these values is greater than 5% of BMP Volume  $(IA-in)_a$  then repeat steps 4 and 5, using BMP Volume  $(IA-in)_a$  as the new starting value for the next iteration (a+1). If the difference is less than or equal to 5 % of BMP Volume  $(IA-in)_a$  then the permittee may proceed to step 7;
- 7) Determine the % phosphorus load reduction for the structural BMP (BMP Reduction %<sub>-P</sub>) using the appropriate BMP performance curve and the BMP-Volume  $(IA-in)_n$  calculated in the final iteration of step 5; and
- 8) Calculate the cumulative phosphorus load reduction in pounds of phosphorus for the structural BMP (BMP Reduction <sub>lbs-P</sub>) using the BMP Load as calculated from the procedure in Attachment 1 to Appendix F and the percent phosphorus load reduction (BMP Reduction %<sub>-P</sub>) determined in step 7 by using equation 3-4:

$$\text{BMP Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{BMP Reduction \%}_{-P} / 100) \quad \text{(Equation 3-4)}$$

**Example 3-4: Determine the phosphorus load reduction for a structural BMP with a known design volume when the contributing drainage area has impervious and pervious surfaces**

A permittee is considering an infiltration basin to capture and treat runoff from a portion of the medium density residential area (MDR). The contributing drainage area is 16.55 acres and has 11.75 acres of impervious area and 4.8 acres of pervious area (PA) made up mostly of lawns and landscaped areas that is 80% HSG D and 20% HSG C. An infiltration basin with the following specifications can be placed at the down-gradient end of the contributing drainage area where soil testing results indicates an infiltration rate (IR) of 0.28 in/hr:

**Table Example 3-4-A: Infiltration basin characteristics**

| Structure          | Bottom area (acre) | Top surface area (acre) | Maximum pond depth (ft) | Design storage volume (ft <sup>3</sup> ) | Infiltration Rate (in/hr) |
|--------------------|--------------------|-------------------------|-------------------------|------------------------------------------|---------------------------|
| Infiltration basin | 0.65               | 0.69                    | 1.65                    | 48,155                                   | 0.28                      |

Determine the:

- A) Percent phosphorus load reduction (BMP Reduction %<sub>-P</sub>) for the specified infiltration basin and the contributing impervious and pervious drainage area; and
- B) Cumulative phosphorus reduction in pounds that would be accomplished by the BMP (BMP-Reduction <sub>lbs-P</sub>)

**Example continued:****Solution:**

- 1) A surface infiltration basin is being considered. Information for the contributing impervious (IA) and pervious (PA) areas are summarized in Tables Example 3-4-A and Example 3-4-B, respectively.

**Table Example 3-4-B: Impervious area characteristics**

| ID  | Land use | Area (acre) |
|-----|----------|-------------|
| IA1 | MDR      | 11.75       |

**Table Example 3-4-C: Pervious area characteristics**

| ID  | Area (acre) | Hydrologic Soil Group (HSG) |
|-----|-------------|-----------------------------|
| PA1 | 3.84        | D                           |
| PA2 | 0.96        | C                           |

- 2) The available storage volume ( $\text{ft}^3$ ) of the infiltration basin (BMP-Volume  $\text{ft}^3$ ) is determined from the design details and basin dimensions; BMP-Volume  $\text{ft}^3 = 48,155 \text{ ft}^3$ .
- 3) To determine what the BMP design storage volume is in terms of runoff depth (in) from IA, an iterative process is undertaken:

**Solution Iteration 1**

For the first iteration (1), the BMP-Volume $\text{ft}^3$  is converted into inches of runoff from the contributing impervious area (BMP Volume  $(\text{IA-in})_1$ ) using equation 3-5a.

$$\begin{aligned}\text{BMP Volume } (\text{IA-in})_1 &= (48,155 \text{ ft}^3 / 11.75 \text{ acre}) \times (12 \text{ in/ft} / 43,560 \text{ ft}^2/\text{acre}) \\ &= 1.13 \text{ in}\end{aligned}$$

- 4-1) The total volume of runoff ( $\text{ft}^3$ ) from the contributing PA (BMP Volume  $\text{PA-ft}^3$ ) for a rainfall size equal to the sum of BMP Volume  $(\text{IA-in})_1$  determined in step 3 is determined for each distinct pervious area identified in Table Example 3-4-B using the information from Table 3-3 and equation 3-5. Interpolation was used to determine runoff depths.

$$\begin{aligned}\text{BMP Volume } (\text{PA-ft}^3)_1 &= ((3.84 \text{ acre} \times (0.33 \text{ in}) + (0.96 \text{ acre} \times (0.13 \text{ in})) \times 3,630 \text{ ft}^3/\text{acre-in}) \\ &= 5052 \text{ ft}^3\end{aligned}$$

- 5-1) For iteration 1, the portion of BMP Volume that is available to treat runoff from only the IA is estimated by subtracting the BMP Volume  $(\text{PA-ft}^3)_1$ , determined in step 4-1, from BMP Volume $\text{ft}^3$ , determined in step 2, and converted to inches of runoff from IA:

$$\begin{aligned}\text{BMP Volume } (\text{IA-ft}^3)_2 &= 48,155 \text{ ft}^3 - 5052 \text{ ft}^3 \\ &= 43,103 \text{ ft}^3\end{aligned}$$

$$\begin{aligned}\text{BMP Volume } (\text{IA-in})_2 &= (43,103 \text{ ft}^3 / 11.75 \text{ acre}) \times (12 \text{ in/ft} \times 1 \text{ acre} / 43,560 \text{ ft}^2) \\ &= 1.01 \text{ in}\end{aligned}$$

**Solution continued:**

- 6-1)** The % difference between BMP Volume  $(IA-in)_2$ , 1.01 in, and BMP Volume  $(IA-in)_1$ , 1.13 in is determined and found to be significantly greater than 5%:

$$\begin{aligned}\% \text{ Difference} &= ((1.13 \text{ in} - 1.01 \text{ in}) / 1.01 \text{ in}) \times 100 \\ &= 12\%\end{aligned}$$

Therefore, steps 4 through 6 are repeated starting with BMP Volume  $(IA-in)_2 = 1.01 \text{ in}$ .

**Solution Iteration 2**

- 4-2)** BMP-Volume  $(PA-ft^3)_2 = ((3.84 \text{ acre} \times 0.21 \text{ in}) + (0.96 \text{ acre} \times 0.12 \text{ in})) \times 3,630 \text{ ft}^3/\text{acre-in}$   
 $= 3,358 \text{ ft}^3$

- 5-2)** BMP-Volume  $(IA-ft^3)_3 = 48,155 \text{ ft}^3 - 3,358 \text{ ft}^3$   
 $= 44,797 \text{ ft}^3$

$$\begin{aligned}\text{BMP-Volume } (IA-in)_3 &= (44,797 \text{ ft}^3 / 11.75 \text{ acre}) \times (12 \text{ in/ft} \times 1 \text{ acre} / 43,560 \text{ ft}^2) \\ &= 1.05 \text{ in}\end{aligned}$$

- 6-2)** % Difference  $= ((1.05 \text{ in} - 1.01 \text{ in}) / 1.05 \text{ in}) \times 100$   
 $= 4\%$

The difference of 4% is acceptable.

- 7)** The % phosphorus load reduction for the infiltration basin (BMP Reduction %<sub>-P</sub>) is determined by using the infiltration basin performance curve for an infiltration rate of 0.27 in/hr and the treatment volume (BMP-Volume <sub>Net IA-in</sub> = 1.05 in) calculated in step 5-2 and is **BMP Reduction %<sub>-P</sub> = 93%**.

The performance curve for IR = 0.27 is used rather than interpolating between the performance curves for IR = 0.27 in/hr and 0.52 in/hr to estimate performance for IR = 0.28 in/hr. An evaluation of the performance curves for IR = 0.27 in/hr and IR = 0.52 in/hr for a design storage volume of 1.05 in indicate a small difference in estimated performance (BMP Reduction %<sub>-P</sub> = 93% for IR = 0.27 in/hr and BMP Reduction %<sub>-P</sub> = 95% for IR = 0.52 in/hr).

- 8)** The cumulative phosphorus load reduction in pounds of phosphorus (BMP-Reduction <sub>lbs-P</sub>) for the proposed infiltration basin is calculated by using equation 3-2 with the BMP Load and the  $P_{\text{target}}$  of 93%.

$$\text{BMP-Reduction }_{\text{lbs-P}} = \text{BMP Load} \times (P_{\text{target}} / 100) \quad \text{(Equation 3-2)}$$

Using Table 3-1, the BMP load is calculated:

$$\begin{aligned}\text{BMP Load} &= (IA \times \text{impervious cover phosphorus export loading rate for industrial}) \\ &\quad + (PA_{\text{HSG D}} \times \text{pervious cover phosphorus export loading rate for HSG D}) \\ &\quad + (PA_{\text{HSG C}} \times \text{pervious cover phosphorus export loading rate for HSG C})\end{aligned}$$

**Solution continued:**

$$\begin{aligned}
 &= (11.75 \text{ acre} \times 1.96 \text{ lbs/acre/yr}) + (3.84 \text{ acre} \times 0.37 \text{ lbs/acre/yr}) \\
 &\quad + (0.96 \text{ acre} \times 0.21 \text{ lbs/acre/yr}) \\
 &= 24.65 \text{ lbs/yr}
 \end{aligned}$$

$$\text{BMP-Reduction}_{\text{lbs-P}} = 24.22 \text{ lbs/yr} \times 93/100 = \mathbf{22.93 \text{ lbs/yr}}$$

**Example 3-5: Determine the phosphorus load reduction for disconnecting impervious area using storage with delayed release.**

A commercial operation has an opportunity to divert runoff from 0.75 acres of impervious roof top to a 5000 gallon (668.4 ft<sup>3</sup>) storage tank for temporary storage and subsequent release to 0.09 acres of pervious area (PA) with HSG C soils.

Determine the:

- Percent phosphorus load reduction rates (BMP Reduction %<sub>-P</sub>) for the specified impervious area (IA) disconnection and storage system assuming release times of 1, 2 and 3 days for the stored volumes to discharge to the pervious area; and
- Cumulative phosphorus reductions in pounds that would be accomplished by the system (BMP-Reduction<sub>lbs-P</sub>) for the three storage release times, 1, 2 and 3 days.

**Solution:**

- Determine the storage volume in units of inches of runoff depth from contributing impervious area:  

$$\text{Storage Volume}_{\text{IA-in}} = (668.4 \text{ ft}^3 / (0.75 \text{ acre} \times 43.560 \text{ ft}^2/\text{acre})) \times 12 \text{ inch/ft}$$

$$= 0.25 \text{ inches}$$
- Determine the ratio of the contributing impervious area to the receiving pervious area:  

$$\text{IA:PA} = 0.75 \text{ acres} / 0.09 \text{ acres}$$

$$= 8.3$$
- Using Table 3-21 for a IA:PA ratio of 8:1, determine the phosphorus load reduction rates for a storage volume of 0.25 inches that discharges to HSG C with release rates of 1, 2 and 3 days: Using interpolation the reduction rates are shown in Table 3-5-A:

**Table Example 3-5-A: Reduction Rates**

| Percent Phosphorus load reduction for IA disconnection with storage HSG C |                            |     |     |
|---------------------------------------------------------------------------|----------------------------|-----|-----|
| Storage Volume <sub>IA-in</sub>                                           | Storage release rate, days |     |     |
|                                                                           | 1                          | 2   | 3   |
| 0.25                                                                      | 39%                        | 42% | 43% |

- The cumulative phosphorus load reduction in pounds of phosphorus for the IA disconnection with storage (BMP-Reduction<sub>lbs-P</sub>) is calculated using Equation 3-2. The BMP Load is first determined using the method described above.

**Solution continued:**

$$\begin{aligned}\text{BMP Load} &= \text{IA} \times \text{phosphorus export loading rate for commercial IA (see Table 3-1)} \\ &= 0.75 \text{ acres} \times 1.78 \text{ lbs/acre/yr} \\ &= 1.34 \text{ lbs/yr}\end{aligned}$$

$$\text{BMP Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{BMP Reduction}_{\%-\text{P}}/100)$$

$$\begin{aligned}\text{BMP Reduction}_{\text{lbs-P}} &= 1.34 \text{ lbs/yr} \times (39/100) \\ &= \mathbf{0.53 \text{ lbs/yr}}\end{aligned}$$

Table Example 3-5-B presents the BMP Reduction  $_{\text{lbs-P}}$  for each of the release rates:

**Table Example 3-5-B: Reduction Load**

| Phosphorus load reduction for IA<br>disconnection with storage HSG C, lbs |                            |      |      |
|---------------------------------------------------------------------------|----------------------------|------|------|
| Storage<br>Volume $_{\text{IA-in}}$                                       | Storage release rate, days |      |      |
|                                                                           | 1                          | 2    | 3    |
| 0.25                                                                      | 0.53                       | 0.56 | 0.58 |

**Example 3-6: Determine the phosphorus load reduction for disconnecting impervious area with and without soil augmentation in the receiving pervious area.**

The same commercial property as in example 3-5 wants to evaluate disconnecting drainage from the 0.75 acre impervious roof top and discharging it directly to 0.09 acres of pervious area (PA) with HSG C. Also, the property has the opportunity to purchase a small adjoining area (0.06 acres), also HSG C, to increase the size of the receiving PA from 0.09 to 0.15 acres and to allow the property owner to avoid having to install a drainage structure to capture overflow runoff from the PA. The property owner has been informed that the existing PA soil can be tilled and augmented with soil amendments to support denser vegetative growth and improve hydrologic function to approximate HSG B.

Determine the:

- Percent phosphorus load reduction rates (BMP Reduction  $_{\%-\text{P}}$ ) for the specified impervious area (IA) disconnection to both the 0.09 and 0.15 acre receiving PAs with and without soil augmentation; and
- Cumulative phosphorus reductions in pounds that would be accomplished by the IA disconnection for the various scenarios (BMP-Reduction  $_{\text{lbs-P}}$ ).

**Solution:**

- Determine the ratio of the contributing impervious area to the receiving pervious area:
 
$$\begin{aligned}\text{IA:PA} &= 0.75 \text{ acres}/0.09 \text{ acres} \\ &= 8.3 \\ \text{IA:PA} &= 0.75 \text{ acres}/0.15 \text{ acres} \\ &= 5.0\end{aligned}$$

**Solution Continued:**

2. Using Table 3-26 and Figure 3-40 for a IA:PA ratios of 8:1 and 5:1, respectively, determine the phosphorus load reduction rates for IA disconnections to HSG C and HSG B:

**Table Example 3-6-A: Reduction Rates**

| Percent Phosphorus load reduction rates for IA disconnection |       |     |
|--------------------------------------------------------------|-------|-----|
| Receiving PA                                                 | IA:PA |     |
|                                                              | 8:1   | 5:1 |
| HSG C                                                        | 7%    | 14% |
| HSG B (soil augmentation)                                    | 14%   | 22% |

3. The cumulative phosphorus load reduction in pounds of phosphorus for the IA disconnection with storage (BMP-Reduction<sub>lbs-P</sub>) is calculated using Equation 3-2. The BMP Load was calculated in example 3-5 and is 1.34 lbs/yr.

$$\text{BMP Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{BMP Reduction}_{\%-\text{P}}/100)$$

For PA of 0.09 acres HSG C the BMP Reduction<sub>lbs-P</sub> is calculated as follows:

$$\begin{aligned} \text{BMP Reduction}_{\text{lbs-P}(0.09\text{ac}-\text{HSG C})} &= 1.34 \text{ lbs/yr} \times (7/100) \\ &= \mathbf{0.09 \text{ lbs/yr}} \end{aligned}$$

Table Example 3-6-B presents the BMP Reduction<sub>lbs-P</sub> for each of the scenarios:

**Table Example 3-6-B: Reduction**

| Pounds Phosphorus load reduction for IA disconnection, lbs/yr |                             |      |
|---------------------------------------------------------------|-----------------------------|------|
| Receiving PA                                                  | Area of Receiving PA, acres |      |
|                                                               | 0.09                        | 0.15 |
| HSG C                                                         | 0.09                        | 0.19 |
| HSG B (soil augmentation)                                     | 0.19                        | 0.29 |

**Example 3-7: Determine the phosphorus load reduction for converting impervious area to permeable/pervious area.**

A municipality is planning upcoming road reconstruction work in medium density residential (MDR) neighborhoods and has identified an opportunity to convert impervious surfaces to permeable/pervious surfaces by narrowing the road width of 3.7 miles (mi) of roadway from 32 feet (ft) to 28 ft and eliminating 3.2 miles of 4 ft wide paved sidewalk (currently there are sidewalks on both sides of the roadways targeted for restoration). The newly created permeable/pervious area will be tilled and treated with soil amendments to support vegetated growth in order to restore hydrologic function to at least HSG B.

Determine the:

- A) Percent phosphorus load reduction rate (BMP Reduction %<sub>-P</sub>) for the conversion of impervious area (IA) to permeable/pervious area (PA); and
- B) Cumulative phosphorus reduction in pounds that would be accomplished by the project (BMP-Reduction <sub>lbs-P</sub>).

**Solution:**

1. Determine the area of IA to be converted to PA:  

$$\text{New PA} = (((3.7 \text{ mi} \times 4 \text{ ft}) + (3.2 \text{ mi} \times 4 \text{ ft})) \times 5280 \text{ ft/mi}) / 43,560 \text{ ft}^2/\text{acre}$$

$$= 3.35 \text{ acres}$$
2. Using Table 3-27, the phosphorus load reduction rate for converting IA to HSG B is 94.1%
3. The BMP Load is first determined using the method described above.  

$$\text{BMP Load} = \text{IA} \times \text{phosphorus export loading rate for MDR IA (see Table 3-1)}$$

$$= 3.35 \text{ acres} \times 1.96 \text{ lbs/acre/yr}$$

$$= 6.57 \text{ lbs/yr}$$
4. The cumulative phosphorus load reduction in pounds of phosphorus for the IA conversion (BMP-Reduction <sub>lbs-P</sub>) is calculated using Equation 3-2.  

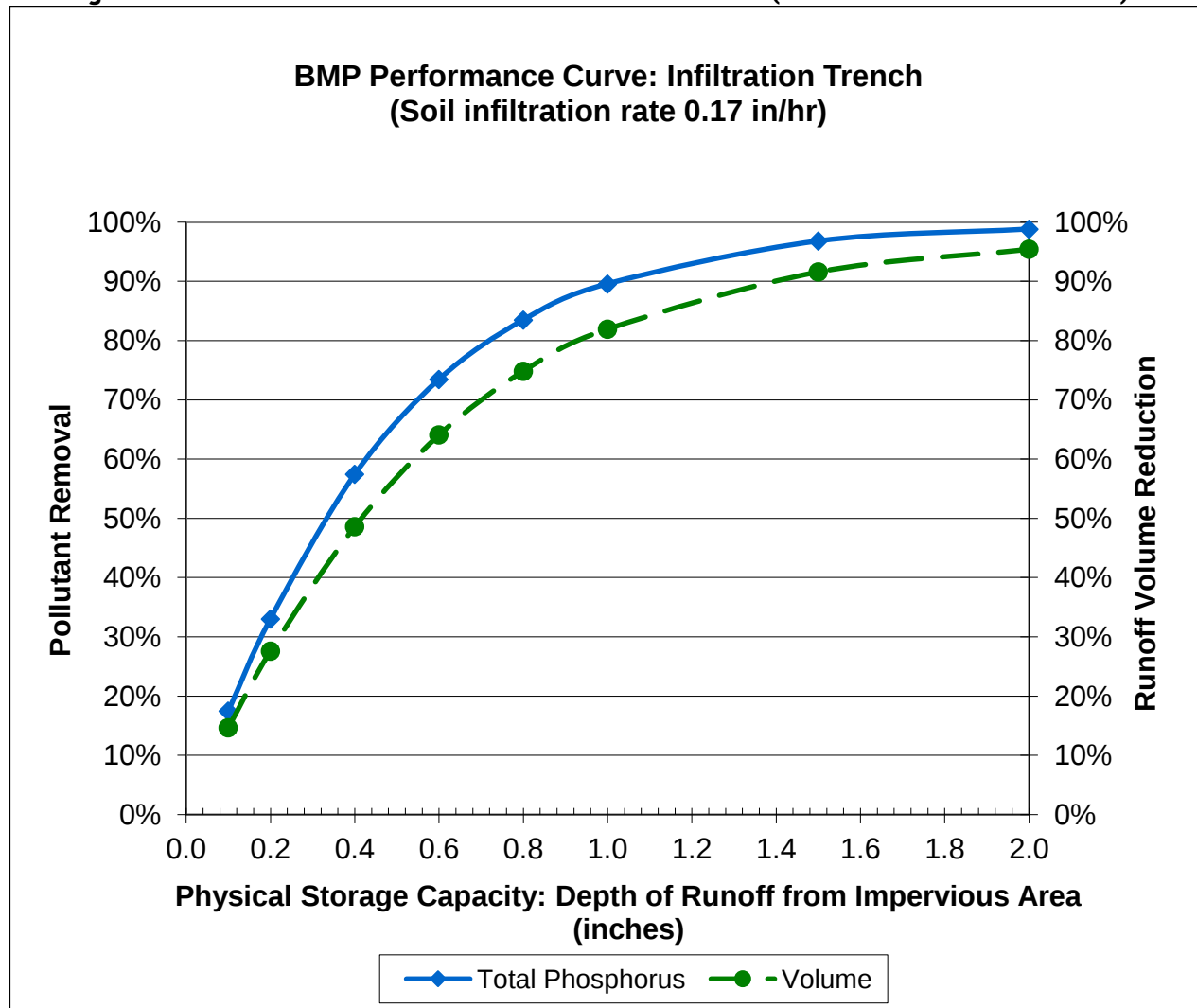
$$\text{BMP Reduction}_{\text{lbs-P}} = \text{BMP Load} \times (\text{BMP Reduction \%}_{-P} / 100)$$

$$\text{BMP Reduction}_{\text{lbs-P}} = 6.57 \text{ lbs/yr} \times (94.1 / 100)$$

$$= 6.18 \text{ lbs/yr}$$

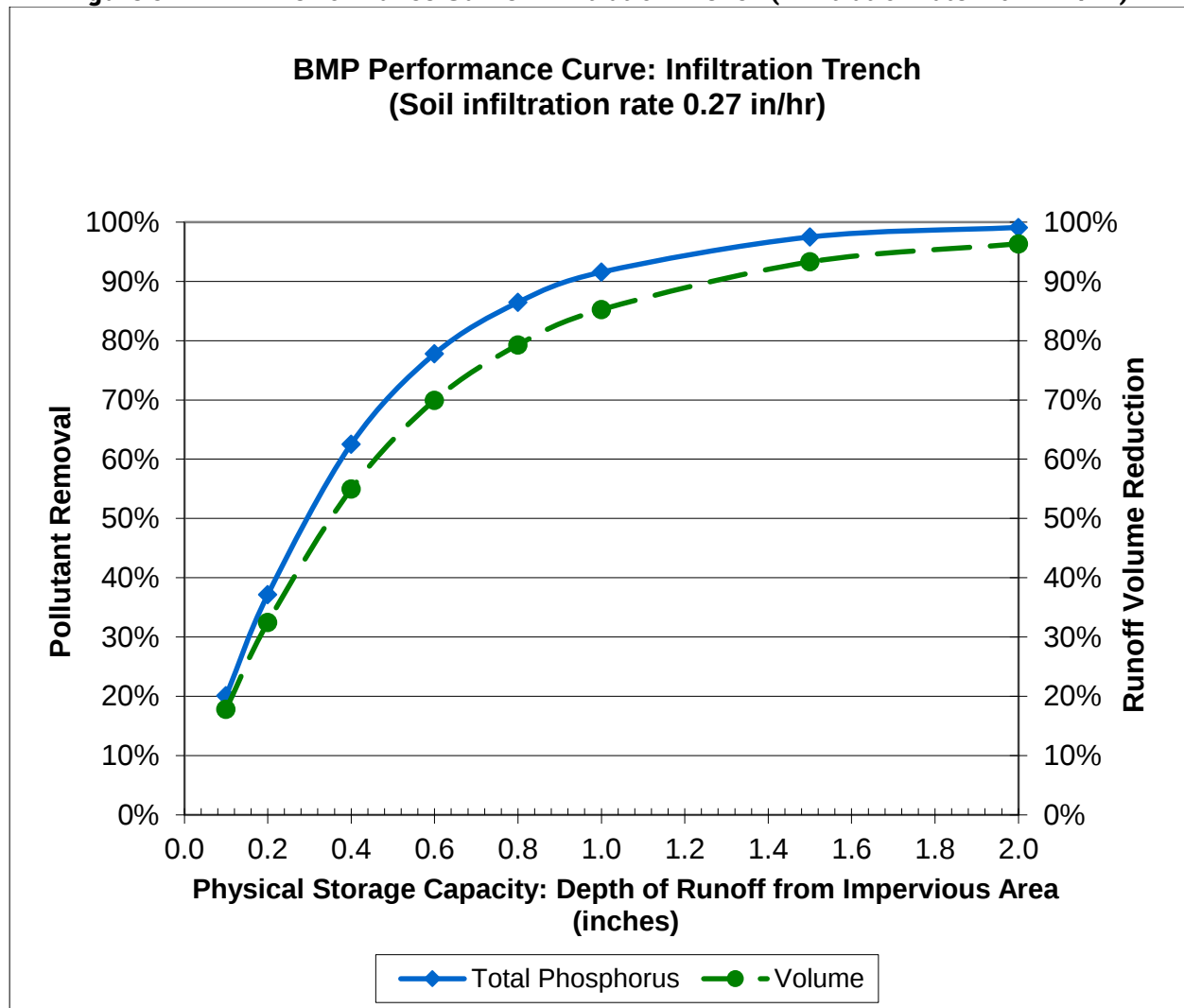
**Table 3- 4: Infiltration Trench (IR = 0.17 in/hr) BMP Performance Table**

| Infiltration Trench (IR = 0.17 in/hr) BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                                 | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                             | 14.7% | 27.6% | 48.6% | 64.1% | 74.9% | 82.0% | 91.6% | 95.4% |
| Cumulative Phosphorus Load Reduction                                                                | 18%   | 33%   | 57%   | 73%   | 83%   | 90%   | 97%   | 99%   |

**Figure 3- 1: BMP Performance Curve: Infiltration Trench (infiltration rate = 0.17 in/hr)**

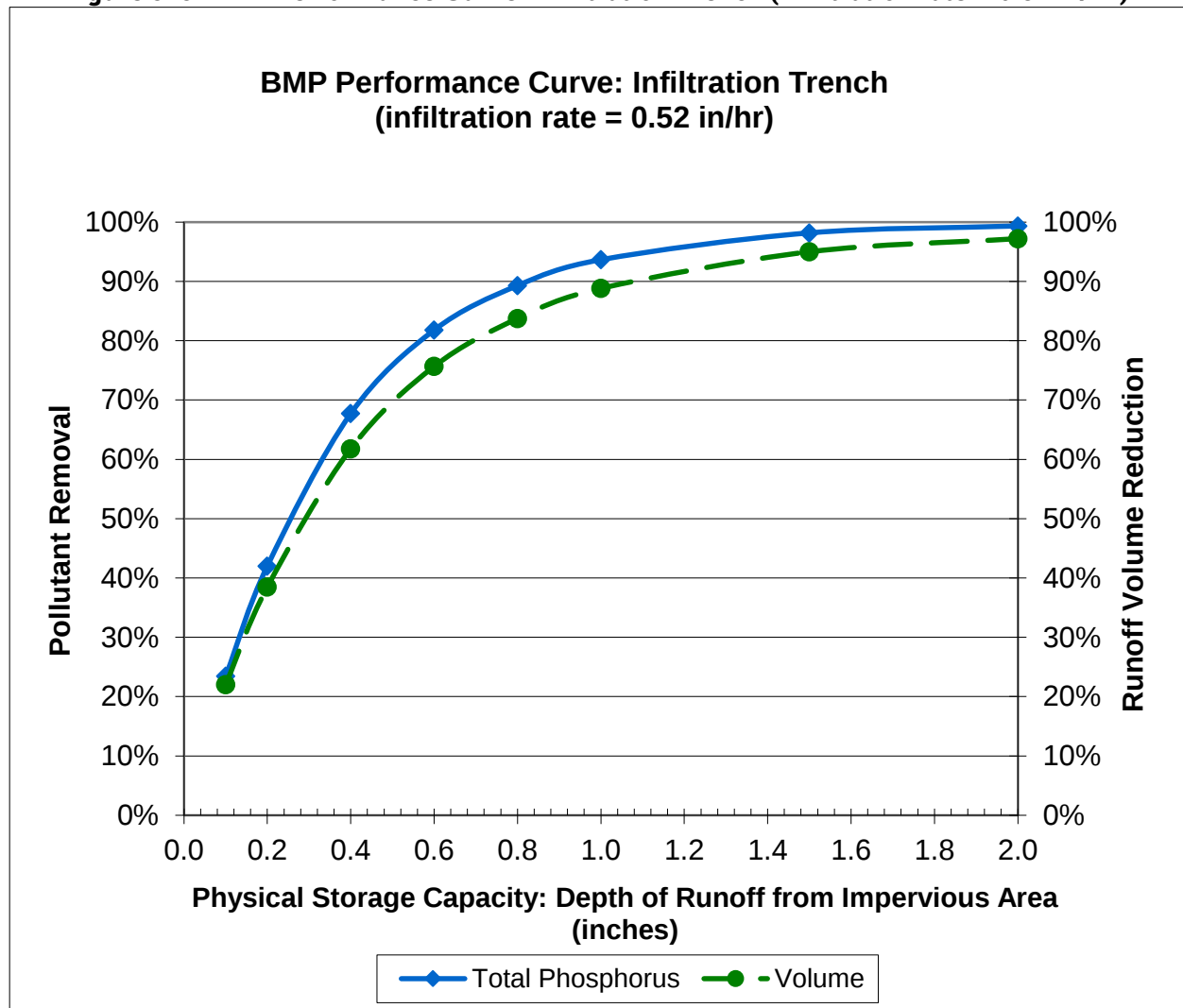
**Table 3- 5: Infiltration Trench (IR = 0.27 in/hr) BMP Performance Table**

| Infiltration Trench (IR = 0.27 in/hr) BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                                 | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                             | 17.8% | 32.5% | 55.0% | 70.0% | 79.3% | 85.2% | 93.3% | 96.3% |
| Cumulative Phosphorus Load Reduction                                                                | 20%   | 37%   | 63%   | 78%   | 86%   | 92%   | 97%   | 99%   |

**Figure 3- 2: BMP Performance Curve: Infiltration Trench (infiltration rate = 0.27 in/hr)**

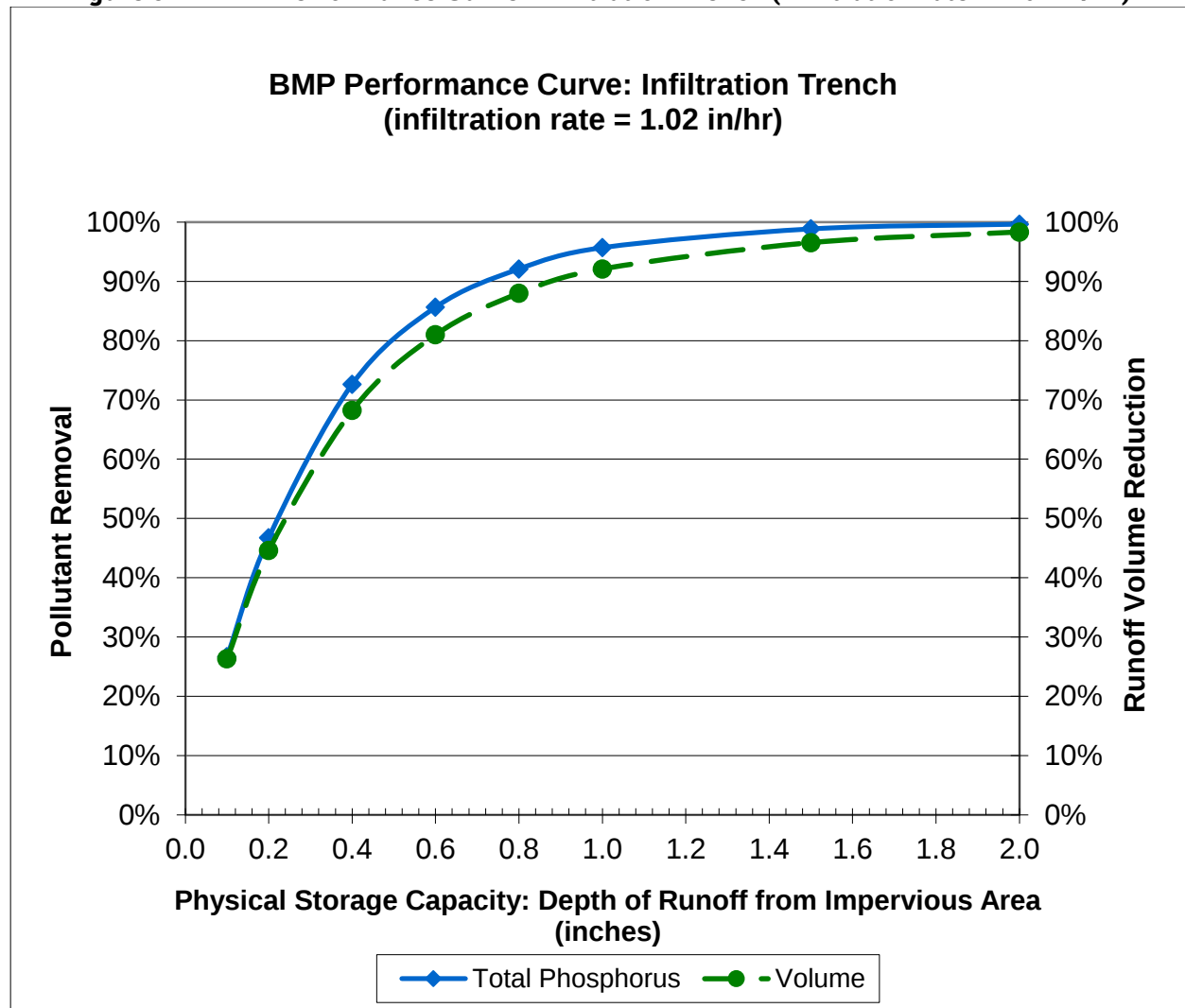
**Table 3- 6: Infiltration Trench (IR = 0.52 in/hr) BMP Performance Table**

| Infiltration Trench (IR = 0.52 in/hr) BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                                 | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                             | 22.0% | 38.5% | 61.8% | 75.7% | 83.7% | 88.8% | 95.0% | 97.2% |
| Cumulative Phosphorus Load Reduction                                                                | 23%   | 42%   | 68%   | 82%   | 89%   | 94%   | 98%   | 99%   |

**Figure 3- 3: BMP Performance Curve: Infiltration Trench (infiltration rate = 0.52 in/hr)**

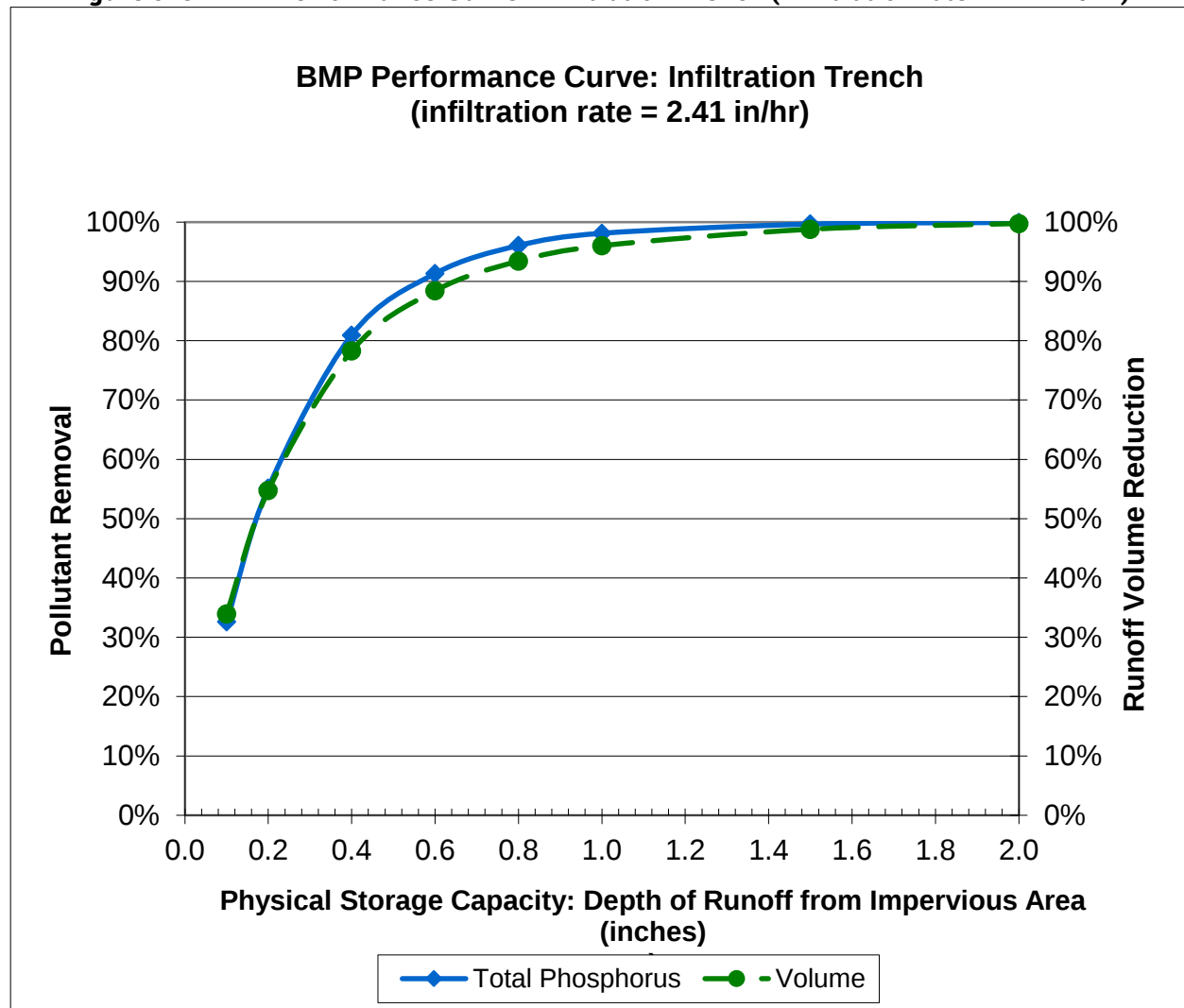
**Table 3- 7: Infiltration Trench (IR = 1.02 in/hr) BMP Performance Table**

| Infiltration Trench (IR = 1.02 in/hr) BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                                 | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                             | 26.3% | 44.6% | 68.2% | 81.0% | 88.0% | 92.1% | 96.5% | 98.3% |
| Cumulative Phosphorus Load Reduction                                                                | 27%   | 47%   | 73%   | 86%   | 92%   | 96%   | 99%   | 100%  |

**Figure 3- 4: BMP Performance Curve: Infiltration Trench (infiltration rate = 1.02 in/hr)**

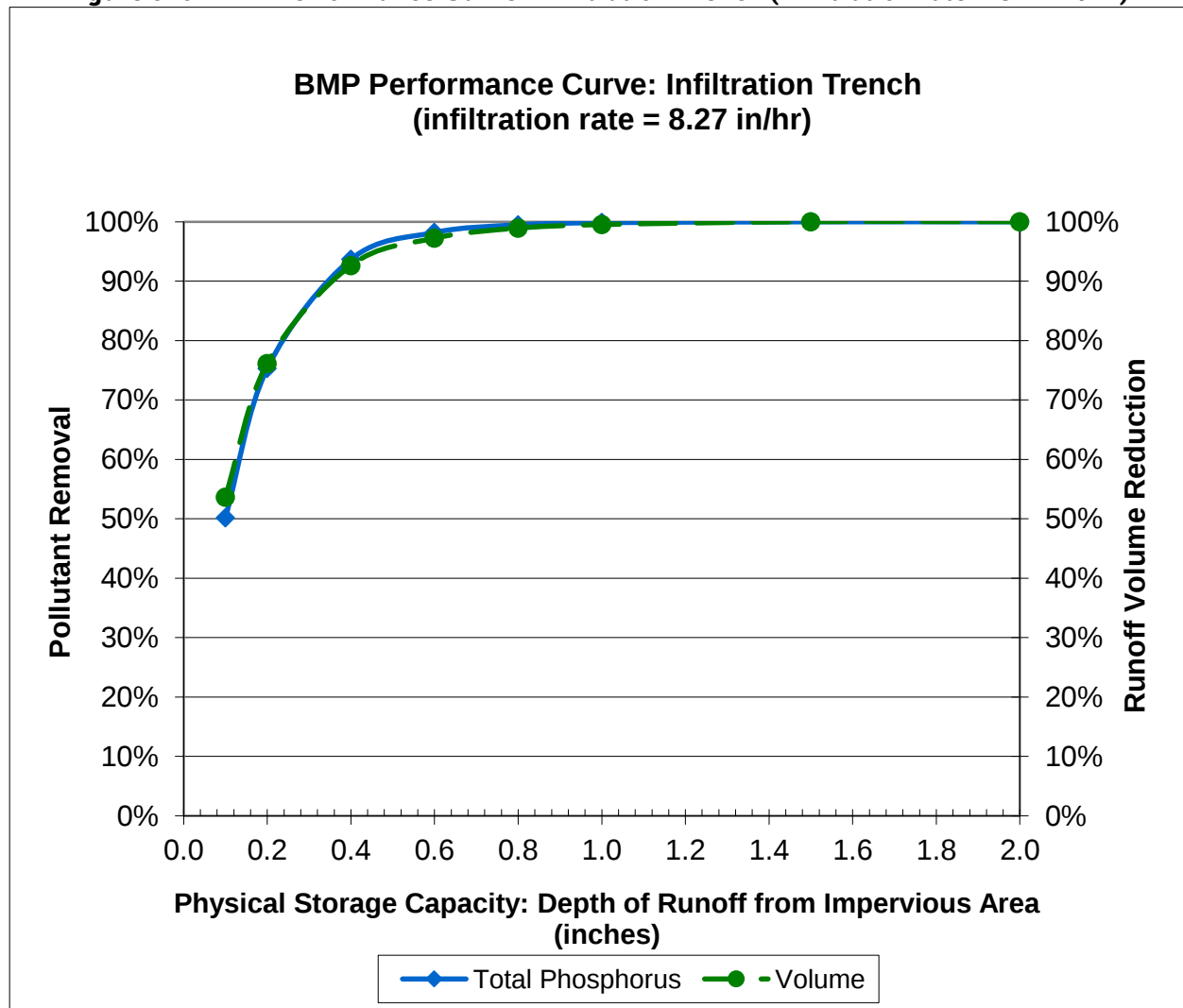
**Table 3- 8: Infiltration Trench (IR = 2.41 in/hr) BMP Performance Table**

| Infiltration Trench (IR = 2.41 in/hr) BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                                 | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                             | 34.0% | 54.7% | 78.3% | 88.4% | 93.4% | 96.0% | 98.8% | 99.8% |
| Cumulative Phosphorus Load Reduction                                                                | 33%   | 55%   | 81%   | 91%   | 96%   | 98%   | 100%  | 100%  |

**Figure 3- 5: BMP Performance Curve: Infiltration Trench (infiltration rate = 2.41 in/hr)**

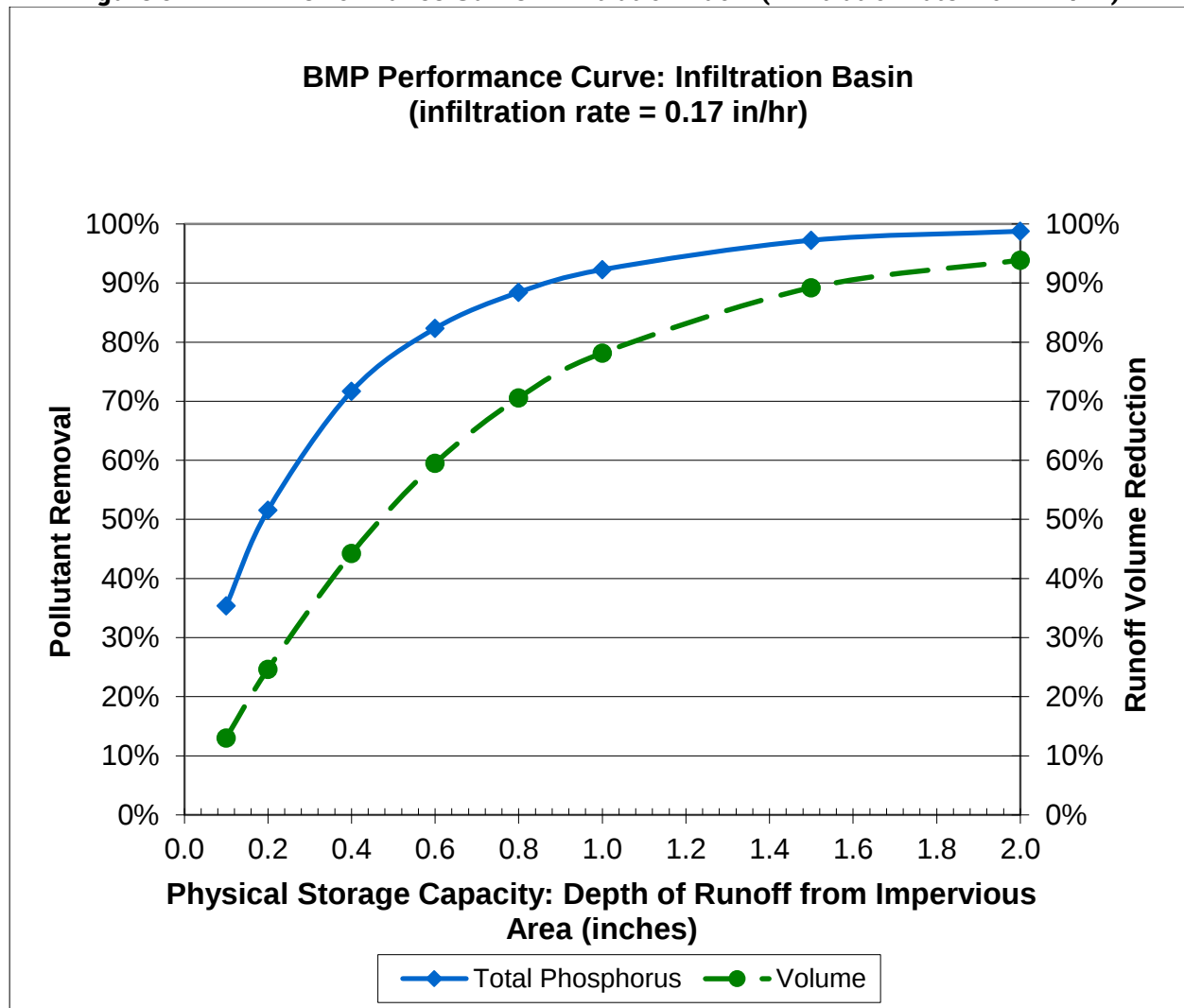
**Table 3- 9: Infiltration Trench (8.27 in/hr) BMP Performance Table**

| Infiltration Trench (8.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |        |        |
|---------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|--------|--------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                         | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5    | 2.0    |
| Runoff Volume Reduction                                                                     | 53.6% | 76.1% | 92.6% | 97.2% | 98.9% | 99.5% | 100.0% | 100.0% |
| Cumulative Phosphorus Load Reduction                                                        | 50%   | 75%   | 94%   | 98%   | 99%   | 100%  | 100%   | 100%   |

**Figure 3- 6: BMP Performance Curve: Infiltration Trench (infiltration rate = 8.27 in/hr)**

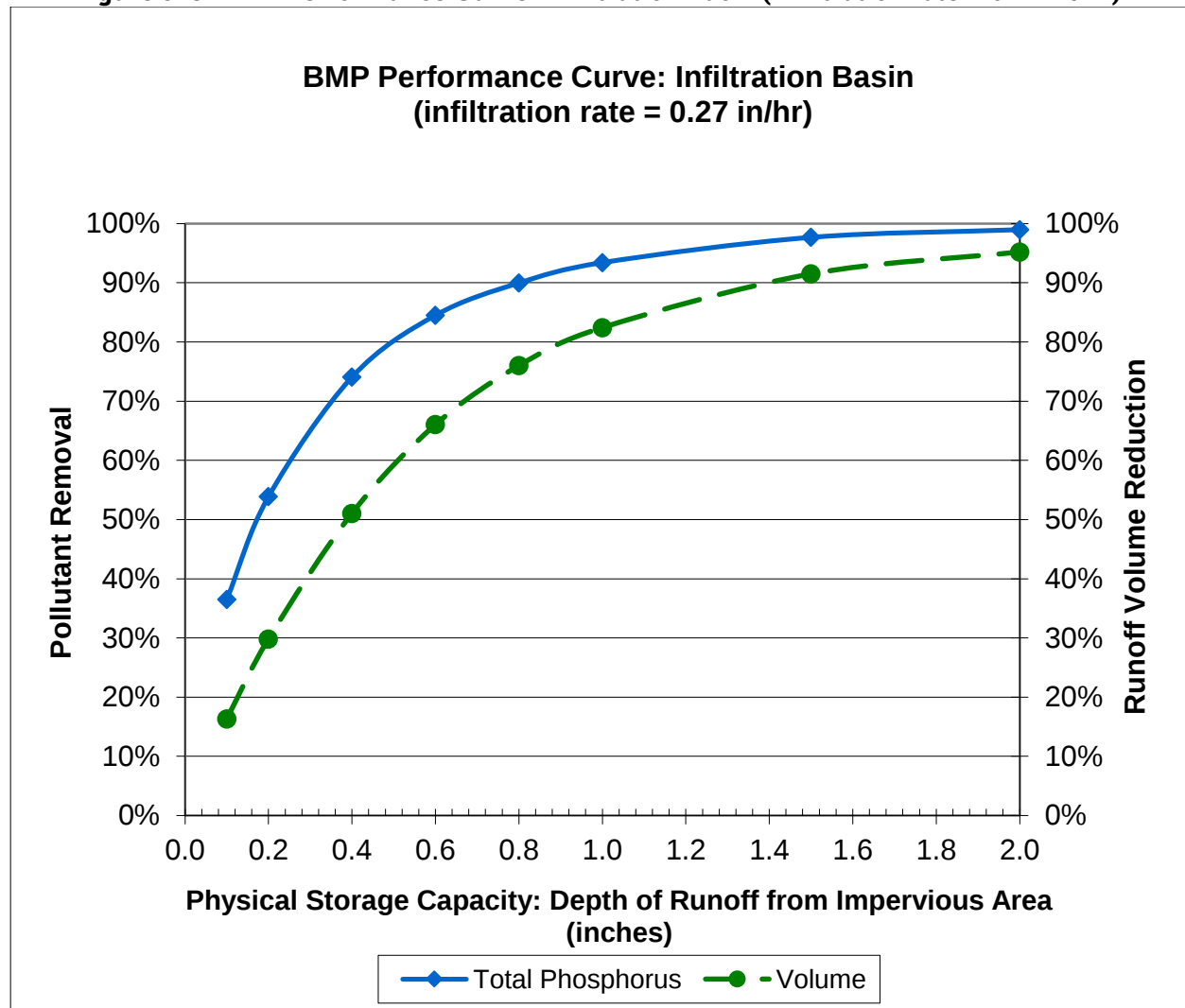
**Table 3- 10: Infiltration Basin (0.17 in/hr) BMP Performance Table**

| Infiltration Basin (0.17 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                    | 13.0% | 24.6% | 44.2% | 59.5% | 70.6% | 78.1% | 89.2% | 93.9% |
| Cumulative Phosphorus Load Reduction                                                       | 35%   | 52%   | 72%   | 82%   | 88%   | 92%   | 97%   | 99%   |

**Figure 3- 7: BMP Performance Curve: Infiltration Basin (infiltration rate = 0.17 in/hr)**

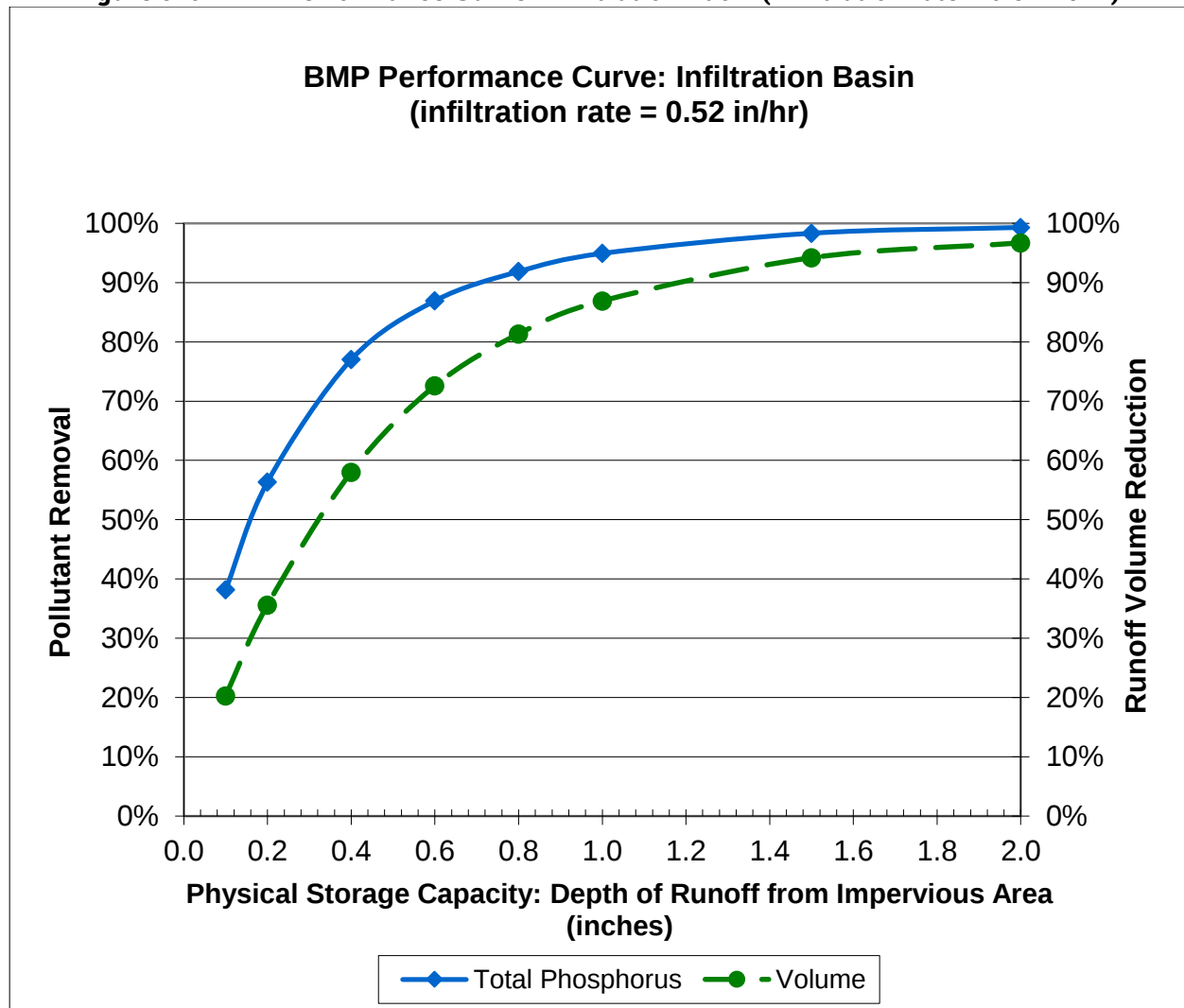
**Table 3- 11: Infiltration Basin (0.27 in/hr) BMP Performance Table**

| Infiltration Basin (0.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                    | 16.3% | 29.8% | 51.0% | 66.0% | 76.0% | 82.4% | 91.5% | 95.2% |
| Cumulative Phosphorus Load Reduction                                                       | 37%   | 54%   | 74 %  | 85%   | 90%   | 93%   | 98%   | 99%   |

**Figure 3- 8: BMP Performance Curve: Infiltration Basin (infiltration rate = 0.27 in/hr)**

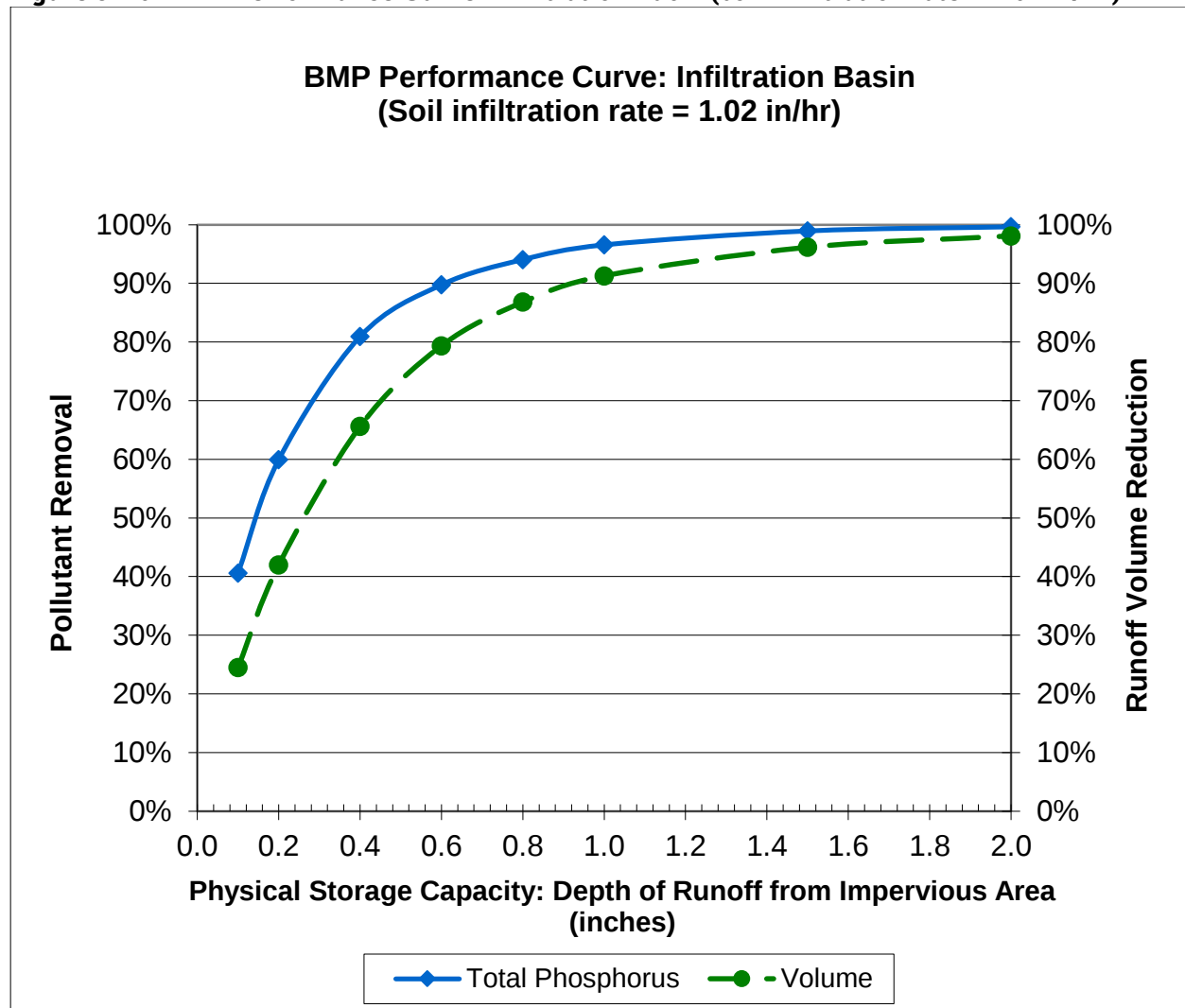
**Table 3- 12: Infiltration Basin (0.52 in/hr) BMP Performance Table**

| Infiltration Basin (0.52 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                    | 20.2% | 35.6% | 58.0% | 72.6% | 81.3% | 86.9% | 94.2% | 96.7% |
| Cumulative Phosphorus Load Reduction                                                       | 38%   | 56%   | 77%   | 87%   | 92%   | 95%   | 98%   | 99%   |

**Figure 3- 9: BMP Performance Curve: Infiltration Basin (infiltration rate = 0.52 in/hr)**

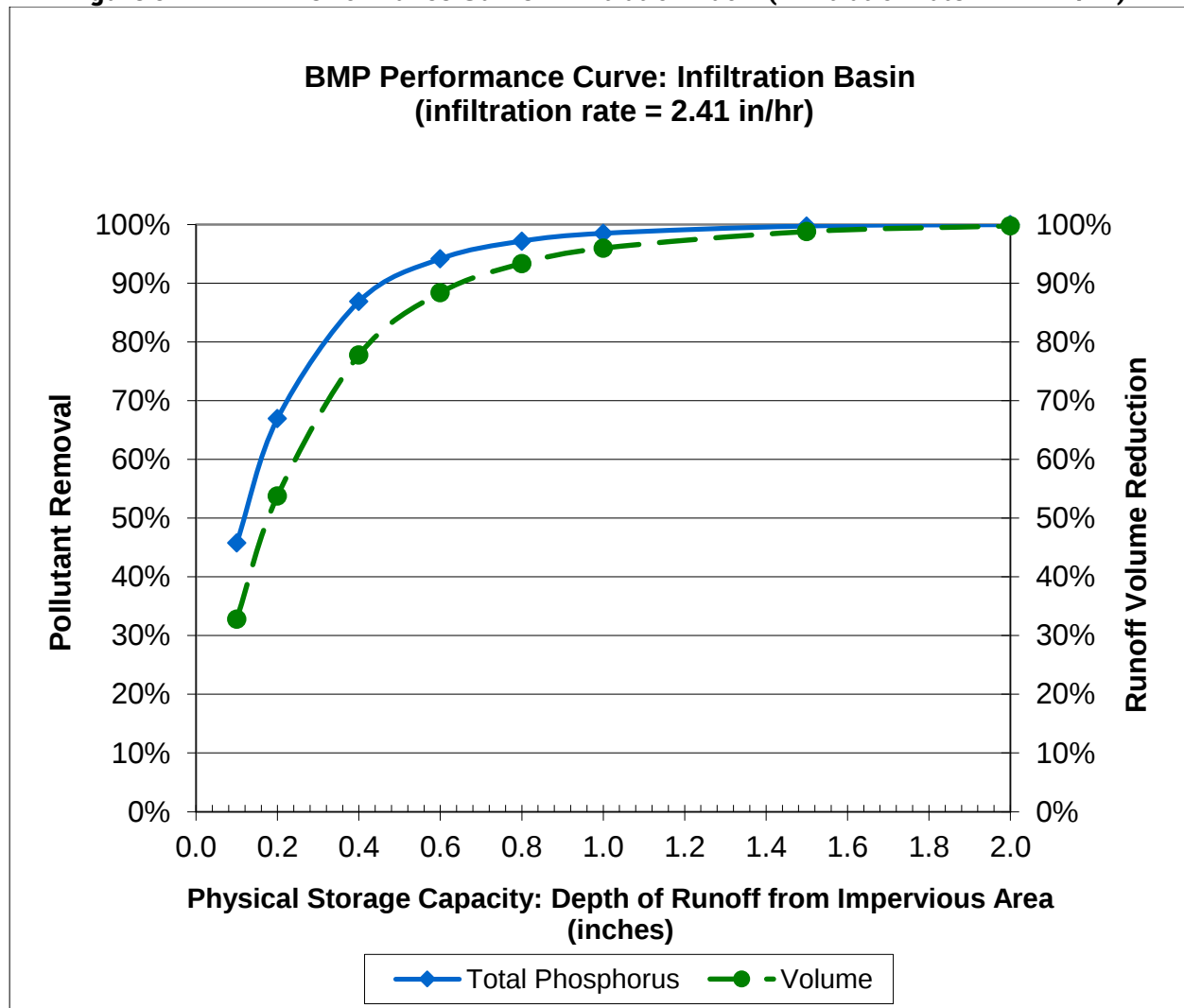
**Table 3- 13: Infiltration Basin (1.02 in/hr) BMP Performance Table**

| Infiltration Basin (1.02 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                    | 24.5% | 42.0% | 65.6% | 79.4% | 86.8% | 91.3% | 96.2% | 98.1% |
| Cumulative Phosphorus Load Reduction                                                       | 41%   | 60%   | 81%   | 90%   | 94%   | 97%   | 99%   | 100%  |

**Figure 3- 10: BMP Performance Curve: Infiltration Basin (Soil infiltration rate = 1.02 in/hr)**

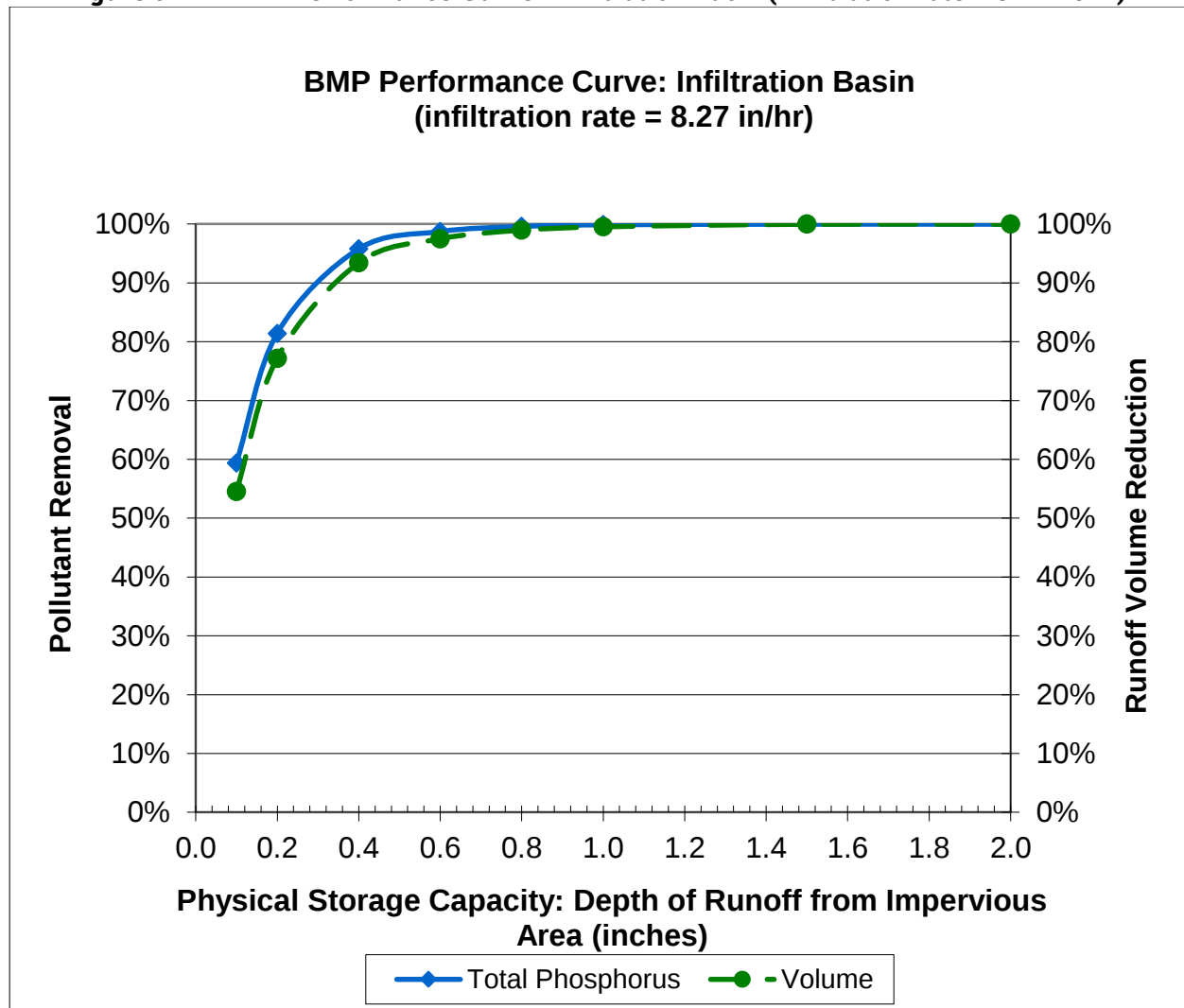
**Table 3- 14: Infiltration Basin (2.41 in/hr) BMP Performance Table**

| Infiltration Basin (2.41 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5   | 2.0   |
| Runoff Volume Reduction                                                                    | 32.8% | 53.8% | 77.8% | 88.4% | 93.4% | 96.0% | 98.8% | 99.8% |
| Cumulative Phosphorus Load Reduction                                                       | 46%   | 67%   | 87%   | 94%   | 97%   | 98%   | 100%  | 100%  |

**Figure 3- 11: BMP Performance Curve: Infiltration Basin (infiltration rate = 2.41 in/hr)**

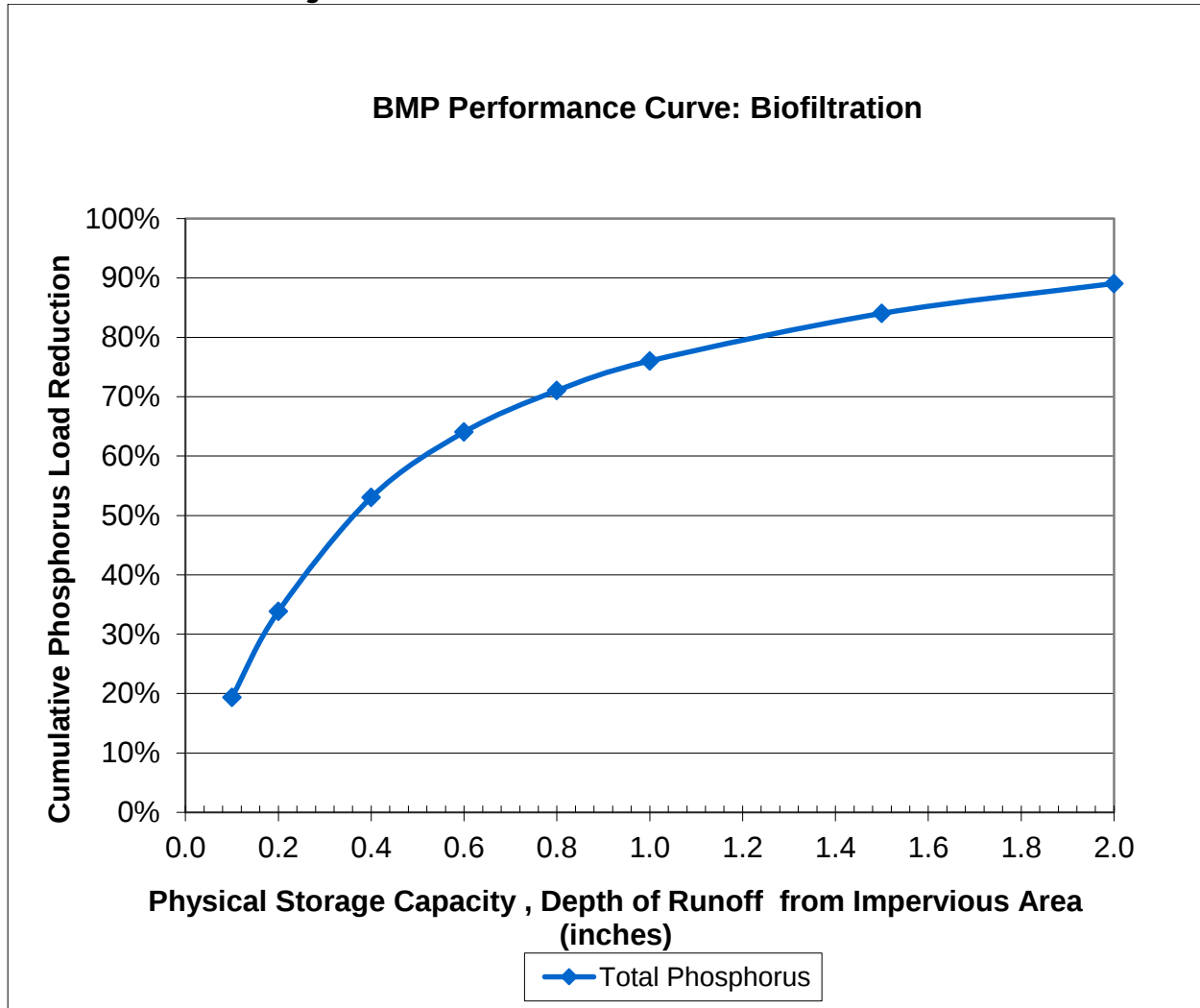
**Table 3- 15: Infiltration Basin (8.27 in/hr) BMP Performance Table**

| Infiltration Basin (8.27 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction |       |       |       |       |       |       |        |        |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|--------|--------|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)                        | 0.1   | 0.2   | 0.4   | 0.6   | 0.8   | 1.0   | 1.5    | 2.0    |
| Runoff Volume Reduction                                                                    | 54.6% | 77.2% | 93.4% | 97.5% | 99.0% | 99.6% | 100.0% | 100.0% |
| Cumulative Phosphorus Load Reduction                                                       | 59%   | 81%   | 96%   | 99%   | 100%  | 100%  | 100%   | 100%   |

**Figure 3- 12: BMP Performance Curve: Infiltration Basin (infiltration rate = 8.27 in/hr)**

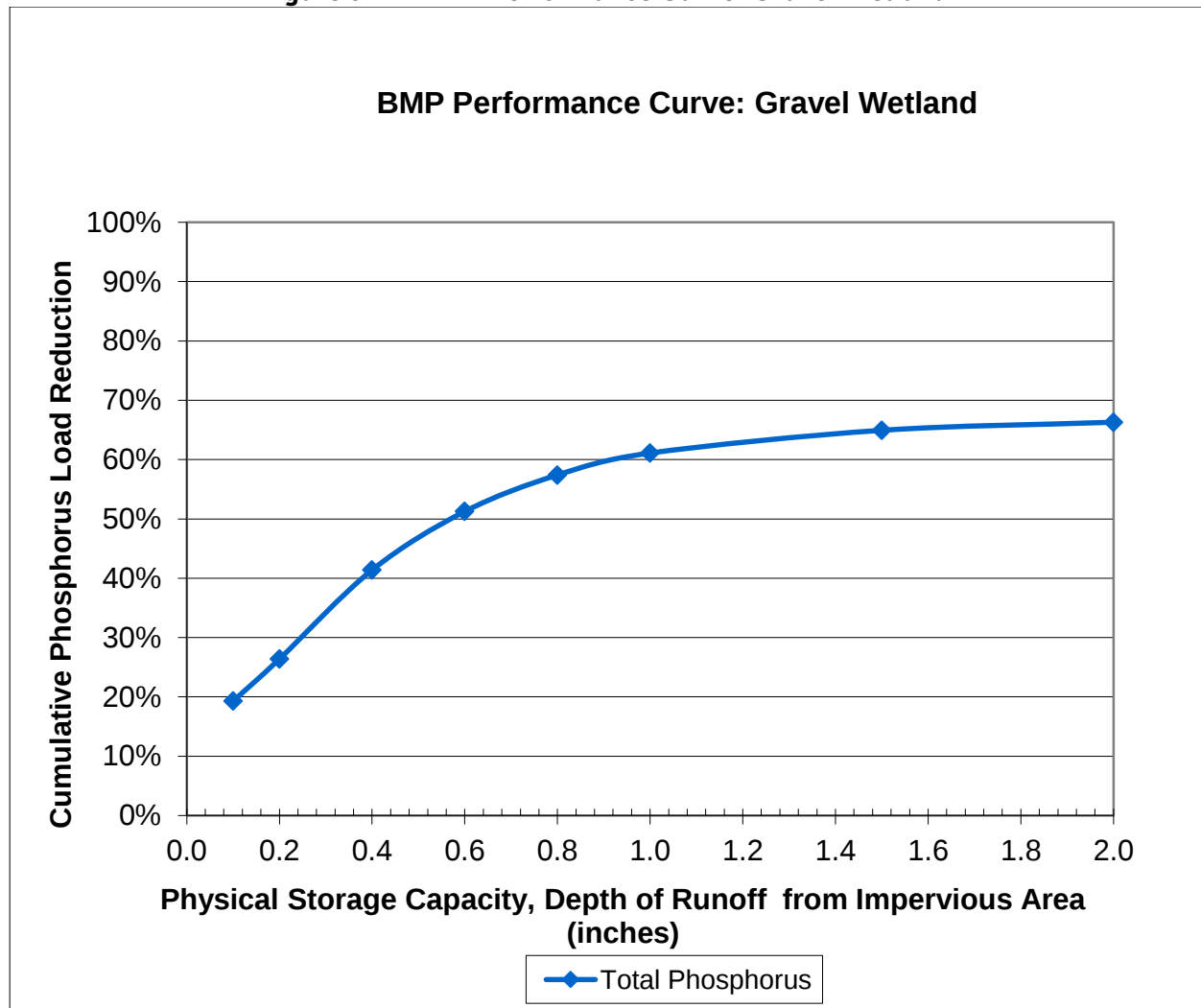
**Table 3- 16: Biofiltration BMP Performance Table**

| Biofiltration BMP Performance Table: Long-Term Phosphorus Load Reduction |     |     |     |     |     |     |     |     |
|--------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)      | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 |
| Cumulative Phosphorus Load Reduction                                     | 19% | 34% | 53% | 64% | 71% | 76% | 84% | 89% |

**Figure 3- 13: BMP Performance Curve: Biofiltration**

**Table 3- 17: Gravel Wetland BMP Performance Table**

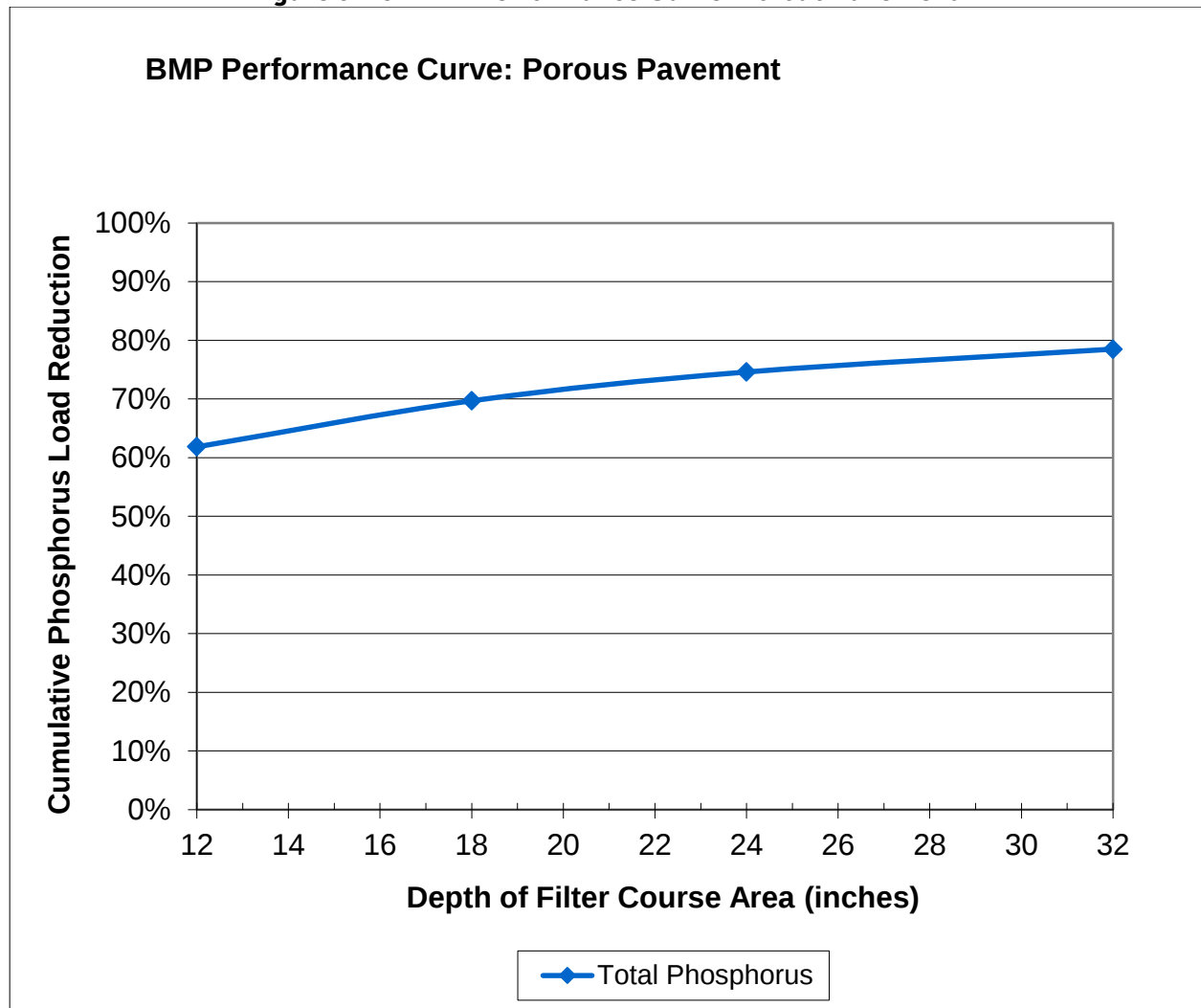
| Gravel Wetland BMP Performance Table: Long-Term Phosphorus Load Reduction |     |     |     |     |     |     |     |     |
|---------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)       | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 |
| Cumulative Phosphorus Load Reduction                                      | 19% | 26% | 41% | 51% | 57% | 61% | 65% | 66% |

**Figure 3- 14: BMP Performance Curve: Gravel Wetland**

**Table 3- 18: Porous Pavement BMP Performance Table**

| Porous Pavement BMP Performance Table:<br>Long-Term Phosphorus Load Reduction |      |      |      |      |
|-------------------------------------------------------------------------------|------|------|------|------|
| BMP Capacity: Depth of Filter Course<br>Area (inches)                         | 12.0 | 18.0 | 24.0 | 32.0 |
| Cumulative Phosphorus Load<br>Reduction                                       | 62%  | 70%  | 75%  | 78%  |

**Figure 3- 15: BMP Performance Curve: Porous Pavement**



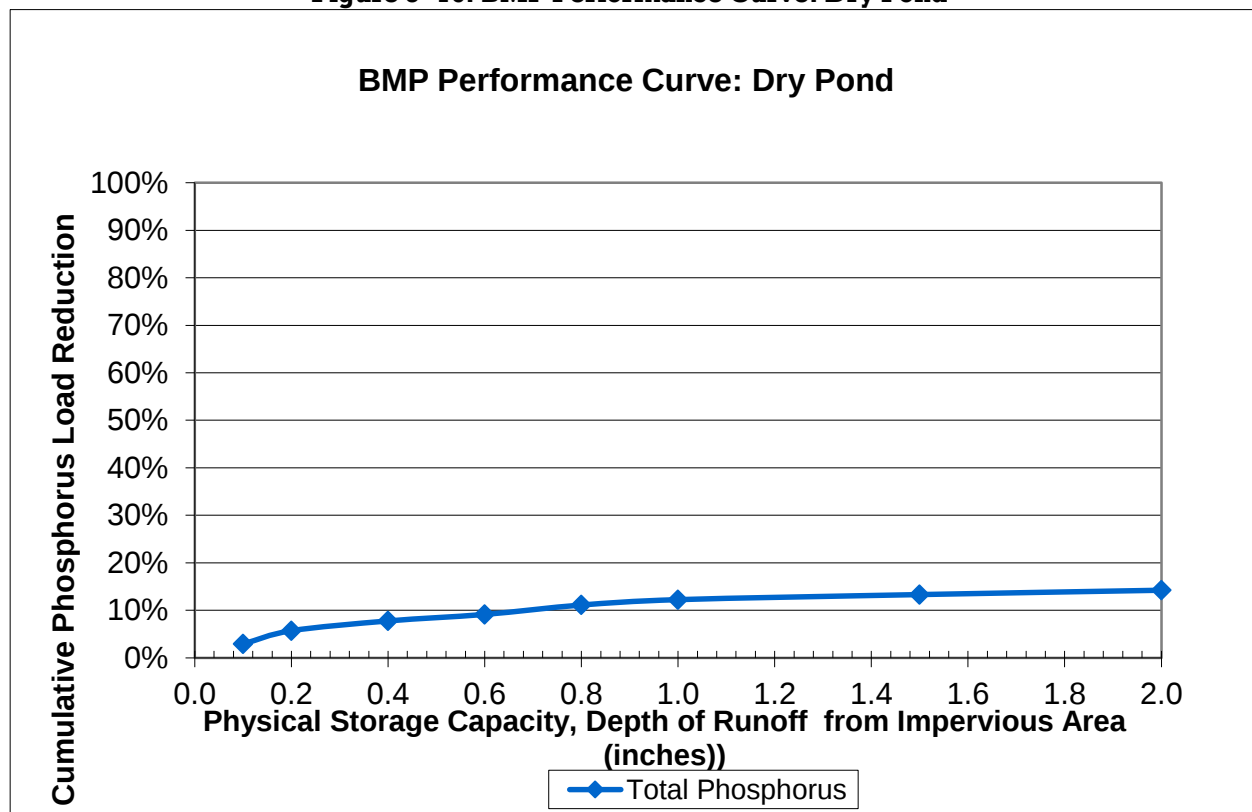
**Table 3- 19: Wet Pond BMP Performance Table**

| Wet Pond BMP Performance Table: Long-Term Phosphorus Load Reduction |     |     |     |     |     |     |     |     |
|---------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches) | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 |
| Cumulative Phosphorus Load Reduction                                | 14% | 25% | 37% | 44% | 48% | 53% | 58% | 63% |

**Table 3- 20: Dry Pond BMP Performance Table**

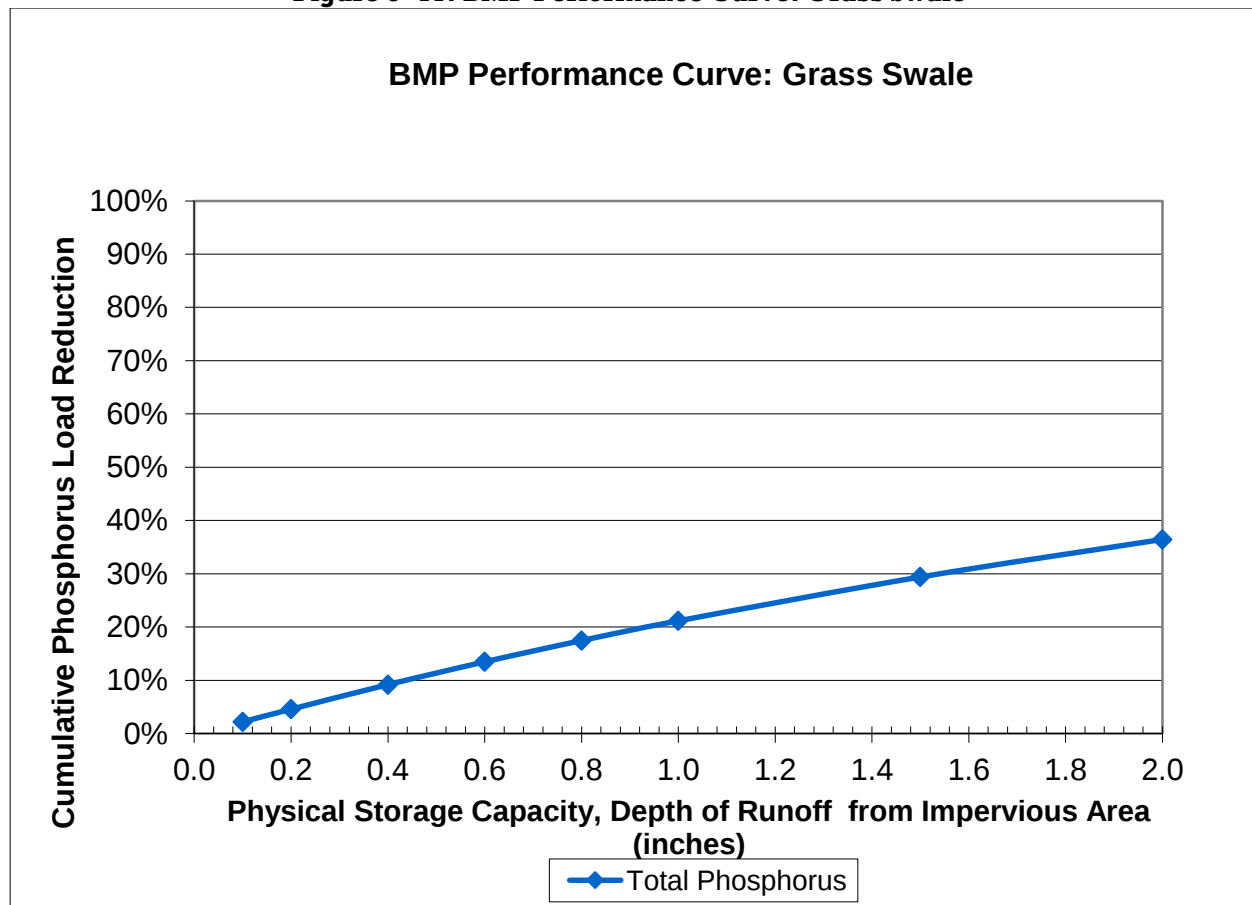
| Dry Pond BMP Performance Table: Long-Term Phosphorus Load Reduction |     |     |     |     |     |     |     |     |
|---------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches) | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 |
| Cumulative Phosphorus Load Reduction                                | 3%  | 6%  | 8%  | 9%  | 11% | 12% | 13% | 14% |

**Figure 3- 16: BMP Performance Curve: Dry Pond**



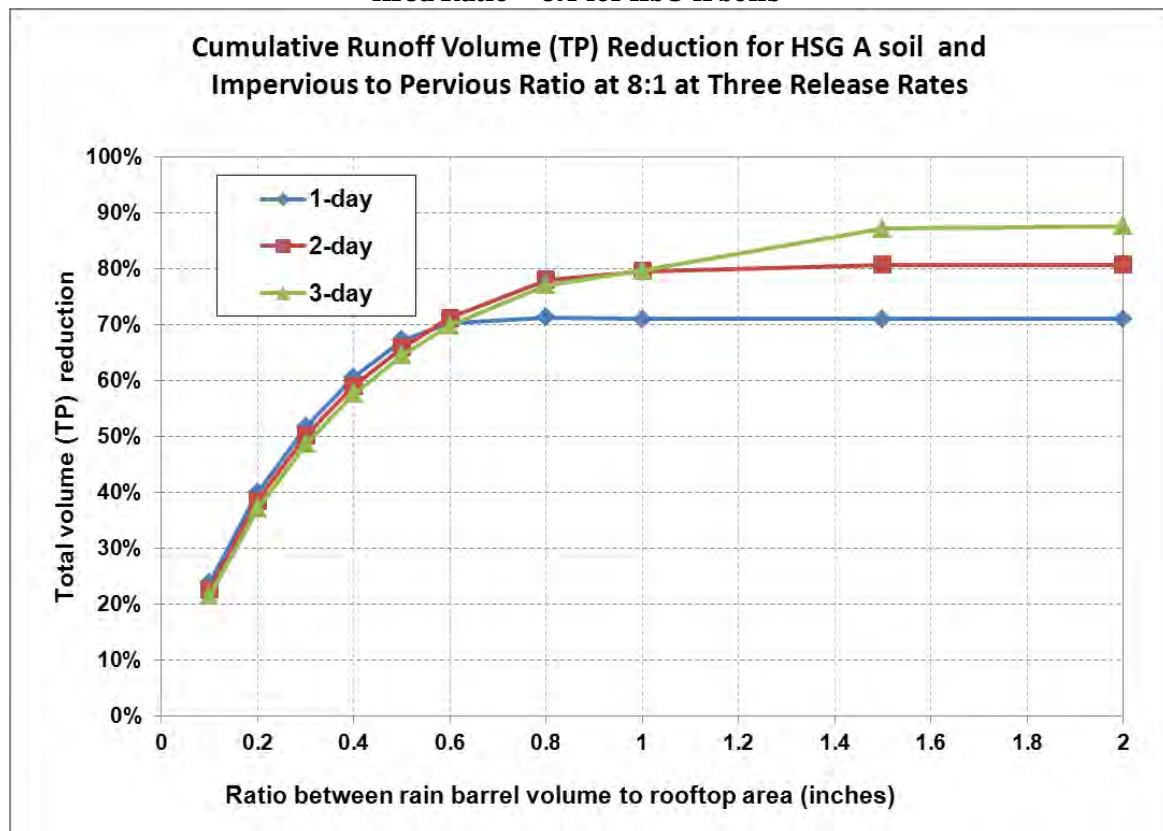
**Table 3- 21: Grass Swale BMP Performance Table**

| Grass Swale BMP Performance Table: Long-Term Phosphorus Load Reduction |     |     |     |     |     |     |     |     |
|------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)    | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 |
| Cumulative Phosphorus Load Reduction                                   | 2%  | 5%  | 9%  | 13% | 17% | 21% | 29% | 36% |

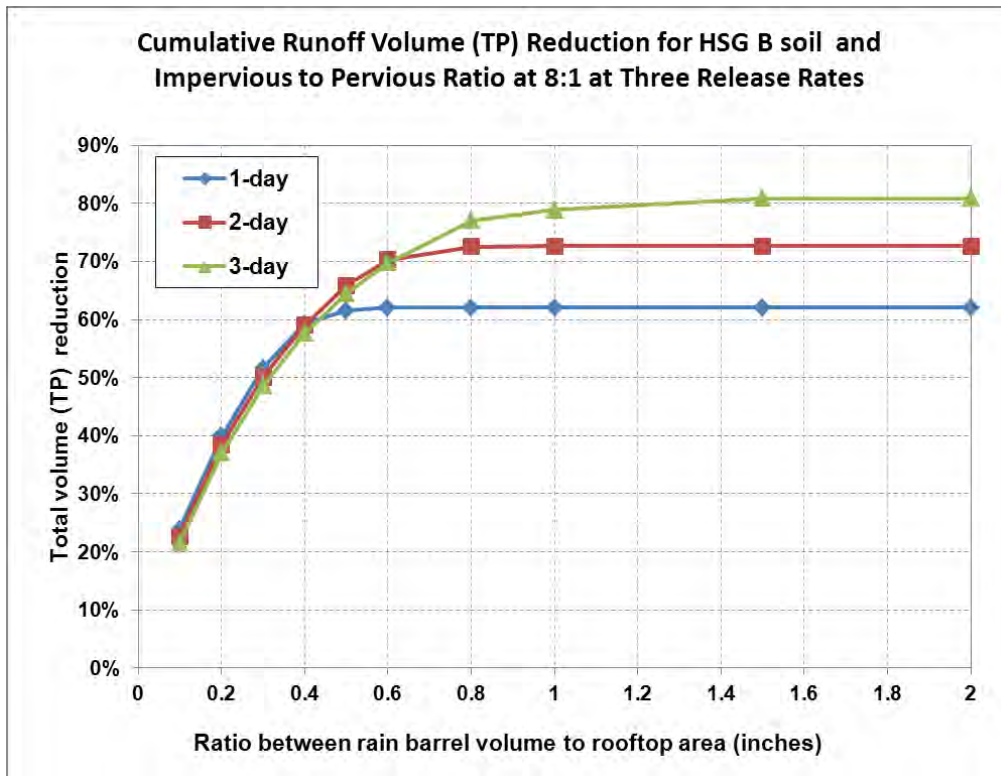
**Figure 3- 17: BMP Performance Curve: Grass Swale**

**Table 3- 22: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 8:1**

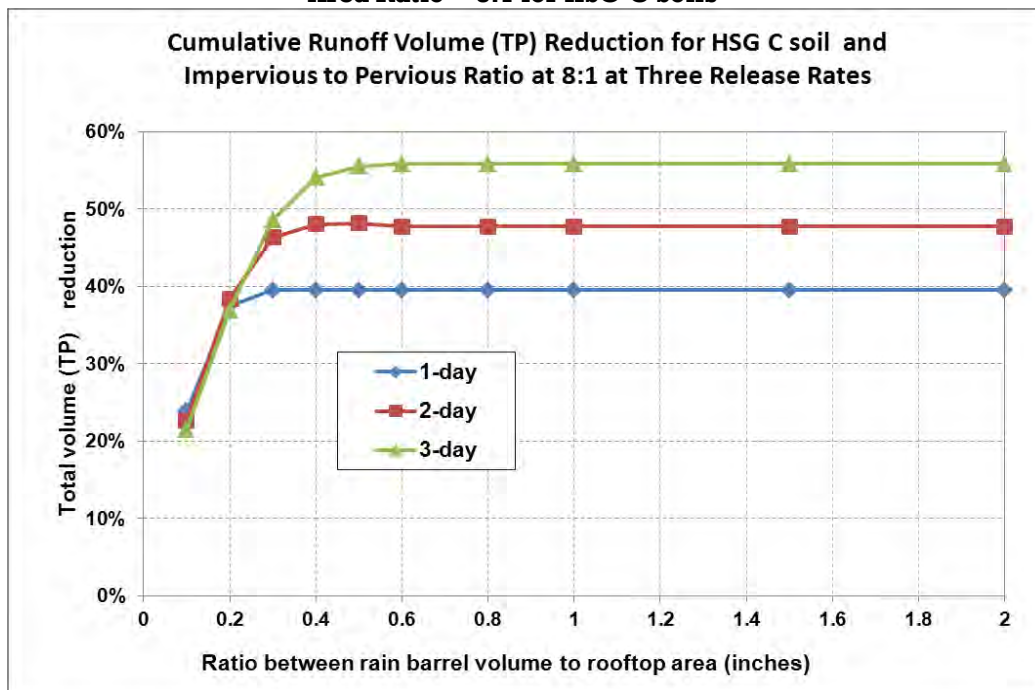
| <b>Impervious Area Disconnection through Storage : Impervious Area to Pervious Area Ratio = 8:1</b> |                                                |       |       |       |       |       |       |       |       |       |       |       |
|-----------------------------------------------------------------------------------------------------|------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Storage volume to impervious area ratio                                                             | Total Runoff Volume (TP) Reduction Percentages |       |       |       |       |       |       |       |       |       |       |       |
|                                                                                                     | HSG A                                          |       |       | HSG B |       |       | HSG C |       |       | HSG D |       |       |
|                                                                                                     | 1-day                                          | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 0.1 in                                                                                              | 24%                                            | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   | 22%   | 22%   | 21%   |
| 0.2 in                                                                                              | 40%                                            | 38%   | 37%   | 40%   | 38%   | 37%   | 37%   | 38%   | 37%   | 24%   | 26%   | 27%   |
| 0.3 in                                                                                              | 52%                                            | 50%   | 49%   | 52%   | 50%   | 49%   | 40%   | 46%   | 49%   | 24%   | 26%   | 27%   |
| 0.4 in                                                                                              | 61%                                            | 59%   | 58%   | 59%   | 59%   | 58%   | 40%   | 48%   | 54%   | 24%   | 26%   | 27%   |
| 0.5 in                                                                                              | 67%                                            | 66%   | 64%   | 62%   | 66%   | 64%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |
| 0.6 in                                                                                              | 70%                                            | 71%   | 70%   | 62%   | 70%   | 70%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |
| 0.8 in                                                                                              | 71%                                            | 78%   | 77%   | 62%   | 73%   | 77%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |
| 1.0 in                                                                                              | 71%                                            | 80%   | 80%   | 62%   | 73%   | 79%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |
| 1.5 in                                                                                              | 71%                                            | 81%   | 87%   | 62%   | 73%   | 81%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |
| 2.0 in                                                                                              | 71%                                            | 81%   | 88%   | 62%   | 73%   | 81%   | 40%   | 48%   | 56%   | 24%   | 26%   | 27%   |

**Figure 3- 18: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 8:1 for HSG A Soils**

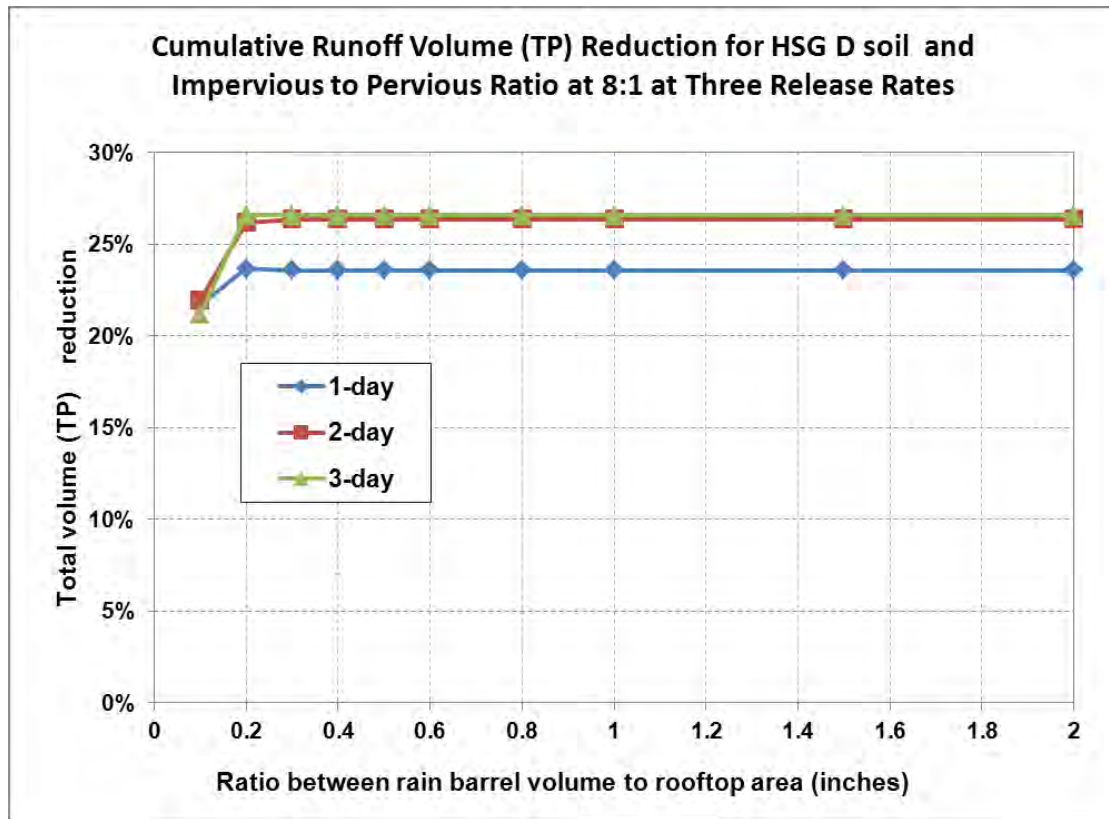
**Figure 3- 19: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 8:1 for HSG B Soils**



**Figure 3- 20: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 8:1 for HSG C Soils**



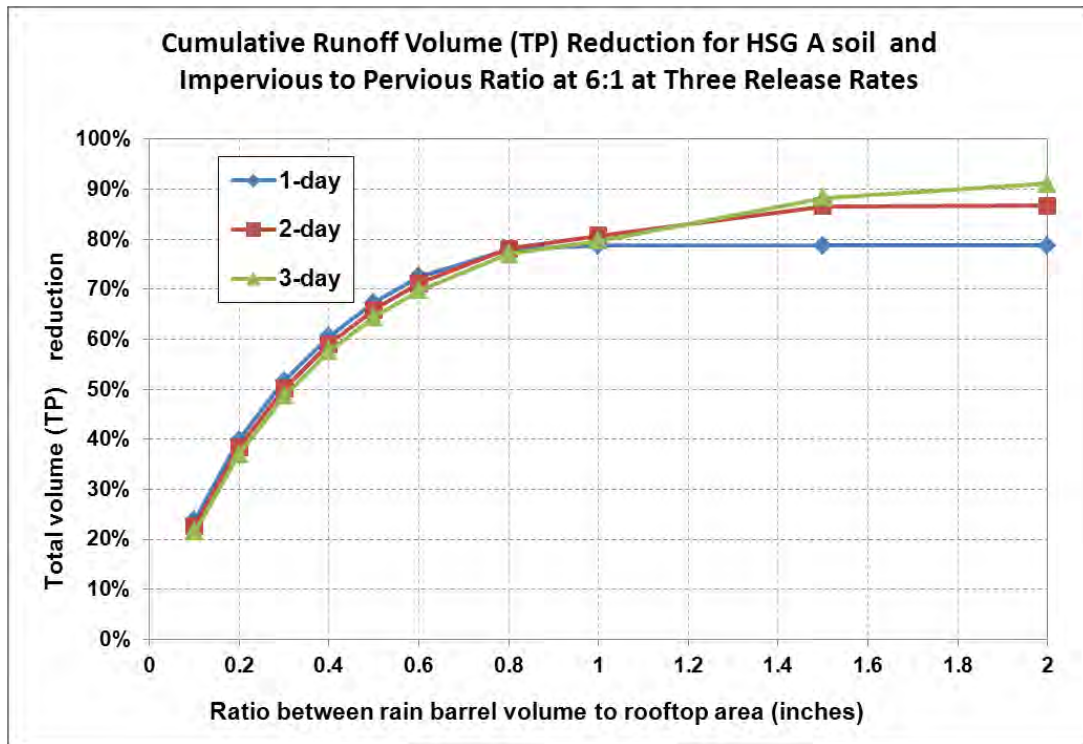
**Figure 3- 21: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 8:1 for HSG D Soils**



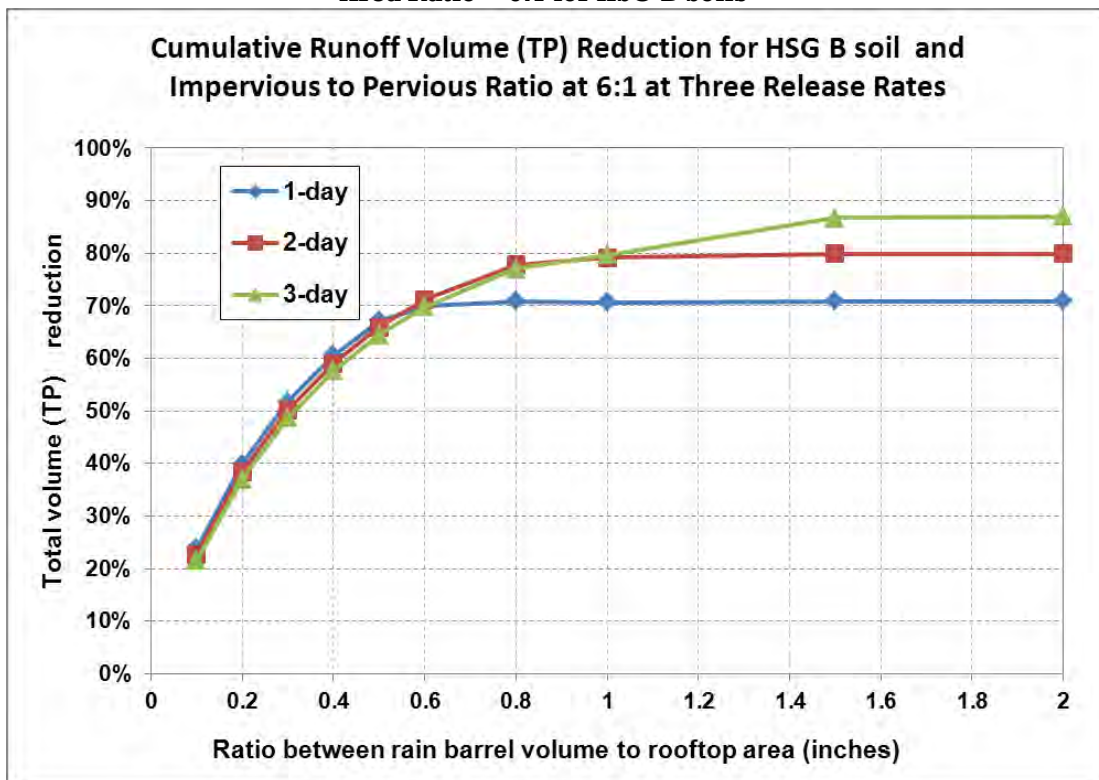
**Table 3- 23: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1**

| Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1 |                                                                    |       |       |       |       |       |       |       |       |       |       |       |
|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rain barrel volume to impervious area ratio                                                 | Total Runoff Volume and Phosphorus Load (TP) Reduction Percentages |       |       |       |       |       |       |       |       |       |       |       |
|                                                                                             | HSG A                                                              |       |       | HSG B |       |       | HSG C |       |       | HSG D |       |       |
|                                                                                             | 1-day                                                              | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 0.1 in                                                                                      | 24%                                                                | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   | 23%   | 23%   | 22%   |
| 0.2 in                                                                                      | 40%                                                                | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   | 28%   | 30%   | 33%   |
| 0.3 in                                                                                      | 52%                                                                | 50%   | 49%   | 52%   | 50%   | 49%   | 47%   | 50%   | 49%   | 29%   | 31%   | 34%   |
| 0.4 in                                                                                      | 61%                                                                | 59%   | 58%   | 61%   | 59%   | 58%   | 48%   | 55%   | 58%   | 29%   | 31%   | 34%   |
| 0.5 in                                                                                      | 67%                                                                | 66%   | 64%   | 67%   | 66%   | 64%   | 48%   | 57%   | 63%   | 29%   | 31%   | 34%   |
| 0.6 in                                                                                      | 73%                                                                | 71%   | 70%   | 70%   | 71%   | 70%   | 48%   | 57%   | 65%   | 29%   | 31%   | 34%   |
| 0.8 in                                                                                      | 78%                                                                | 78%   | 77%   | 71%   | 78%   | 77%   | 48%   | 57%   | 66%   | 29%   | 31%   | 34%   |
| 1.0 in                                                                                      | 79%                                                                | 81%   | 80%   | 71%   | 79%   | 80%   | 48%   | 57%   | 66%   | 29%   | 31%   | 34%   |
| 1.5 in                                                                                      | 79%                                                                | 87%   | 88%   | 71%   | 80%   | 87%   | 48%   | 57%   | 66%   | 29%   | 31%   | 34%   |
| 2.0 in                                                                                      | 79%                                                                | 87%   | 91%   | 71%   | 80%   | 87%   | 48%   | 57%   | 66%   | 29%   | 31%   | 34%   |

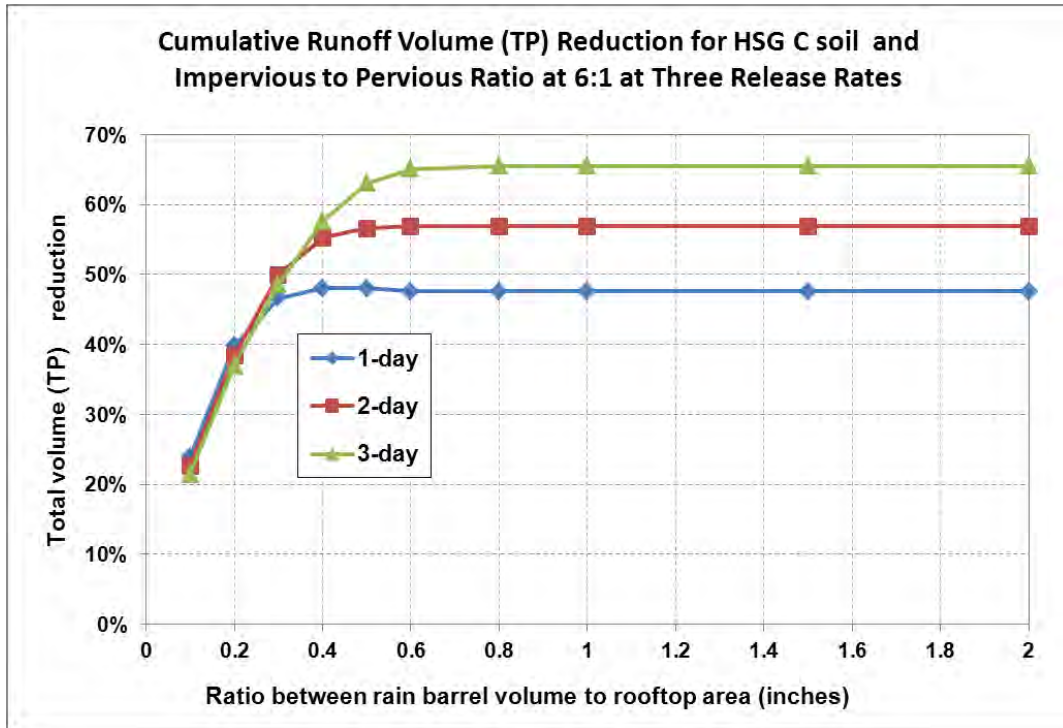
**Figure 3- 22: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1 for HSG A Soils**



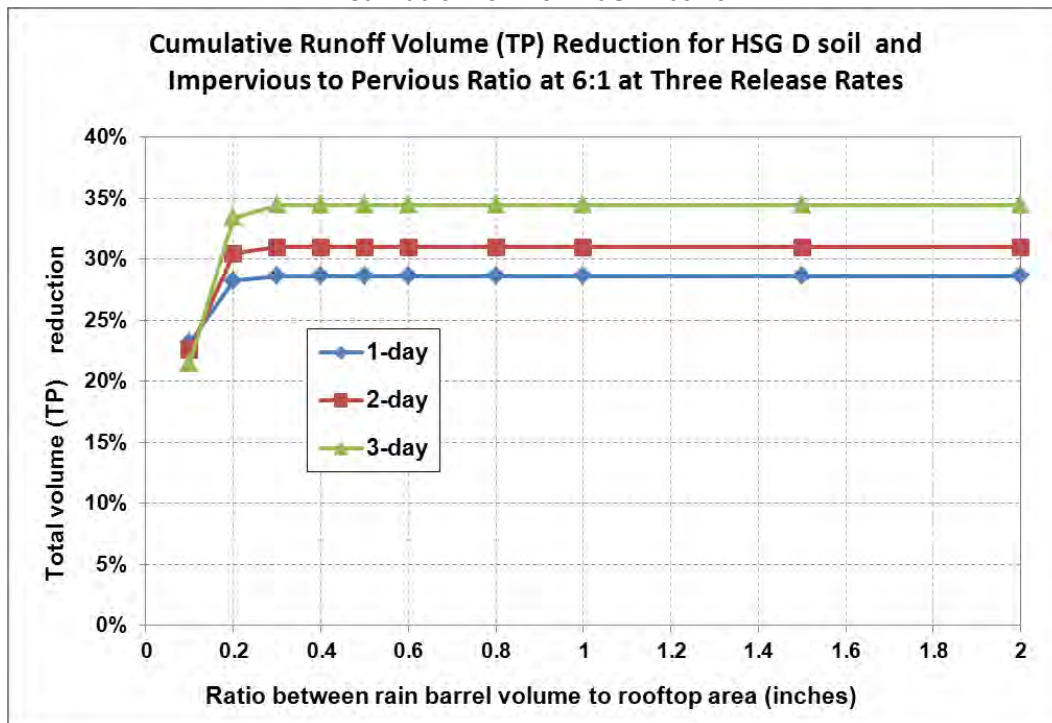
**Figure 3- 23: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1 for HSG B Soils**



**Figure 3- 24: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1 for HSG C Soils**



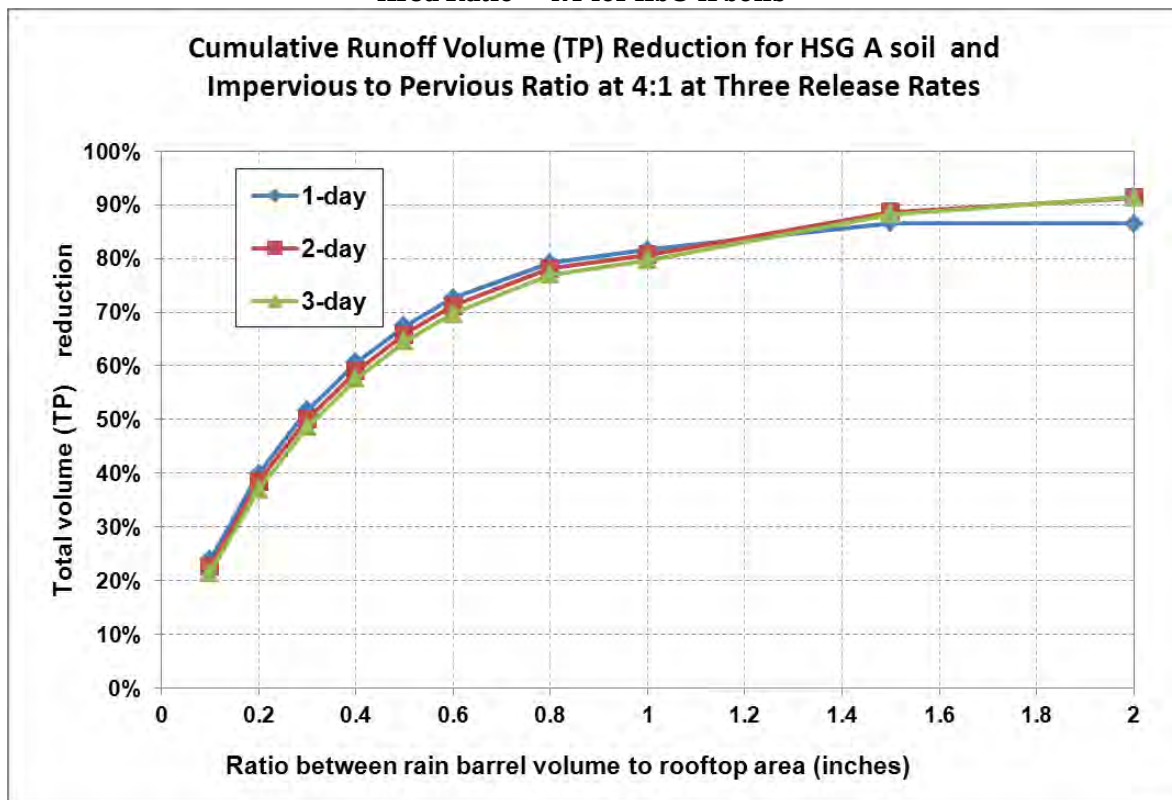
**Figure 3- 25: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 6:1 for HSG D Soils**



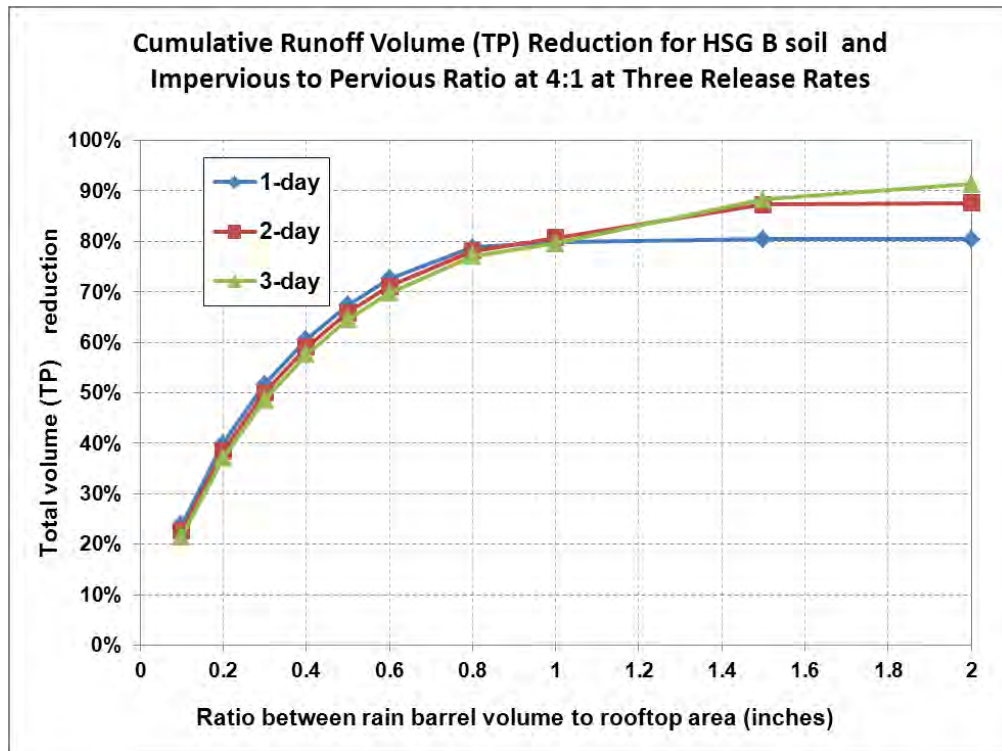
**Table 3- 24: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1**

| <b>Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1</b> |                                                                    |       |       |       |       |       |       |       |       |       |       |       |
|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Storage volume to impervious area ratio                                                            | Total Runoff Volume and Phosphorus Load (TP) Reduction Percentages |       |       |       |       |       |       |       |       |       |       |       |
|                                                                                                    | HSG A                                                              |       |       | HSG B |       |       | HSG C |       |       | HSG D |       |       |
|                                                                                                    | 1-day                                                              | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 0.1 in                                                                                             | 24%                                                                | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   |
| 0.2 in                                                                                             | 40%                                                                | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   | 37%   | 37%   | 37%   |
| 0.3 in                                                                                             | 52%                                                                | 50%   | 49%   | 52%   | 50%   | 49%   | 52%   | 50%   | 49%   | 39%   | 42%   | 45%   |
| 0.4 in                                                                                             | 61%                                                                | 59%   | 58%   | 61%   | 59%   | 58%   | 58%   | 59%   | 58%   | 39%   | 42%   | 47%   |
| 0.5 in                                                                                             | 67%                                                                | 66%   | 64%   | 67%   | 66%   | 64%   | 60%   | 65%   | 64%   | 40%   | 42%   | 47%   |
| 0.6 in                                                                                             | 73%                                                                | 71%   | 70%   | 73%   | 71%   | 70%   | 61%   | 68%   | 70%   | 40%   | 42%   | 47%   |
| 0.8 in                                                                                             | 79%                                                                | 78%   | 77%   | 79%   | 78%   | 77%   | 61%   | 69%   | 75%   | 40%   | 42%   | 47%   |
| 1.0 in                                                                                             | 82%                                                                | 81%   | 80%   | 80%   | 81%   | 80%   | 61%   | 69%   | 76%   | 40%   | 42%   | 47%   |
| 1.5 in                                                                                             | 87%                                                                | 89%   | 88%   | 80%   | 87%   | 88%   | 61%   | 69%   | 76%   | 40%   | 42%   | 47%   |
| 2.0 in                                                                                             | 87%                                                                | 91%   | 91%   | 80%   | 88%   | 91%   | 61%   | 69%   | 76%   | 40%   | 42%   | 47%   |

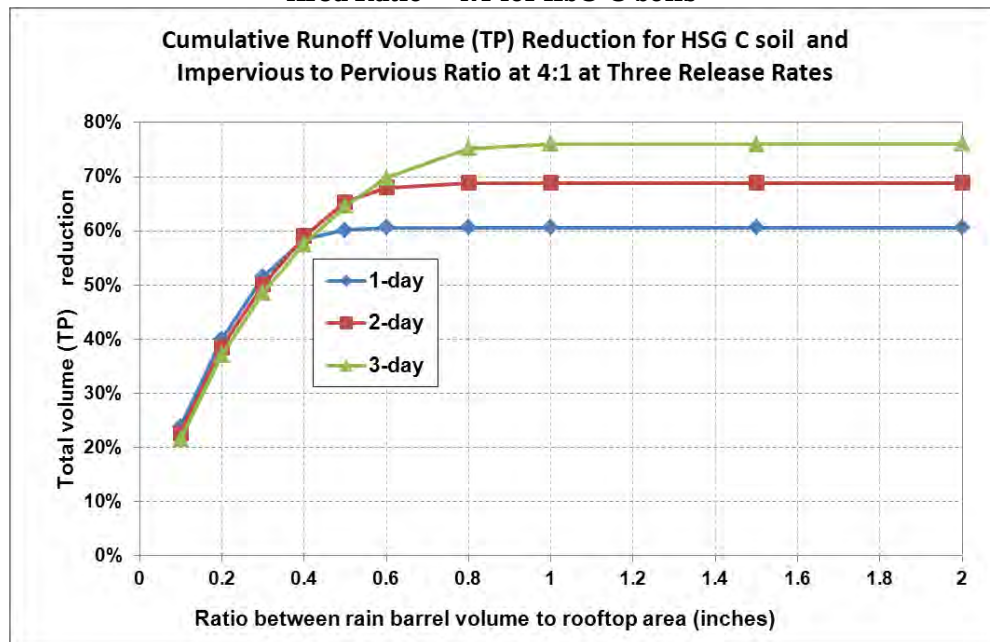
**Figure 3- 26: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1 for HSG A Soils**



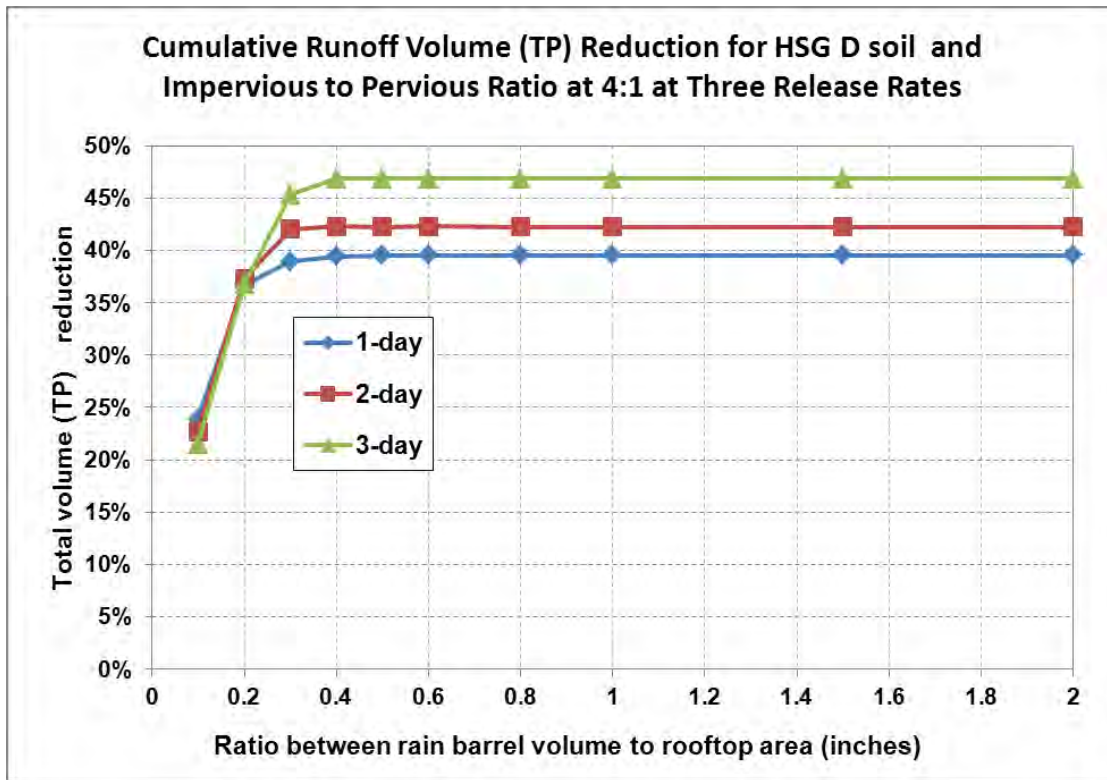
**Figure 3- 27: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1 for HSG B Soils**



**Figure 3- 28: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1 for HSG C Soils**



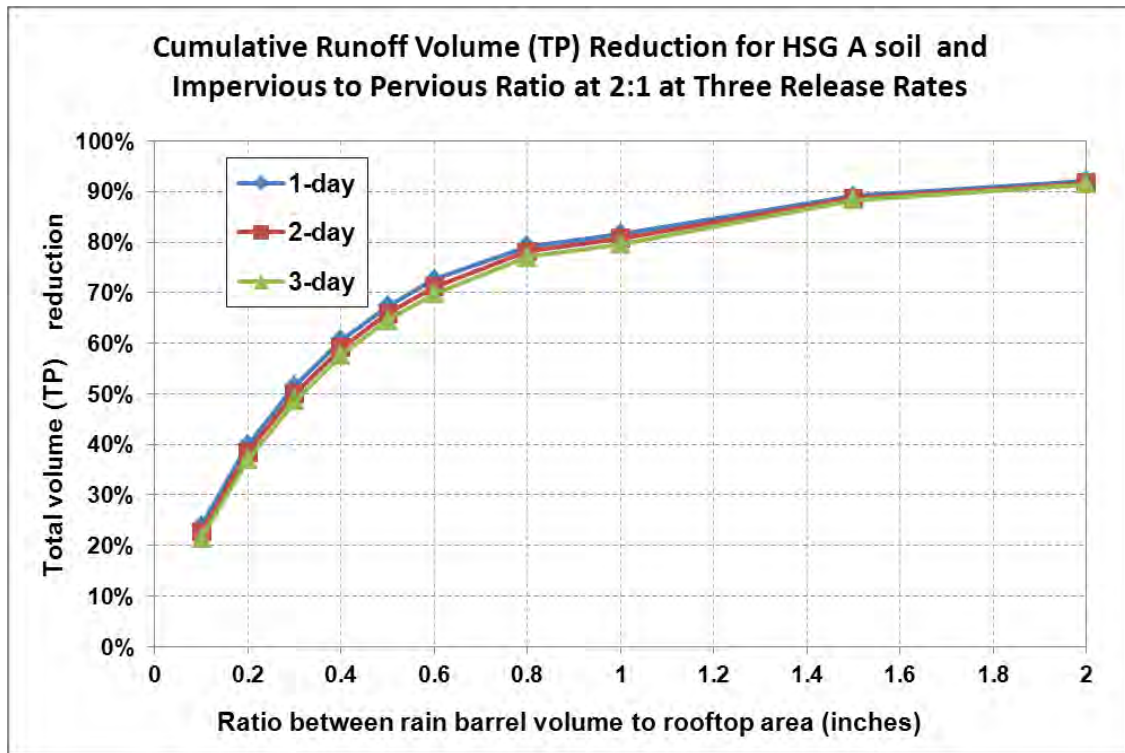
**Figure 3- 29: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 4:1 for HSG D Soils**



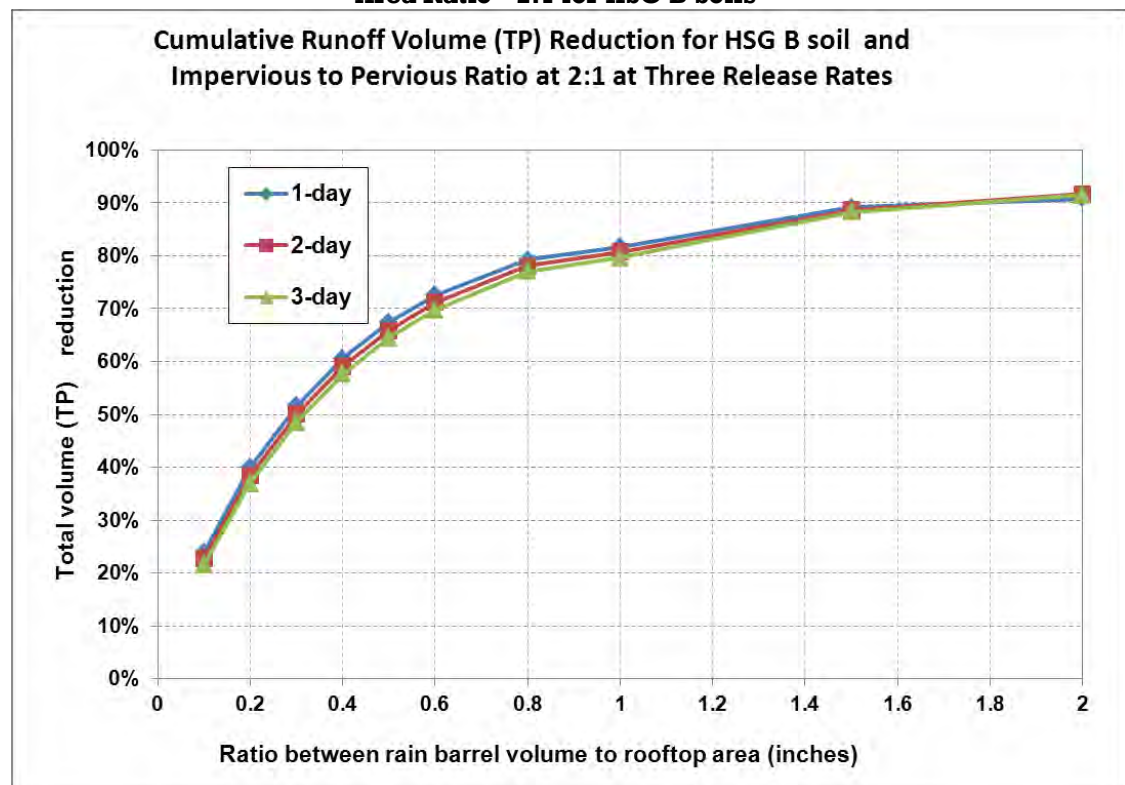
**Table 3- 25: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 2:1**

| Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 2:1 |                                                                    |       |       |       |       |       |       |       |       |       |       |       |
|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Storage volume to impervious area ratio                                                     | Total Runoff Volume and Phosphorus Load (TP) Reduction Percentages |       |       |       |       |       |       |       |       |       |       |       |
|                                                                                             | HSG A                                                              |       |       | HSG B |       |       | HSG C |       |       | HSG D |       |       |
|                                                                                             | 1-day                                                              | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 0.1 in                                                                                      | 24%                                                                | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   |
| 0.2 in                                                                                      | 40%                                                                | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   |
| 0.3 in                                                                                      | 52%                                                                | 50%   | 49%   | 52%   | 50%   | 49%   | 52%   | 50%   | 49%   | 51%   | 50%   | 49%   |
| 0.4 in                                                                                      | 61%                                                                | 59%   | 58%   | 61%   | 59%   | 58%   | 61%   | 59%   | 58%   | 57%   | 58%   | 57%   |
| 0.5 in                                                                                      | 67%                                                                | 66%   | 64%   | 67%   | 66%   | 64%   | 67%   | 66%   | 64%   | 59%   | 62%   | 63%   |
| 0.6 in                                                                                      | 73%                                                                | 71%   | 70%   | 73%   | 71%   | 70%   | 72%   | 71%   | 70%   | 59%   | 62%   | 67%   |
| 0.8 in                                                                                      | 79%                                                                | 78%   | 77%   | 79%   | 78%   | 77%   | 77%   | 78%   | 77%   | 59%   | 62%   | 67%   |
| 1.0 in                                                                                      | 82%                                                                | 81%   | 80%   | 82%   | 81%   | 80%   | 78%   | 81%   | 80%   | 59%   | 62%   | 67%   |
| 1.5 in                                                                                      | 89%                                                                | 89%   | 88%   | 89%   | 89%   | 88%   | 78%   | 84%   | 88%   | 59%   | 62%   | 67%   |
| 2.0 in                                                                                      | 92%                                                                | 92%   | 91%   | 91%   | 92%   | 91%   | 78%   | 84%   | 89%   | 59%   | 62%   | 67%   |

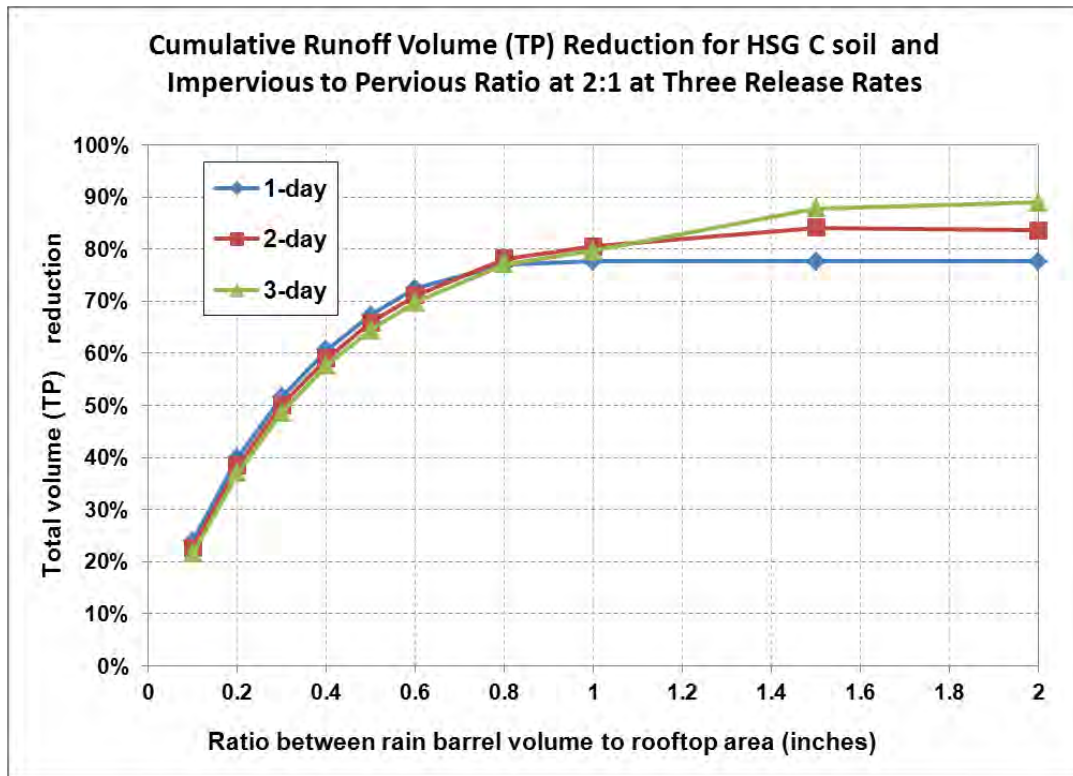
**Figure 3- 30: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio= 2:1 for HSG A Soils**



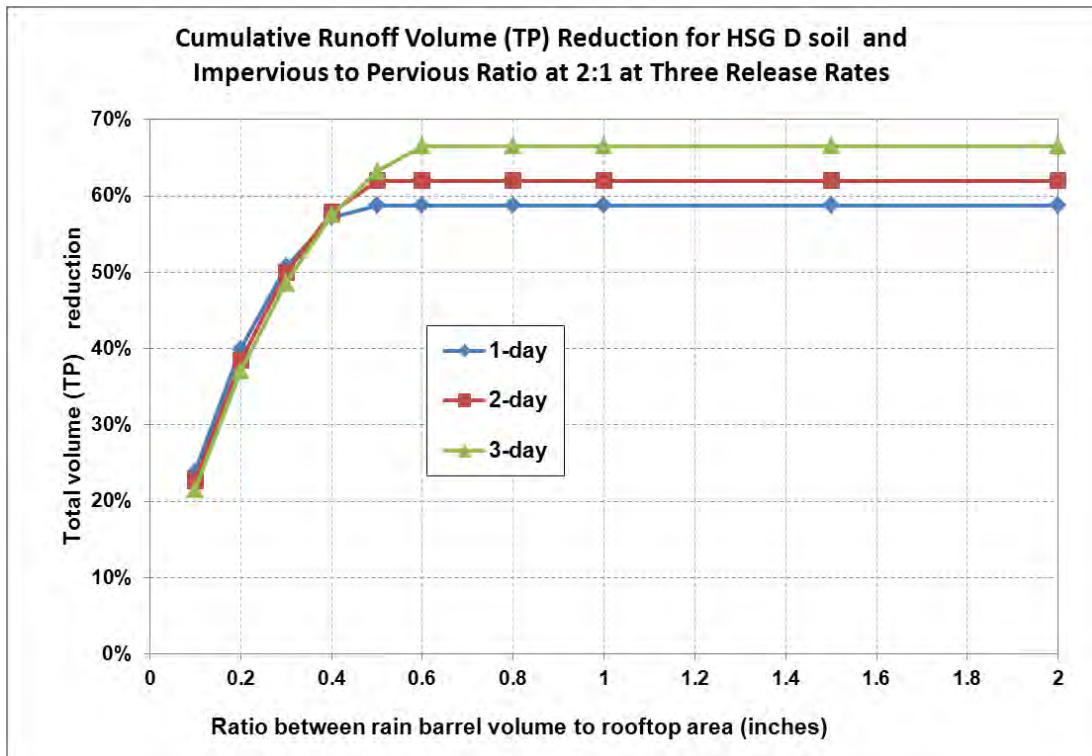
**Figure 3- 31: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio= 2:1 for HSG B Soils**



**Figure 3- 32: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio= 2:1 for HSG C Soils**



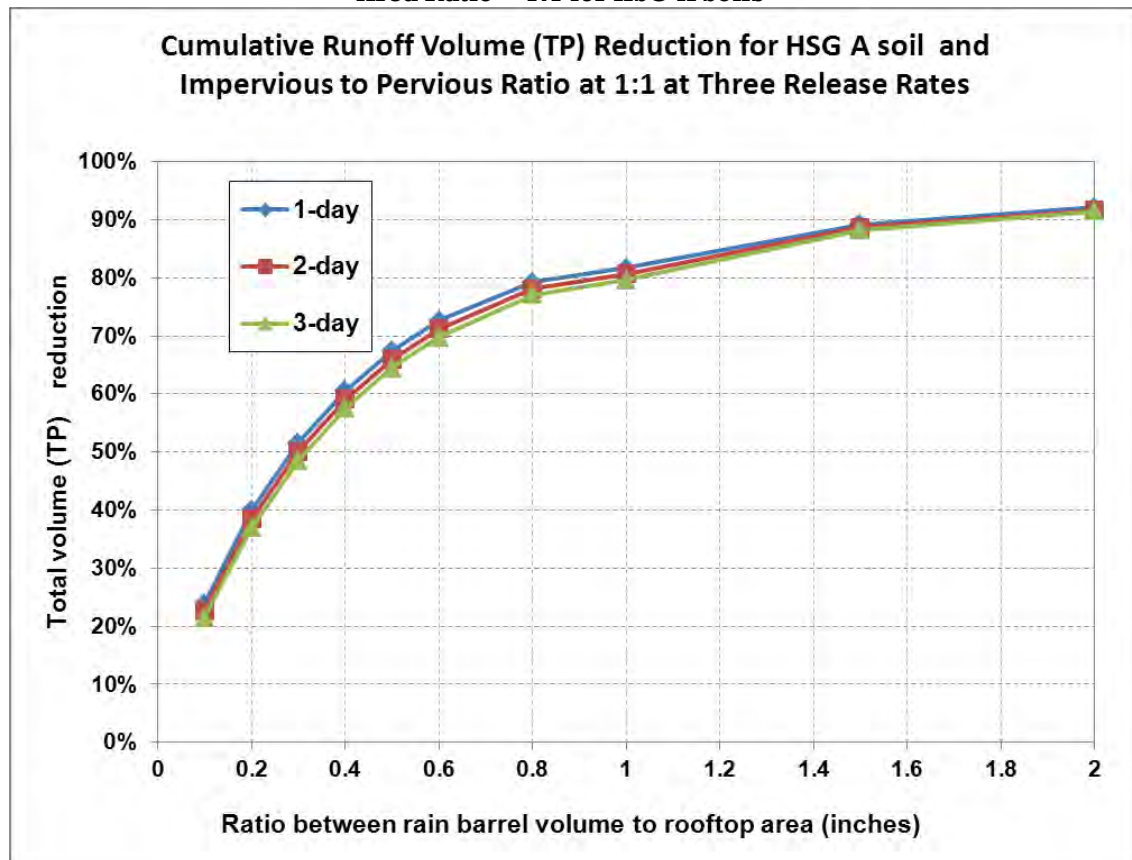
**Figure 3- 33: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio= 2:1 for HSG D Soils**



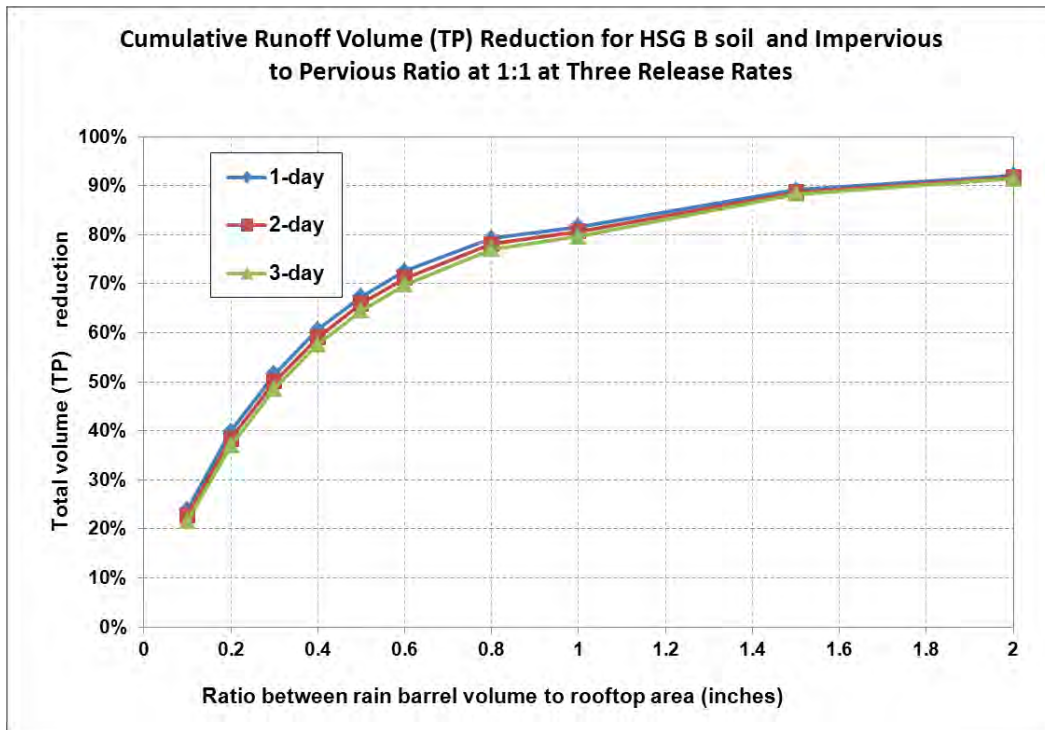
**Table 3- 26: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1**

| Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1 |                                                                    |       |       |       |       |       |       |       |       |       |       |       |
|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Storage volume to impervious area ratio                                                     | Total Runoff Volume and Phosphorus Load (TP) Reduction Percentages |       |       |       |       |       |       |       |       |       |       |       |
|                                                                                             | HSG A                                                              |       |       | HSG B |       |       | HSG C |       |       | HSG D |       |       |
|                                                                                             | 1-day                                                              | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 0.1 in                                                                                      | 24%                                                                | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   | 24%   | 23%   | 22%   |
| 0.2 in                                                                                      | 40%                                                                | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   | 40%   | 38%   | 37%   |
| 0.3 in                                                                                      | 52%                                                                | 50%   | 49%   | 52%   | 50%   | 49%   | 52%   | 50%   | 49%   | 52%   | 50%   | 49%   |
| 0.4 in                                                                                      | 61%                                                                | 59%   | 58%   | 61%   | 59%   | 58%   | 61%   | 59%   | 58%   | 61%   | 59%   | 58%   |
| 0.5 in                                                                                      | 67%                                                                | 66%   | 64%   | 67%   | 66%   | 64%   | 67%   | 66%   | 64%   | 67%   | 66%   | 64%   |
| 0.6 in                                                                                      | 73%                                                                | 71%   | 70%   | 73%   | 71%   | 70%   | 73%   | 71%   | 70%   | 72%   | 71%   | 70%   |
| 0.8 in                                                                                      | 79%                                                                | 78%   | 77%   | 79%   | 78%   | 77%   | 79%   | 78%   | 77%   | 78%   | 78%   | 77%   |
| 1.0 in                                                                                      | 82%                                                                | 81%   | 80%   | 82%   | 81%   | 80%   | 82%   | 81%   | 80%   | 79%   | 80%   | 80%   |
| 1.5 in                                                                                      | 89%                                                                | 89%   | 88%   | 89%   | 89%   | 88%   | 89%   | 89%   | 88%   | 80%   | 82%   | 86%   |
| 2.0 in                                                                                      | 92%                                                                | 92%   | 91%   | 92%   | 92%   | 91%   | 91%   | 92%   | 91%   | 80%   | 82%   | 86%   |

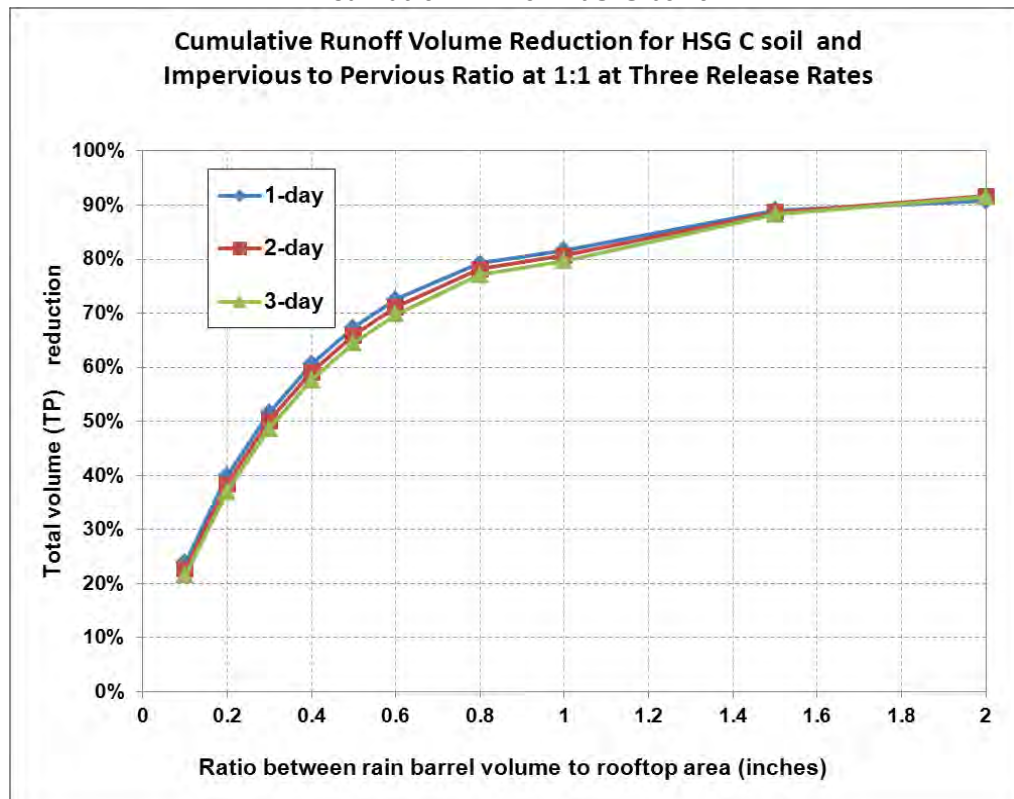
**Figure 3- 34: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1 for HSG A Soils**



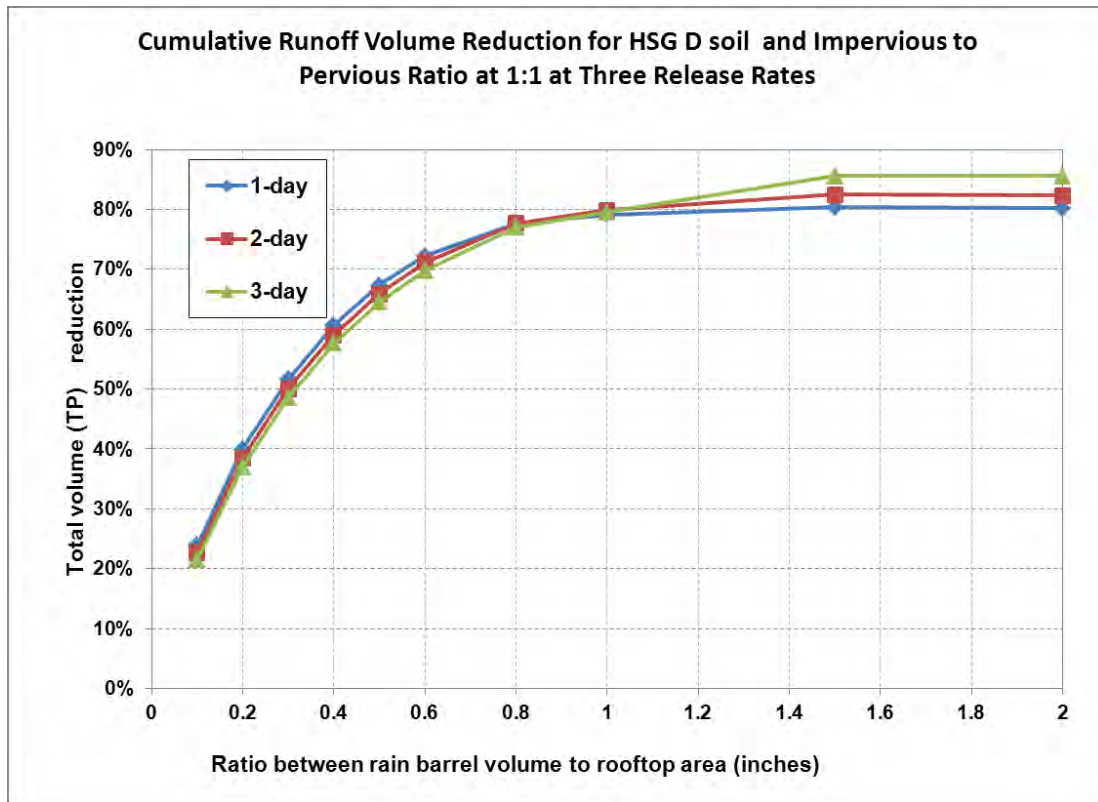
**Figure 3- 35: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1 for HSG B Soils**



**Figure 3- 36: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1 for HSG C Soils**

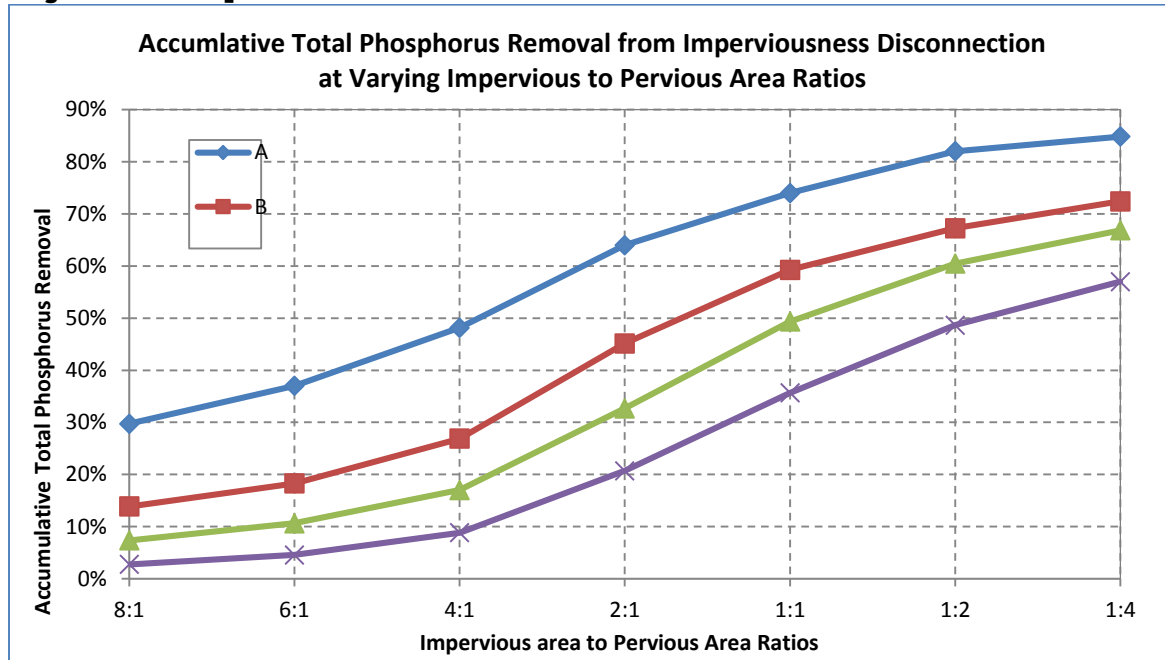


**Figure 3- 37: Impervious Area Disconnection through Storage: Impervious Area to Pervious Area Ratio = 1:1 for HSG D Soils**



**Table 3- 27: Impervious Area Disconnection Performance Table**

| Impervious area to pervious area ratio | Soil type of Receiving Pervious Area |       |       |       |
|----------------------------------------|--------------------------------------|-------|-------|-------|
|                                        | HSG A                                | HSG B | HSG C | HSG D |
| 8:1                                    | 30%                                  | 14%   | 7%    | 3%    |
| 6:1                                    | 37%                                  | 18%   | 11%   | 5%    |
| 4:1                                    | 48%                                  | 27%   | 17%   | 9%    |
| 2:1                                    | 64%                                  | 45%   | 33%   | 21%   |
| 1:1                                    | 74%                                  | 59%   | 49%   | 36%   |
| 1:2                                    | 82%                                  | 67%   | 60%   | 49%   |
| 1:4                                    | 85%                                  | 72%   | 67%   | 57%   |

**Figure 3- 38: Impervious Area Disconnection Performance Curves****Table 3- 28: Performance Table for Conversion of Impervious Areas to Pervious Area based on Hydrological Soil Groups**

| Land-Use Group                                        | Cumulative Reduction in Annual Stormwater Phosphorus Load |                                                      |                                                      |                                                        |                                                      |
|-------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------|------------------------------------------------------|
|                                                       | Conversion of impervious area to pervious area-HSG A      | Conversion of impervious area to pervious area-HSG B | Conversion of impervious area to pervious area-HSG C | Conversion of impervious area to pervious area-HSG C/D | Conversion of impervious area to pervious area-HSG D |
| Commercial (Com) and Industrial (Ind)                 | 98.5%                                                     | 93.5%                                                | 88.0%                                                | 83.5%                                                  | 79.5%                                                |
| Multi-Family (MFR) and High-Density Residential (HDR) | 98.8%                                                     | 95.0%                                                | 90.8%                                                | 87.3%                                                  | 84.2%                                                |
| Medium -Density Residential (MDR)                     | 98.6%                                                     | 94.1%                                                | 89.1%                                                | 85.0%                                                  | 81.4%                                                |
| Low Density Residential (LDR) - "Rural"               | 98.2%                                                     | 92.4%                                                | 85.9%                                                | 80.6%                                                  | 75.9%                                                |
| Highway (HWY)                                         | 98.0%                                                     | 91.3%                                                | 84.0%                                                | 78.0%                                                  | 72.7%                                                |
| Forest (For)                                          | 98.2%                                                     | 92.4%                                                | 85.9%                                                | 80.6%                                                  | 75.9%                                                |
| Open Land (Open)                                      | 98.2%                                                     | 92.4%                                                | 85.9%                                                | 80.6%                                                  | 75.9%                                                |
| Agriculture (Ag)                                      | 70.6%                                                     | 70.6%                                                | 70.6%                                                | 70.6%                                                  | 70.6%                                                |

**Table 3- 29: Performance Table for Conversion of Low Permeable Pervious Area to High Permeable Pervious Area based on Hydrological Soil Group**

| Land Cover              | Cumulative Reduction in Annual SW Phosphorus Load from Pervious Area |                                                          |                                                          |                                                          |                                                          |
|-------------------------|----------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
|                         | Conversion of pervious area HSG D to pervious area-HSG A             | Conversion of pervious area HSG D to pervious area-HSG B | Conversion of pervious area HSG D to pervious area-HSG C | Conversion of pervious area HSG C to pervious area-HSG A | Conversion of pervious area HSG C to pervious area-HSG B |
| Developed Pervious Land | 92.7%                                                                | 68.3%                                                    | 41.5%                                                    | 83.5%                                                    | 79.5%                                                    |

**Table 3-30 Method for determining stormwater control design volume (DSV) (i.e., capacity) using Long-term cumulative performance curves**

| Stormwater Control Type                                                                                                                                                                                                                                                                                                            | Description                                                                                                                                                                                                                                                                                                                                                                                                                            | Applicable Structural Stormwater Control Performance Curve                                        | Equation for calculating Design Storage Capacity for Estimating Cumulative Reductions using Performances Curves                                                                                                                                   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Infiltration Trench</b>                                                                                                                                                                                                                                                                                                         | Provides temporary storage of runoff using the void spaces within the soil/sand/gravel mixture that is used to backfill the trench for subsequent infiltration into the surrounding sub-soils.                                                                                                                                                                                                                                         | Infiltration Trench (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour) | DSV = void space volumes of gravel and sand layers<br>$DSV = (L \times W \times D_{stone} \times n_{stone}) + (L \times W \times D_{sand} \times n_{sand})$                                                                                       |
| <b>Subsurface Infiltration</b>                                                                                                                                                                                                                                                                                                     | Provides temporary storage of runoff using the combination of storage structures (e.g., galleys, chambers, pipes, etc.) and void spaces within the soil/sand/gravel mixture that is used to backfill the system for subsequent infiltration into the surrounding sub-soils.                                                                                                                                                            | Infiltration Trench (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour) | DSV = Water storage volume of storage units and void space volumes of backfill materials. Example for subsurface galleys backfilled with washed stone:<br>$DSV = (L \times W \times D)_{galley} + (L \times W \times D_{stone} \times n_{stone})$ |
| <b>Surface Infiltration</b>                                                                                                                                                                                                                                                                                                        | Provides temporary storage of runoff through surface ponding storage structures (e.g., basin or swale) for subsequent infiltration into the underlying soils.                                                                                                                                                                                                                                                                          | Infiltration Basin (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour)  | DSV = Water volume of storage structure before bypass. Example for linear trapezoidal vegetated swale<br>$DSV = (L \times ((W_{bottom} + W_{top@Dmax})/2) \times D)$                                                                              |
| <b>Rain Garden/Bio-retention (no underdrains)</b>                                                                                                                                                                                                                                                                                  | Provides temporary storage of runoff through surface ponding and possibly void spaces within the soil/sand/gravel mixture that is used to filter runoff prior to infiltration into underlying soils.                                                                                                                                                                                                                                   | Infiltration Basin (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour)  | DSV = Ponding water storage volume and void space volumes of soil filter media. Example for raingarden :<br>$DSV = (A_{pond} \times D_{pond}) + (A_{soil} \times D_{soil} \times n_{soil \text{ mix}})$                                           |
| <b>Tree Filter (no underdrain)</b>                                                                                                                                                                                                                                                                                                 | Provides temporary storage of runoff through surface ponding and void spaces within the soil/sand/gravel mixture that is used to filter runoff prior to infiltration into underlying soils.                                                                                                                                                                                                                                            | Infiltration Trench (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour) | DSV = Ponding water storage volume and void space volumes of soil filter media.<br>$DSV = (L \times W \times D_{ponding}) + (L \times W \times D_{soil} \times n_{soil \text{ mix}})$                                                             |
| <b>Bio-Filtration (w/underdrain)</b>                                                                                                                                                                                                                                                                                               | Provides temporary storage of runoff for filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff has passed through the filter media it is collected by an under-drain pipe for discharge. Manufactured or packaged bio-filter systems such as tree box filters may be suitable for using the bio-filtration performance results. | Bio-filtration                                                                                    | DSV = Ponding water storage volume and void space volume of soil filter media. Example of a linear biofilter:<br>$DSV = (L \times W \times D_{ponding}) + (L \times W \times D_{soil} \times n_{soil})$                                           |
| <b>Gravel Wetland</b>                                                                                                                                                                                                                                                                                                              | Based on design by the UNH Stormwater Center (UNHSC). Provides temporary surface ponding storage of runoff in a vegetated wetland cell that is eventually routed to an underlying saturated gravel internal storage reservoir (ISR) for nitrogen treatment. Outflow is controlled by an elevated orifice that has its invert elevation equal to the top of the ISR layer and provides a retention time of at least 24 hours.           | Gravel Wetland                                                                                    | DSV = pretreatment volume + ponding volume + void space volume of gravel ISR.<br>$DSV = (A_{pretreatment} \times D_{pretreatment}) + (A_{wetland} \times D_{ponding}) + (A_{ISR} \times D_{gravel} \times n_{gravel})$                            |
| <b>Porous Pavement with subsurface infiltration</b>                                                                                                                                                                                                                                                                                | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces of a subsurface gravel reservoir prior to infiltration into subsoils.                                                                                                                                                                                                                                                      | Infiltration Trench (6 infiltration rates: 0.17, 0.27, 0.52, 1.02, 2.41 and 8.27 inches per hour) | DSV = void space volumes of gravel layer<br>$DSV = (L \times W \times D_{stone} \times n_{stone})$                                                                                                                                                |
| <b>Porous pavement w/ impermeable underliner w/underdrain</b>                                                                                                                                                                                                                                                                      | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces prior to discharge by way of an underdrain.                                                                                                                                                                                                                                                                                | Porous Pavement                                                                                   | Depth of Filter Course = $D_{FC}$                                                                                                                                                                                                                 |
| <b>Wet Pond</b>                                                                                                                                                                                                                                                                                                                    | Provides treatment of runoff through routing through permanent pool.                                                                                                                                                                                                                                                                                                                                                                   | Wet Pond                                                                                          | DSV= Permanent pool volume prior to high flow bypass<br>$DSV = A_{pond} \times D_{pond}$ (does not include pretreatment volume)                                                                                                                   |
| <b>Extended Dry Detention Basin</b>                                                                                                                                                                                                                                                                                                | Provides temporary detention storage for the design storage volume to drain in 24 hours through multiple out let controls.                                                                                                                                                                                                                                                                                                             | Dry Pond                                                                                          | DSV= Ponding volume prior to high flow bypass<br>$DSV = A_{pond} \times D_{pond}$ (does not include pretreatment volume)                                                                                                                          |
| <b>Dry Water Quality Swale/Grass Swale</b>                                                                                                                                                                                                                                                                                         | Based on MA design standards. Provides temporary surface ponding storage of runoff in an open vegetated channel through permeable check dams. Treatment is provided by filtering of runoff by vegetation and check dams and infiltration into subsurface soils.                                                                                                                                                                        | Grass swale                                                                                       | DSV = Volume of swale at full design depth<br>$DSV = L_{swale} \times A_{swale}$                                                                                                                                                                  |
| <b>Definitions:</b> DSV= Design Storage Volume = physical storage capacity to hold water; VSV = Void Space Volume; L = length, W = width, D = depth at design capacity before bypass, n = porosity fill material, A= average surface area for calculating volume; <b>Infiltration rate</b> = saturated soil hydraulic conductivity |                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                   |                                                                                                                                                                                                                                                   |