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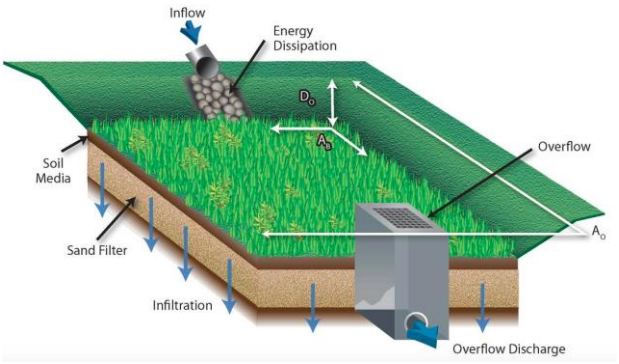
Infiltration Basins: Standards and Procedures to Ensure Performance

Prepared by CTC & Associates LLC



Infiltration basins have been a common means of stormwater management across the United States, as well as internationally, for more than three decades. A large constructed soil basin—up to 50 acres in area—with a complex permeable base and engineered pretreatment inflow and sides is designed to allow stormwater to infiltrate into the soil within 72 hours of inundation. When planned, designed and constructed correctly, infiltration basins can function effectively for 15 years or longer. Unfortunately, a high percentage of infiltration basins fail well in advance of their planned service life. It is a widespread problem that has been addressed with standards, guidelines, manuals and definitive regulations over many decades. Yet, the high failure rate of infiltration basins persists. MnDOT's Office of Environmental Stewardship sought to learn the best practices that other state agencies employ to mitigate infiltration basin failure and make corrections when failure occurs.

This Transportation Research Synthesis presents findings from a literature search for relevant practices of other state agencies for the planning, design and construction of infiltration basins along with guidance from national organizations. It also investigated nongovernmental and international sources and research. There is a significant amount of literature on this subject. Standards and procedures appear to be clear and accepted, but essential preconstruction evaluations and procedures are not always followed. A survey of selected state departments of transportation sought further information concerning standards and procedures that agencies employ to construct effective infiltration basins, as well as their solutions to common challenges that arise in infiltration basin construction. The results of the survey follow the findings of the literature search.

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Infiltration Basins: Standards and Procedures to Ensure Performance

Introduction

MnDOT's Office of Environmental Stewardship is interested in learning about best practices that other state agencies use to mitigate infiltration basin failure and make corrections when failure occurs. This Transportation Research Synthesis presents the findings from a literature search for relevant practices of other state agencies for the planning, design and construction of infiltration basins along with guidance from national, nongovernmental and international organizations. The results of a survey of state department of transportation (DOT) professionals with knowledge and experience in infiltration basin planning, design, construction and maintenance are also presented.

Summary of Findings

This Transportation Research Synthesis is divided into two sections:

- Related Resources.
- Survey of Practice.

Related Resources

The literature search revealed that there appears to be a consensus across agencies regarding appropriate planning, design and construction procedures of infiltration basins but that failures often stem from procedural errors: making unverified assumptions and omitting (or making errors in) required steps to evaluate the site, design the basin or construct the basin. For example, infiltration testing may be inadequate or the highest infiltration rate (rather than lowest) may be presented as typical throughout a site, data about groundwater mounding may be absent, percentage of clay may be misrepresented or the presence of karst may be missed.

Compaction of the basin during construction is a widespread problem, easy to avoid, yet often a factor in infiltration failure. While occasionally failure may result from geological aspects, the literature suggests that a large proportion of infiltration basin failures results from a disregard or omission of steps in accepted protocols.

Findings from state and national resources reveal a consensus of acceptance of standards regarding sites, planning, design and construction. Highlights include the following:

- **State practices.** Manuals and other guidance from California, Maryland, Minnesota, New Jersey, Pennsylvania and Wisconsin present comprehensive information about standards and procedures.
- **National guidance.** Online guidance from the U.S. Environmental Protection Agency and Federal Highway Administration is included.
- **Other resources.** Websites are included that address soil science, infiltration problems and sustainable drainage. Other research investigates transitional states of basins and future improvements.

Survey of Practice

An online survey was sent to 36 state DOT professionals expected to have knowledge and experience in infiltration basin construction and failures. Representatives from eight states responded to the survey;

respondents reported numbers of basins in service ranging from three to 250 and failure rates ranging from no failures to greater than 50 percent failures.

Responses frequently mirrored findings of the literature search: Failures could be traced to poor or no soil testing, decisions based on erroneous assumptions or missing data, compaction of the basin and sedimentation. Some respondents reported good results, which were attributed to more rigorous procedures with checklists and special language in infiltration contracts that clarified the steps that must be followed to construct effective infiltration basins.

Below are highlights of the survey results.

Overview of Infiltration Basins

In states that had 100 to 250 infiltration basin projects in the last 10 years (Massachusetts and Minnesota) as well as 15 to 30 percent failures, the reasons for failures were known and understood. Respondents noted the primary reasons as inadequate soil infiltration rate test data, compaction during construction and, to a lesser extent, sedimentation. Respondents from states with relatively few basins in service noted the same reasons underlying failures. Responses indicating no failures came from states with very few infiltration basin projects or from sources that were uncertain of the results.

Protocols and Procedures for Constructing Infiltration Basins

Three respondents noted that infiltration basins were built by their agencies without any soil infiltration rate testing. Five respondents reported that infiltration rate testing was performed before construction; only one (Minnesota) reported that testing was performed during construction. Massachusetts and Delaware reported the inclusion of special language and detailed sequences of construction in contracts for infiltration projects. These two states were among the five that incorporated quality assurance methods, such as preactivity meetings and checklists, into the construction process.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

Only three of the responding state agencies have well-developed specifications and/or methods to control erosion and siltation of an infiltration basin construction site (Delaware, Massachusetts and Washington).

Actions related to failing basins involved a closer examination of the site, for example, with the assistance of a new geotechnologist, followed by manipulations of the basin through replacement of geotextile; deep ripping of the soil; and modification of the site to a retention or detention facility, or even to a wet pond. Remedies for failing infiltration basins appear to be few, though some measures were successful (such as replacing geotextile with sandy soil).

Most responding agencies prefer not to acquire rights of way or purchase land for additional stormwater management. In Washington, however, many acquisitions have taken place, some for infiltration best management practices (BMPs).

Next Steps

Going forward, MnDOT could consider:

- Closely examining the images and discussion of infiltration testing, compaction and sedimentation at this website: https://www.soilhub.com/3-common-problems-with-stormwater-infiltration-and-how-to-correct-them. The state DOT survey respondents who discussed reasons for basin failure listed compaction, sedimentation and erosion, and inaccurate infiltration testing as probable causes.

- Examining infiltration testing and construction practices in Washington State DOT's Highway Runoff Manual (https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf). Appendix 4D, Infiltration Testing and Design (beginning on page 187 of the PDF), describes the "testing methods used to determine infiltration rates (and saturated hydraulic conductivities) used for stormwater design." Chapter 5, Stormwater Best Management Practices (beginning on page 217 of the PDF), provides "specific guidelines and criteria on the proper selection, design and application of stormwater management techniques."
- Reviewing Washington State DOT's Temporary Erosion and Sediment Control Manual (https://www.wsdot.wa.gov/publications/manuals/fulltext/M3109/TESCM.pdf) for practices that mitigate compaction and sedimentation. Element 13 (page 25 of the report, page 35 of the PDF) describes low-impact development BMPs during construction activity.
- Contacting respondents at Delaware and Massachusetts DOTs about approaches these agencies have taken to encourage use of detailed sequences of construction, special provisions in contracts for infiltration projects, and quality assurance throughout construction. (Contact information for these DOT representatives is available in Appendix C.)

  Delaware

  - Delaware DOT has built about 25 infiltration facilities in the last 10 years with a 1 to 15 percent failure rate. Vince Davis of Delaware DOT cited reasons for failure as compaction, sedimentation and, in some cases, poor design.
  - Davis reported that there is now a detailed sequence of construction, a construction checklist (see Appendix E) and extensive quality assurance protocols.
  - Delaware DOT was the only respondent to report that the state employs all of the listed quality assurance procedures included in the survey: hold points, preactivity meetings and checklists.
  - The agency is establishing a criterion for infiltration testing before construction. It is currently determined by the design engineer.
  - The Delaware Erosion and Sediment Control Handbook may also be useful to MnDOT (http://www.dnrec.delaware.gov/swc/Drainage/Documents/Sediment%20and%20Stormwater%20Program/Technical%20Document/Latest%20Version%20of%20all%20Articles/3.06.1%20Delaware%20ESC%20Handbook.pdf).

  Massachusetts

  - Massachusetts DOT has built about 250 infiltration basins in the last 10 years with a 15 to 30 percent failure rate. Henry Barbaro of Massachusetts DOT reported that failures were caused by compaction and inaccurate geotechnical data or incorrect assumptions about subsurface soil conditions.
  - The agency recently began adding a special provision for managing infiltration areas to every contract that has an infiltration BMP (see Appendix D).
  - Massachusetts DOT uses preactivity meetings as a quality assurance method. Further, there must be an observed drawdown within 72 hours of a precipitation event before demobilization of the construction site.
  - The agency uses the Massachusetts Department of Environmental Protection Stormwater Handbook, Volumes 1 and 2, for regulatory and BMP guidance (https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards).

Detailed Findings

Related Resources

The citations below are organized in the following sections:

- Basin Design and Design Parameters.
- Construction Techniques and Protocols.
- Materials Specifications.
- Quality Assurance Measures.
- Standard Details.
- Challenges and Solutions.
- Research in Progress.

Most, if not all, national and state stormwater best management practice (BMP) manuals and guidance address all the categories listed above through standard details. The state manuals in this literature search are included for their clarity and comprehensiveness, and for the states' broad similarity to Minnesota.

Basin Design and Design Parameters

Design Criteria for Infiltration, Minnesota Stormwater Manual, Minnesota Stormwater Steering Committee, Minnesota Pollution Control Agency, revised July 13, 2017**.**
https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_infiltration
From the web page:

> This page provides a discussion of design elements and design steps for infiltration practices. These practices include infiltration trench, infiltration basin, dry wells, and underground infiltration practices, although many of the design guidelines can be applied to other infiltration practices.

This online version of the manual offers CADD images, as well as detailed presentations and discussions of the following and other relevant aspects of infiltration basin design considerations:

- Physical feasibility, including drainage, topography and soils.
- Practice and site considerations, such as conveyance, underdrains, pretreatment, treatment, landscaping and snow considerations.
- Materials specifications, including filter materials.
- Design steps.

BMP 6.4.2: Infiltration Basin, Pennsylvania Stormwater Best Management Practices Manual, Pennsylvania Department of Environmental Protection, December 2006.
http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-67990/6.4.2%20BMP%20Infiltration%20Basin.pdf
Complete manual at http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-8305
Chapter 6.4.2 of this manual includes information on site evaluation, testing, design and construction.

In Appendix C, Site Evaluation and Soil Testing (http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48483/13_Appendix_C.pdf), a discussion of (deep) pit testing for site evaluation includes this guideline (page 4 of the report; page 5 of the PDF):

> For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four (4) to six (6) tests per acre of BMP [best management practice] area.

Basin Best Management Practices, Volume 3, Stormwater Best Management Practice Design Guide, Michael L. Clar, Billy J. Barfield and Thomas P. O'Connor, U.S. Environmental Protection Agency, 2004.
https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000D1L8.txt
This comprehensive guide covers design and BMPs for a range of basin types. Section 4, (pages 81-92), provides a detailed presentation and discussion of criteria for infiltration basin siting and design, with references to the Maryland Stormwater Design Manual (see citation below).

Maryland Stormwater Design Manual, Volumes 1 and 2, Maryland Department of the Environment, revised 2009.
http://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/stormwater_design.aspx.
This manual addresses design of stormwater management techniques. Chapter 3 discusses infiltration trenches and basins (beginning on page 3.25 of the report, page 27 of the PDF). The chapter provides drawings and discusses the following criteria:

- Feasibility criteria.
- Conveyance criteria.
- Pretreatment criteria.
- Treatment criteria.
- Landscaping criteria.
- Maintenance criteria.

Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Leslie Shoemaker, Mohammed Lahlou, Amy Doll and Patricia Cazenas, *Environmental Review Toolkit*, Federal Highway Administration, undated.
https://www.environment.fhwa.dot.gov/ecosystems/ultraurb/index.asp
From the abstract:

> This report builds on recent FHWA manuals by expanding and presenting additional data, design criteria, and monitoring study results on stormwater best management practices (BMPs) implemented in ultra-urban areas. … The purpose of this report is to provide a planning-level review of the applicability and use of new and more traditional BMPs in ultra-urban areas. This report focuses on the unique characteristics specific to ultra-urban settings and provides specific guidance for selecting and siting stormwater management technologies. The information is structured in a user-friendly format, with case studies highlighting examples of BMP monitoring throughout the country and tables illustrating the characteristics of each BMP to facilitate comparison and identification of specific technologies appropriate to a given site. BMP information is provided in fact sheets, which address applicability, effectiveness, siting and design, maintenance, and cost considerations.

Infiltration basin standards and methods are addressed in detail, including site considerations, tables of estimated pollutant filtration and monitored case studies.

Construction Techniques and Protocols

Construction Specifications for Infiltration, Minnesota Stormwater Manual, Minnesota Stormwater Steering Committee, Minnesota Pollution Control Agency, revised February 16, 2017**.**
https://stormwater.pca.state.mn.us/index.php?title=Construction_specifications_for_infiltration
This section of the manual provides information about the construction techniques and protocols used to build infiltration basins, from access agreements, site protection, pretreatment, erosion and sediment control, and compaction prevention to the seven-step process of the construction sequence. Step 2 of that sequence, Excavation, follows:

> Sub-cut the infiltration area as shown on the plans. Where possible, excavation should be performed with a backhoe and work should be done from the sides and outside the footprint of the infiltration area to avoid soil compaction. If it is necessary to work in the infiltration area, only low ground pressure tracked equipment should be allowed to complete the work. Rubber tire equipment should be strictly prohibited within the infiltration area, unless working from pavement outside of the basin or trench. The contractor should start the work at the far side of the trench or basin and work their way out.

The manual also includes a detailed construction inspection checklist (https://stormwater.pca.state.mn.us/index.php/Infiltration_basin_-_system_construction_inspection_checklist) as well as CADD drawings.

Appendix C: Site Evaluation and Soil Testing, Pennsylvania Stormwater Best Management Practices Manual, Pennsylvania Department of Environmental Protection, December 2006.
http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48483/13_Appendix_C.pdf
This appendix presents site evaluation protocols for infiltration testing, including guidance for when to conduct testing. *From page 2:*

> Designers are encouraged to conduct the Soil Evaluation and Investigation early in the site planning and design process. The Site Development process outlined in Chapters 4 and 5 of this Manual describe a process for site development and BMPs. Soil Evaluation and Investigation should be conducted early in the preliminary design of the project so that information developed in the testing process can be incorporated into the design. Adjustments to the design can be made as necessary. It is recommended that Soil Evaluation and Investigation be conducted following the development of an early Preliminary Plan. The Designer should possess a preliminary understanding of potential BMP locations prior to testing. Prescreening test may be carried out in advance to site potential BMP locations.

Fact Sheet—Infiltration Basin, Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Leslie Shoemaker, Mohammed Lahlou, Amy Doll and Patricia Cazenas, *Environmental Review Toolkit*, Federal Highway Administration, undated.
https://www.environment.fhwa.dot.gov/ecosystems/ultraurb/3fs2.asp.
From Siting and Design Considerations:

> Construction activities will greatly affect the performance of infiltration basins and the potential for failure. It is critical to install the basin only after the construction site has been stabilized to minimize introduction of fine sediment into the basin. In one study, approximately 40 percent of the investigated basins had partially or totally clogged within their first few years of operation. Many of these systems failed almost immediately after construction (Maintenance of Stormwater Management Structures: A Departmental Summary, Maryland Department of the Environment, 1986). During excavation, compaction of the bottom and sides of the infiltration basin must be minimized by using vehicles equipped with oversized tires. The infiltration basin should be marked off or bermed prior to any construction activity to ensure vehicle entrance to the footprint area is not possible**.**

Materials Specifications

Infiltration Media and Material Specifications, Minnesota Stormwater Manual, Minnesota Stormwater Steering Committee, Minnesota Pollution Control Agency, revised June 28, 2017
https://stormwater.pca.state.mn.us/index.php?title=Infiltration_media_and_material_specifications.
This webpage lists and discusses the materials required for infiltration basins. It is available as a table or as an Excel spreadsheet.

Infiltration Basins, Chapter 9.5, New Jersey Stormwater Best Management Practices Manual, New Jersey Department of Environmental Protection, revised February 2016 (2017 revision forthcoming).
http://www.nj.gov/dep/stormwater/bmp_manual/NJ_SWBMP_9.5.pdf
Complete manual at http://www.nj.gov/dep/stormwater/bmp_manual2.htm
From Surface Infiltration Basins (page 10):

Sand Layer

- To ensure that the design permeability rate is maintained over time, a sand layer is required at the bottom of every surface type infiltration basin.
- The minimum depth is 6 inches.
- The sand must meet all the specifications for clean, medium-aggregate concrete sand in accordance with AASHTO M-6 or ASTM C-33, as certified by a professional engineer licensed in the State of New Jersey.
- The maximum percentage of fines is 15%.
- The minimum tested permeability rate is 20 inches/hour.
- The use of topsoil and vegetation is prohibited. If a vegetated BMP is desired, refer to Chapter 9.1: Bioretention Systems.
- Filter fabric is required along the sides of the infiltration basin to prevent the migration of fine particles from the surrounding soil; filter fabric may not be used along the bottom of the basin because it may result in a loss of permeability.

Quality Assurance Measures

Infiltration Basins and Trenches, Wisconsin Storm Water Manual: Technical Design Guidelines for Storm Water Management Practices, Terry Donovan, Mary Anne Lowndes, Peg McBrien and John Pfender, Cooperative Extension of the University of Wisconsin–Extension, 2000.
http://learningstore.uwex.edu/assets/pdfs/g3691-3.pdf
The section on construction guidelines for infiltration basins (page 8) begins with this caveat:

Infiltration basins usually fail for one of more of the following reasons:

- Premature clogging.
- A design infiltration rate was greater than the actual infiltration rates.
- Because the basin site was used for construction site erosion control.
- Soil was compacted during construction.
- The upland soils or basin walls were not stabilized with vegetation, and sediment was delivered to the basin.

Note that all of these failures result from improper planning, design or construction.

Conservation Practice Standard: Site Evaluation for Storm Water Infiltration, Technical Standard 1002, Bureau of Watershed Management Program Guidance, Storm Water Management Program**,** Wisconsin Department of Natural Resources, September 2017.
http://dnr.wi.gov/news/input/documents/guidance/TS1002Final.pdf
This guide provides very detailed instructions and guidance for performing site evaluation for stormwater infiltration devices. It includes discussions of topography, soil types, percolation testing and groundwater locations. It offers examples and provides forms for recording necessary information about hydrologic conditions and site and soil data. According to the standard, a carefully executed comprehensive site evaluation can "avoid costly redesigns."

Guidelines for Geotechnical Investigation and Reporting: Low Impact Development Stormwater Infiltration, Administrative Manual, Geotechnical and Materials Engineering Division, County of Los Angeles Department of Public Works, June 2017.
http://ladpw.org/gmed/permits/docs/policies/GS200.1.pdf.
From Geotechnical Investigation (page 3):

> A site-specific geotechnical investigation performed for proposed stormwater infiltration quality control measures shall include subsurface exploration, laboratory testing, soil type classification, groundwater investigation, and in-situ percolation testing. The investigation must be conducted by or under direct supervision of a State of California certified professional geologist, geotechnical engineer, or civil engineer experienced in geotechnical engineering. Projects proposing to infiltrate a cumulative [storm water quality] design volume of SWQDv greater than 10,000 gallons must also include a hydrogeologic assessment and be signed by a State of California certified professional geologist. It is highly desirable that large projects also utilize the services and input of a State of California certified hydrogeologist.

This portion of the manual discusses in detail infiltration testing performed using the following procedures:

- Double-ring infiltrometer.
- Well permeameter.
- Boring percolation.
- Excavation percolation.
- High flow-rate percolation.
- Infiltration basin percolation test.
- Dry well percolation test.

Included with the test instructions are drawings, photographs and worksheets for field data entry. The section concludes with this discussion (page 15):

> Infiltration rates are understood to have a very large range by orders of magnitude for different soil types. There is also substantial uncertainty associated with even the most rigorous testing procedures. For these reasons, it is important that the recommended design infiltration rate fall in the general order of magnitude for the soil type classifications at the site. If there is discrepancy between the presented data and the recommended infiltration rates, the consultant shall revisit soil descriptions, soil data, percolation testing procedure and analyses to provide a substantiated explanation for any variance. Additional testing and discussion may be necessary to verify the infiltration rates prior to acceptance by the County.

The Checklist Manifesto: How to Get Things Right, Atul Gawande, Metropolitan Books (New York: Henry Holt and Company LLC), 2009.
http://atulgawande.com/book/the-checklist-manifesto/
Although not a document directly related to infiltration basins, The Checklist Manifesto addresses the significant role of quality assurance measures such as checklists. Using examples from a range of highly technical fields—medicine, skyscraper construction, aircraft construction and operation—surgeon and writer Atul Gawande presents how people working in technical fields and charged with completing extremely complex tasks can and do avoid error and failure. Problems and tasks can be categorized as simple, complicated or complex. In complex problems, the context is changeable and unpredictable: what is required in one instance may not apply in the next situation. Such is the case in medicine—as it is also in siting and constructing infiltration basins. Checklists that are scrupulously consulted throughout a process provide a means of preventing memory lapses, unverifiable assumptions, omissions, short cuts, errors and, ultimately, failure. This is a very effective quality control solution—one of "what engineers call 'forcing functions': relatively straightforward solutions that force the necessary behavior" (page 50)—that has been used successfully in the construction industry for years. Constructing a skyscraper is an extremely complex undertaking, involving thousands of workers, thousands of tasks. Few of the thousands of skyscrapers built every year fail. Checklists control the process.

Standard Details

Minimum Standard 14.01: Infiltration Basin, Storm Water Minimum Standards, Regional Water Resource Agency, Daviess County, Kentucky, 2011.
http://www.rwra.org/wp-content/uploads/2011/09/Stormwater-Fact-Sheets-Minimum-Standards.pdf
This publication offers extensive minimum standards for infiltration basins and similar stormwater management practices.

Infiltration Basin, Technical Standard 1003, Conservation Practice Standards, Wisconsin Department of Natural Resources, 2004.
http://dnr.wi.gov/topic/stormwater/documents/infiltrationbasin_1003.pdf
This standard provides protocols and details required for infiltration basins in Wisconsin.

Infiltration Basins, Chapter 9.5, New Jersey Stormwater Best Management Practices Manual, New Jersey Department of Environmental Protection, revised February 2016.
http://www.nj.gov/dep/stormwater/bmp_manual/NJ_SWBMP_9.5.pdf
This chapter presents standards for siting, designing and constructing infiltration basins. Page 5 of the chapter addresses groundwater mounding:

> As with any infiltration BMP, groundwater mounding impacts must be assessed, as required by N.J.A.C. 7:8-5.4(a)2.iv. This includes an analysis of the reduction in permeability rate when groundwater mounding is present. Where the mounding analysis identifies adverse impacts, the infiltration basin shall be redesigned or relocated, as appropriate. The mounding analysis shall provide details and supporting documentation on the methods used and assumptions made, including values used in calculations.

Page 6 addresses construction methods:

> Excavation and construction of an infiltration basin must be performed using equipment placed outside the limits of the basin.
>
> The excavation to the final design elevation of the infiltration basin bottom may only occur after all construction within its drainage area is completed and the drainage area is stabilized. If construction of the infiltration basin cannot be delayed, berms must be placed around the perimeter of the basin during all

phases of construction to divert all flows away from the basin. The berms may not be removed until all construction within the drainage area is completed, and the area is stabilized.

Challenges and Solutions

This section presents resources that address various issues. The first listings are current and active websites concerned with soil science, infiltration and sustainable drainage. In a short presentation, Soilhub.com addresses three common problems of infiltration failure, with photographs and incisive discussion. A brief report from the New Jersey Department of Transportation reveals the common missteps that are often taken when building an infiltration basin. Research papers present information concerning transitional states, successes and the prospect for improvement.

"Three Common Problems with Stormwater Infiltration and How to Correct Them," Soilhub.com, October 2016.
https://www.soilhub.com/3-common-problems-with-stormwater-infiltration-and-how-to-correct-them/
Soilhub.com represents a private sector community that appears to be grappling with current problems with stormwater management. The website is managed by stormwater engineers dedicated to the understanding of soil, with discussions, blogs, and online and field courses, including "Stormwater Infiltration Boot Camp" (https://www.soilhub.com/stormwater/). The presentation cited here addresses three problems—soils, compaction and siltation—with photos and discussion.

Susdrain—The Community for Sustainable Drainage, CIRIA (Construction Industry Research and Information Association), undated.
http://www.susdrain.org/resources/policy.html
This international website covers drainage policy and innovation in Europe and the United Kingdom. It provides a wide range of information, including a presentation on infiltration basins (http://www.susdrain.org/delivering-suds/using-suds/suds-components/infiltration/infiltration-basin.html). It is noteworthy that the description of infiltration basins includes this widely experienced disadvantage:

> Potentially high failure rates due to improper siting, poor design and lack of maintenance, especially if appropriate pre-treatment is not incorporated.

State of Infiltration Basin Designs, Sandra Blick, Hydrology and Hydraulics, New Jersey Department of Transportation, June 29, 2017.
http://www.nj.gov/dep/workgroups/docs/20170629-stormwater-inf-pres1.pdf
Many infiltration basins in New Jersey fail. This short slide presentation for a department report examines a range of shortcuts, errors and omissions made in infiltration basin planning in New Jersey. For example, in slide 9 the author discusses groundwater mounding, noting that many involved in infiltration device siting do not understand what it is or why application of its data is significant. The report reveals the extent to which quality control measures must reach (and currently may not reach) to prevent actions that can lead to failed projects.

Related Resource:

> **Stormwater Management**, David Ahdout, Ryan Reali and David Rauzino, New Jersey Department of Transportation, 2004.
> http://www.state.nj.us/transportation/publicat/pdf/stormwater_failure.pdf
> This presentation addresses similar issues with infiltration basin failures.

Broad Review Comments to Conservation Practice Standard: Site Evaluation for Storm Water Infiltration, Technical Standard 1002, Bureau of Watershed Management Program Guidance, Storm Water Management Program**,** Wisconsin Department of Natural Resources, 2016.
http://dnr.wi.gov/news/input/documents/guidance//TS1002Response.pdf
These pages present the comments of those in the field charged with siting and building infiltration devices regarding new Wisconsin Department of Natural Resources site evaluation changes for infiltration basins presented as Technical Standard 1002 (TS 1002). The problems the commentators describe—primarily those related to permits acquired before adequate site evaluation is completed, the assumption that a space relegated to stormwater on a plan will actually pass the required tests for infiltration, as well as the difficulties created by uncoordinated scheduling—can easily lead to costly redesigns or, worse, to stormwater management devices that do not function. TS 1002 was accepted and published in September 2017 (see **Quality Assurance Measures** in this report).

"Road Runoff Management Using Improved Infiltration Ponds," Maciej Mrowiec, *Transportation Research Procedia*, Vol. 14, pages 2659-2667, 2016.
Citation at http://dx.doi.org/10.1016/j.trpro.2016.05.435
From the abstract:

> The paper presents research focused on the development of the improved infiltration pond that: a) reduces runoff volume, b) keeps the required quality of soaking water, c) reduces maintenance needs. The paper presents the construction and hydraulic principles of the infiltration pond that can be applied to manage the runoff from roads and highways. It restores the natural hydrology and improves water quality by reducing the volume and frequency of flows that cause pollution and physical disturbance. Firstly the stormwaters are conveyed by the inlet channel to the settling chamber designed to settle out coarse sediments and floating debris (oil separators can also be mounted depending on the local law requirements). Settling chamber and infiltration chamber are connected by the filtration column filled with sand or other soil material to remove pollutants from the water. Stormwater flows through the porous media and then flows over the weir to the infiltration chamber. The filtration column is designed to cause reverse flow during emptying phase—it allows to rinse the pollutants from filter to settling chamber. Selection of the optimal grain size in the filter to get better efficiency of treatment is currently developed in laboratory tests. A hydrodynamic model of the proposed construction is presented to show its hydraulic efficiency. The presented infiltration basin provides an effective management of runoff generated from roads, highways and from parking lots considering both quantity (reduction of volumes) as well as quantity aspects (reduction of pollutant loads).

"Hydrologic Performance of a Transitioned Infiltration Basin Managing Highway Runoff," Poornima Natarajan and Allen P. Davis, *Journal of Sustainable Water in the Built Environment*, Vol. 1, Issue 3, August 2015.
Citation at http://ascelibrary.org/doi/abs/10.1061/JSWBAY.0000797
From the abstract:

> Infiltration basins are widely used stormwater control measures (SCMs) for urban stormwater runoff management. However, these SCMs can experience progressive failure to hydrologically perform as originally designed (i.e., primarily infiltration-based runoff control) and the functionality of such failed infiltration basins in managing stormwater runoff is unknown. In this field-scale research study, the hydrologic performance of a failed stormwater infiltration basin was investigated over 3 years. Visual indications of wet pond/wetland like conditions on-site suggested that the infiltration basin had evolved or transitioned to an alternate type of SCM. The transitioned infiltration basin mitigated runoff flows by providing dynamic flow attenuation, total volume and peak flow reductions, and reduced discharge durations. Performance of the transitioned basin can be classified into the following three hydrologic regimes: 100% volume reduction due to complete capture for small storm events; variable volume reductions (4–100%) for most medium and some large storm events depending on the season; and small or

no net impact on the largest and extreme events. Although the original infiltration capacity was found to be diminished, detention, retention, and evapotranspiration promoted by the presence of open water and vegetation in the transitioned infiltration basin enabled effective management of runoff.

"Restoration of Stormwater Infiltration Basin Performance," Richard Brunton and Andrew Brough, 8th South Pacific Stormwater Conference & Expo, New Zealand, 2013.
https://www.pdp.co.nz/wp-content/uploads/2017/02/2013-Stormwater_BruntonBrough1.pdf
From the abstract:

> Stormwater infiltration basins form a key part of the suite of low impact urban design devices to treat and dispose of urban stormwater runoff. These basins may suffer a reduction in performance with time, either as a result of improper construction or some step change, such as effects relating to an earthquake. In this paper several methods and tools available for remediation of stormwater infiltration basins that exhibit reduced performance are discussed, with reference to relevant case studies in the Christchurch area.

Case Studies: Innovative Stormwater Management Approaches and Practices, Chapter 9, Pennsylvania Stormwater Best Management Practices Manual, Pennsylvania Department of Environmental Protection, revised 2012.
http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48480/10_Chapter_9.pdf.
From the introduction:

> Although examples of BMPs have been included throughout all chapters of this manual with a considerable number of illustrations, in most cases these examples have been necessarily condensed and highly summarized. Most examples have not been able to do justice to all aspects of the site development program and the site design and stormwater management plans that have been developed. Consequently, early in the process of developing this new manual, the decision was made to include a chapter that highlights functioning projects in Pennsylvania communities that have successfully incorporated many of the Non-Structural and Structural BMPs that are described in this manual. Clearly, seeing is believing—there is great value in being able to visit and view firsthand successful applications of the many different BMPs which have been presented. … The case studies that have been included in this chapter are designed to focus on successful BMP application — what works. Over time, this case study discussion will be expanded to include lists of what to avoid — what doesn't work — as well. PADEP [Pennsylvania Department of Environmental Protection] invites all interested stormwater stakeholders to submit case study information in the future for additional projects. Section 9.2 is a list of information and data items that case study descriptions should address, although it is recognized that some data gaps may exist.

The following are the successful stormwater management projects presented in detail in this section:

1. Penn State University — Centre County Visitor Center, Centre County.
2. Dennis Creek Streambank Restoration, Franklin County.
3. Commerce Plaza III, Lehigh County.
4. Flying J. Truck Plaza for Welsh Oil of Indiana Truck Refueling Terminal, Cumberland County.
5. Ephrata Performing Arts Center, Lancaster County.
6. Lebanon Valley Agricultural Center, Lebanon County.
7. Penn State University Berks County Campus, Berks County.
8. Warm Season Meadows at Williams Transco, East Whiteland Township, Chester County.
9. Hills of Sullivan Residential Subdivision, London Grove Township, Chester County.

10. Applebrook Golf Course Community, Chester County.
11. Swan Lake Drive Development, Delaware County.

"Experimental Assessment of Stormwater Infiltration Basin Evolution," Magali Dechesne, Sylvie Barraud and Jean-Pascal Bardin, *Journal of Environmental Engineering*, Vol. 131, Issue 7 (July 2005).
Citation at https://doi.org/10.1061/(ASCE)0733-9372(2005)131:7(1090).
From the abstract:

> Infiltration basins are frequently used for stormwater drainage. They can operate for periods over 20 years but long-term evolution is not well understood or controlled. The two main problems encountered are clogging, which compromises the hydraulic capacity of the basin, and possible contamination of underlying soil and groundwater. This paper focuses on studying long-term evolution of clogging and soil pollution of infiltration basins. Basins of different ages are compared. Also, clogging and soil pollutant concentrations are explored for four infiltration basins in Lyon, France. Ages of the sites range from 10 to 21 years old. Clogging is characterized by the hydraulic resistance. Soil samples were collected at different depths in each basin and analyzed for different pollution parameters (metals, hydrocarbons, pH, and particle size distribution). All four basins have good infiltration capacities. Their hydraulic resistance is low. Such uniformity is surprising because of the age difference between the basins. Pollutant concentrations decrease rapidly with depth whereas pH and grain size increase. Concentrations reach an acceptable value at a 30 cm depth, even after 21 years of operation. Multivariate data analysis does not show significant relation between age, hydraulic resistance, and pollution.

Research in Progress

Limitations of the Infiltration Approach to Stormwater Management in the Highway Environment, NCHRP Project 25-51**,** start date: August 2015; expected completion date: February 2018.
http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3891.
From the project description:

> The objective of this research is to develop guidance for state DOTs to determine appropriate siting of stormwater infiltration BMPs based on the limitations, risks, and benefits in the context of the built and natural environments (e.g., surface water and groundwater, soils, existing infrastructure). The guidance should address a broad range of issues and needs associated with choosing and siting infiltration BMPs for mitigating roadway stormwater that may include but not be limited to the following:
>
> - Limitations (e.g., cost, maintenance, regulatory, receiving waters, geotechnical).
> - Effects of climate, soils, topography, geology, vegetation, and land use.
> - Effects of pollutants of concern on surface water and groundwater quality.
> - Effects on surface water and groundwater quantity (e.g., recharge, baseflow augmentation, groundwater mounding).
> - Identification of gaps in the body of knowledge.
> - Options for improving the effectiveness and reducing risks.
>
> The guidance should outline decision-making processes and criteria that would assist agencies in identifying flexible solutions.

Survey of Practice

Survey Approach

An online survey was distributed to selected state department of transportation (DOT) representatives who had recently attended a conference sponsored by the AASHTO Standing Committee on the Environment and to several state DOT hydrologists. The survey examined agency procedures for infiltration basin construction, site maintenance practices during construction and procedures for failing basins.

Appendix A provides the full text of the survey questions.

Summary of Survey Results

Representatives from eight states responded to the survey:

- Delaware
- Massachusetts
- Michigan
- Minnesota
- Ohio
- Vermont
- Washington
- West Virginia

Appendix B provides the full text of survey responses. Appendix C provides the contact information for all survey respondents.

Below is a discussion of survey results in three topic areas:

- Overview of infiltration basins.
- Protocols and procedures for constructing infiltration basins.
- Procedures for site maintenance during construction of infiltration basins and for failing basins.

Overview of Infiltration Basins

Use of infiltration basins among survey respondents is diverse, as shown in the table below. The number of infiltration basins constructed in the last 10 years varied widely, ranging from three to 250. The failure rate ranged from no failures to more than 50 percent.

Overview of Infiltration Basins

State	Number of Basins in 10 Years	Percentage of Failed Basins	Reasons for Failure
Delaware	12 basins, 10 trenches	1%-15%	Compaction, sedimentation, poor design.
Massachusetts	250	15%-30%	Compaction, inaccurate soil data/assumptions.
Michigan	25	No failures	Meaning of “failure” unclear.

Overview of Infiltration Basins			
State	**Number of Basins in 10 Years**	**Percentage of Failed Basins**	**Reasons for Failure**
Minnesota	More than 100	15%-30%	Initially, poor locations and practices; later, compaction, sedimentation, subcontractor tracking, basin phasing.
Ohio	15 trenches, 1 basin on 2 sites	More than 50%	Poor or no infiltration testing, poor stabilization leading to sedimentation.
Vermont	3	No failures	N/A
Washington	111 infiltration ponds, 81 bioinfiltration ponds	Uncertain	No response.
West Virginia	15-20	No failures	N/A

Additional comments from respondents follow:

- **Massachusetts:** The failure rate is based upon available maintenance and inspection data, and attributed to compaction during construction and inaccurate data or assumptions about subsurface soil.
- **Ohio:** Poor infiltration: 95 percent of Ohio's soils are sandy clay loam or sandy silt (Hydrologic Soil Groups C and D). Failed projects are due to poor or absent soil tests and poor stabilization of surrounding soil, leading to clogging of the base.
- **Vermont:** Although only three basins were constructed, upstream erosion in one caused sedimentation and another basin experienced internal erosion. Both were reconstructed or stabilized, and not considered failures.
- **West Virginia:** Only a minimum number of permanent infiltration basins were installed due to the long-term maintenance requirements of these structures.

Regulatory Body or Jurisdiction

Seven respondents cited a regulatory body or jurisdiction that oversees the construction standards of the agency's infiltration basins:

- **Delaware:** Delaware DOT, delegated by the state Environmental Protection Agency's (EPA's) Department of Natural Resources and Environmental Control (DNREC).
- **Massachusetts:** Massachusetts Department of Environmental Protection and U.S. EPA Region 1.
- **Minnesota:** Minnesota Pollution Control Agency (MPCA) and the state's watershed districts, especially in the Metro District.
- **Ohio:** Infiltration practices designed and built according to Ohio DOT's design requirements; Ohio EPA has regulatory authority, but it seldom oversees construction.
- **Vermont:** Vermont Agency of Natural Resources' stormwater program.

- **Washington:** Washington Department of Ecology approves design specifications, as listed in Washington State DOT's Highway Runoff Manual.
- **West Virginia:** West Virginia Department of Environmental Protection.

In Michigan, construction standards for infiltration basins, other than soil erosion, are not overseen by any agency.

Related Resources

Highway Runoff Manual, Washington State Department of Transportation, February 2016.
Complete manual: http://www.wsdot.wa.gov/publications/fulltext/hydraulics/hrm/app4d_2014.pdf
Appendix 4D: http://www.wsdot.wa.gov/publications/fulltext/hydraulics/hrm/app4d_2014.pdf
This manual provides guidance for planning and designing stormwater management facilities, including details for integrating stormwater-related elements into the project development process. Appendix 4D, Infiltration Testing and Design (beginning on page 187 of the PDF), describes the "testing methods used to determine infiltration rates (and saturated hydraulic conductivities) used for stormwater design." Chapter 5 (beginning on page 217 of the PDF) provides "specific guidelines and criteria on the proper selection, design and application of stormwater management techniques."

Water and Waste Permits, West Virginia Department of Environmental Protection, undated.
http://dep.wv.gov/WWE/permit/Pages/default.aspx
This website provides access to the permitting section of the Division of Water and Waste Management, including stormwater permitting.

Alternative Methods of Stormwater Management

All agencies are allowed to use alternative methods of stormwater management if an infiltration site proved too problematic to construct. Alternative methods were varied, as described in the table below:

Alternatives Methods of Stormwater Management

State	Alternative Methods Allowed
Delaware	Extended detention (48-hour versus normal 24-hour infiltration) and a banking agreement.
Massachusetts	Off-site mitigation for extraordinary circumstance only; other methods allowed to the maximum extent practicable for constrained redevelopment projects.
Michigan	Retention and detention.
Minnesota	MPCA: Sizing and infeasibility. Watershed districts: Criteria for new and redevelopment of parcels of land.
Ohio	Extended detention basins, bioretention cells, retention basins or constructed wetlands.

Alternatives Methods of Stormwater Management	
State	**Alternative Methods Allowed**
Vermont	Infiltration where possible, but other practices accepted where necessary. Infiltration prohibited at hotspots and in shallow water table or bedrock areas.
Washington	Infiltration trenches or vaults, natural or engineered dispersion, dry wells.
West Virginia	Permitted to mitigate in other areas of the watershed; can include monetary payments.

Protocols and Procedures for Constructing Infiltration Basins

Contract Specifications and Standard Manuals

Five respondents reported using standard contract specifications and procedures for infiltration basin construction. Both Massachusetts and Delaware require particular contract specifications be included in every project. Massachusetts adds a special provision (see Appendix D) for managing infiltration areas to every contract that has an infiltration BMP. Delaware has a detailed sequence for constructing an infiltration basin, a facility construction checklist (see Appendix E) and standard specifications for stormwater management facilities.

The Ohio respondent explained that while Ohio DOT has standards, they were not followed for the construction sites listed in the survey (16 total units); the failure rate was greater than 50 percent. Respondents from West Virginia and Washington listed their agency's manuals, which include guidelines for construction, but no required language.

Three respondents—Michigan, Minnesota and Vermont—reported that their agencies did not have standard contract specifications that are applicable to different stages of infiltration basin construction.

All of the respondents provided an agency manual or related publications as construction guidance for infiltration basins in their state. [See **Related Resources** below.] Minnesota DOT provided guidance on infiltration basins from the MnDOT Design-Build Program (see Appendix F).

None of the respondents mentioned using guidance from the Federal Highway Administration (FHWA) or other states with a long history of stormwater management, such as Maryland.

Related Resources

Delaware

Delaware Erosion and Sediment Control Handbook, Division of Watershed Stewardship, Delaware Department of Natural Resources and Environmental Control, March 2013.
http://www.dnrec.delaware.gov/swc/Drainage/Documents/Sediment%20and%20Stormwater%20Program/Technical%20Document/Latest%20Version%20of%20all%20Articles/3.06.1%20Delaware%20ESC%20Handbook.pdf
Chapter 3 of this handbook addresses standards and specifications for land management BMPs.

Post Construction Stormwater BMP Standards and Specifications, Division of Watershed Stewardship, Delaware Department of Natural Resources and Environmental Control, April 2016.
http://regulations.delaware.gov/register/may2016/emergency/PostConstruction.pdf
This manual provides standards and specifications for stormwater management, beginning with stormwater infiltration practices.

Standard Specifications for Road and Bridge Construction, Delaware Department of Transportation August 2016.
https://deldot.gov/Publications/manuals/standard_specifications/pdfs/2016/2016_standard_specifications_08-2016.pdf
Section 900 of this manual (beginning on page 456 of the PDF) provides guidance for erosion, sediment and stormwater measures.

Massachusetts

Massachusetts Stormwater Handbook, Volumes 1 and 2, Massachusetts Department of Environmental Protection, February 2008.
https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards
This handbook provides the regulations governing stormwater pollution management. Volume 1 presents the legal and regulatory framework; Volume 2 presents BMPs and other elements of stormwater management.

Storm Water Handbook for Highways and Bridges, Massachusetts Highway Department, May 2004.
http://www.massdot.state.ma.us/Portals/8/docs/environmental/wetlands/Stormwater_Handbook.pdf
The goal of this handbook is to provide guidance for complying with the Massachusetts Department of Environmental Protection stormwater management policy.

Urban Street Stormwater Guide, National Association of City Transportation Officials, undated.
https://nacto.org/publication/urban-street-stormwater-guide/
From the website: The Urban Street Stormwater Guide is a first-of-its-kind collaboration between city transportation, public works, and water departments to advance the discussion about how to design and construct sustainable streets. The Urban Street Stormwater Guide provides cities with national best practices for sustainable stormwater management in the public right-of-way, including core principles about the purpose of streets, strategies for building inter-departmental partnerships around sustainable infrastructure, technical design details for siting and building bioretention facilities, and a visual language for communicating the benefits of such projects. The guide sheds light on effective policy and programmatic approaches to starting and scaling up green infrastructure, provides insight on innovative street design strategies, and proposes a framework for measuring performance of streets comprehensively.

Michigan

Drainage Manual, Michigan Department of Transportation, January 2006.
http://www.michigan.gov/stormwatermgt/0,1607,7-205--93193--,00.html
This manual provides guidance for designing drainage facilities that meet the stormwater BMPs of Michigan DOT's stormwater management program. Chapter 8 provides general design criteria for various stormwater storage facilities, including detention, retention, infiltration and basin sizing. Chapter 9 briefly addresses stormwater BMPs.

Ohio

Drainage Design, Location and Design Manual, Volume 2, Ohio Department of Transportation, January 2018.
https://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Location%20and%20Design%20Volume%202/Pages/LandD-Vol-2.aspx
Volume 2 of the Location and Design Manual provides guidance for the hydraulic design of highway drainage facilities. Section 1115 (beginning on page 110 of the PDF) addresses post-construction stormwater BMPs.

Vermont

2017 Vermont Stormwater Management Manual Rule and Design Guidance, Vermont Agency of Natural Resources, 2017.
http://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/2017%20VSMM_Rule_and_Design_Guidance_04172017.pdf
From the introduction: This Manual more fully integrates approaches for designing and sizing STPs [stormwater treatment practices] for water quality treatment, groundwater recharge, downstream channel protection, and flood protection under the umbrella of runoff reduction through the Hydrologic Condition Method to ensure runoff volumes delivered to local receiving waters after site development more closely mimics pre-development conditions. In addition, this Manual provides instruction on a range of site planning and green stormwater infrastructure design practices for minimizing the generation of runoff from the developed portions of Vermont's landscape, including requirements for restoring healthy soils as part of development activity.

Washington

Highway Runoff Manual, Washington State Department of Transportation, February 2016.
Complete manual: https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf
Appendix 4D: http://www.wsdot.wa.gov/publications/fulltext/hydraulics/hrm/app4d_2014.pdf
The Highway Runoff Manual provides guidance for planning and designing stormwater management facilities, including details for integrating stormwater-related elements into the project development process. Appendix 4D, Infiltration Testing and Design (beginning on page 187 of the PDF), describes the "testing methods used to determine infiltration rates (and saturated hydraulic conductivities) used for stormwater design." Chapter 5 (beginning on page 217 of the PDF) provides "specific guidelines and criteria on the proper selection, design and application of stormwater management techniques."

Temporary Erosion and Sediment Control Manual, Washington State Department of Transportation, April 2014.
https://www.wsdot.wa.gov/publications/manuals/fulltext/M3109/TESCM.pdf
This guide outlines Washington State DOT's policies for complying with National Pollutant Discharge Elimination System (NPDES) requirements. Element 13 (page 25 of the report, page 35 of the PDF) describes low-impact development BMPs during construction activity.

West Virginia

Standard Specifications: Roads and Bridges, 2017 edition, Division of Highways, West Virginia Department of Transportation, 2017.
https://transportation.wv.gov/highways/contractadmin/specifications/2017StandSpec/Documents/2017_Standard.pdf
Section 107.21.1 addresses contractor requirements in erosion and sedimentation control.

2018 Supplemental Specifications, Division of Highways, West Virginia Department of Transportation, 2018.
https://transportation.wv.gov/highways/contractadmin/specifications/2018%20Supplemental%20Specifications/Documents/2018%20%20Supplemental_20171207.pdf
This handbook accompanies the 2017 Standard Specifications: Roads and Bridges manual.

Erosion and Sediment Control Best Management Practice Manual, Division of Water and Waste Management, West Virginia Department of Environmental Protection, August 2016.
http://dep.wv.gov/WWE/Programs/stormwater/csw/Documents/E%20and%20S_BMP_2006.pdf
From the introduction: The purpose of this manual is to provide standardized and comprehensive erosion and sediment control management practices that can be implemented on construction projects throughout West Virginia.

Drainage Manual, 3rd edition, Engineering Division, Division of Highways, West Virginia Department of Transportation, December 2007.
https://transportation.wv.gov/highways/engineering/Manuals/Drainage/WVDOH%202007%20Drainage%20Manual%20with%20Addendum%201%20and%202.pdf
This edition of the Drainage Manual "provides the designer with the needed information and tools to perform drainage analysis and design for highway facilities."

Design Directives, Engineering Division, Division of Highways, West Virginia Department of Transportation, November 2016.
http://transportation.wv.gov/highways/engineering/DD/2014%20DD%20Manual%20MASTER.pdf
Section 506 of the design directives (page 338 of the PDF) addresses post-construction stormwater management for both new and existing highway system projects.

Soil Tests for Infiltration Rates

Conducting soil tests before construction to establish infiltration sufficiency is a common practice among most agencies, but not during construction. Survey responses for this portion of the survey are summarized in the table below.

Soil Tests to Establish Infiltration Sufficiency Before and During Construction

State	Before	During	Comments
Delaware	Yes	No	Currently determined by design engineer, but soon will have established criteria.
Massachusetts	Yes	No	One test (minimum) per basin.
Michigan	Yes	No	Tests defined in Drainage Manual.
Minnesota	Yes	Yes	Before: Variable, based on soil analysis and some test pits. During: ASTM Double Ring Infiltrometer. Five tests unless less than 0.4 acre; then two tests per layer. Borings and piezometer tests prior to construction.
Ohio	No	No	Expect to incorporate testing soon.

Soil Tests to Establish Infiltration Sufficiency Before and During Construction			
State	Before	During	Comments
Vermont	Yes	No	Tested at a basin location at proposed bottom elevation.
Washington	Yes	No	Infiltration testing methods available in Appendix 4D of Highway Runoff Manual.
West Virginia	No	No	

Six agencies address issues with varying rates of infiltration at a proposed basin site and when there is evidence of infiltration insufficiency during construction. While three respondents referenced a manual or said the problem would be referred back to the designer, respondents from Massachusetts, Minnesota and Vermont offered possible solutions:

- **Massachusetts:** With varying infiltration rates, the agency takes the average measurement or takes new measurements and then reassesses. For infiltration insufficiency, the basin remains offline until it is fully vegetated. When it doesn't infiltrate, sedimentation removal and deep tilling to 18 inches is performed. The agency recommends avoiding compaction and tracking during construction.
- **Minnesota:** For insufficient infiltration during construction, the agency stops basin construction and contacts the designer and water resource engineer. The solution may involve new media or a new method, or the agency may initiate a design change from infiltration to filtration, and, as last resort, to wet pond.
- **Vermont:** With varying infiltration rates, the agency typically uses the most conservative test rates for sizing. To resolve insufficient infiltration in one basin, the agency partially excavated the basin, removed the geotextile and replaced it with a sandier soil.

Quality Assurance Methods

Five respondents reported that their agencies use quality assurance methods during infiltration basin construction, as summarized in the table below. Two states used quality assurance methods that followed the construction along from task to task, while three depended upon the project's final performance after construction was complete. Michigan, Vermont and West Virginia do not use quality assurance methods.

Quality Assurance Methods Used During Infiltration Basin Construction	
Method	**State Employing Method**
Hold points	Delaware
Preactivity meetings	Delaware, Massachusetts

Quality Assurance Methods Used During Infiltration Basin Construction	
Method	**State Employing Method**
Checklists	Delaware Washington: the WSDOT construction manual uses many checklists to aid project inspectors during construction of the project.
Other methods	Minnesota: 1717 Site Management Plan (contractor submitted means and methods). Massachusetts: Must observe drawdown within 72 hours of precipitation event before demobilization. Ohio: Site manager ensures that basin is built according to plans before the contractor is paid.

Note: Hold points are stopping points in a process during which past tasks are examined for correctness and accuracy before work is allowed to continue.

Related Resources

> **Construction Manual**, Washington State Department of Transportation, January 2018.
> https://www.wsdot.wa.gov/publications/manuals/fulltext/M41-01/Construction.pdf
> *From the foreword*: This manual is provided for our construction engineering personnel as instruction for fulfilling the objectives, procedures, and methods for construction administration of Washington State transportation projects. … [T]he instructions prescribe detailed methods and procedures, or detailed performance measures, designed to assure the objective of a safe and adequate finished product.

Groundwater Elevations and Compaction

Six states (Delaware, Massachusetts, Michigan, Minnesota, Ohio and Washington) use soil boring, test pits and the findings of a geotechnical engineer to determine groundwater elevations. Delaware and Minnesota use evidence of redoximorphic features to determine seasonal high water. Other states did not respond or used no methods to determine years that were unusually dry or wet that would consequently affect the groundwater levels during some years.

To avoid compaction during construction of infiltration basins, Delaware does not allow equipment within 1 foot of the basin bottom elevation. Five other states responded similarly; Minnesota noted that the agency had not been able to avoid compaction.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

Site Maintenance During Construction

When asked to describe methods used to maintain a site during construction, three respondents reported that their states have plans in place to address site erosion and siltation. Delaware has a detailed sequence of construction and a detailed erosion and sedimentation plan. In Massachusetts, the basin must be cleaned out before it is planted, and construction is conducted offline when feasible. Washington refers to its Temporary Erosion and Sediment Control Manual for practices that protect infiltration projects during construction.

Ohio noted that the contractor was responsible for stormwater pollution prevention. Minnesota does not have a working system to avoid erosion and siltation of the site.

Plant Establishment

Massachusetts, Delaware and Washington have more developed approaches to promote perennial plantings on infiltration basins. Massachusetts and Delaware write seeding specifications into their contracts, such as performance-based provisions for contract completion. Washington has its own landscape architects and provides three years of funding for perennial plant establishment.

The Ohio respondent noted that their infiltration facilities are covered with aggregate rather than planted. Vermont relies on a low-mow seed mixture with lime, fertilizer and mulch or temporary matting. Minnesota relies on the knowledge and skills of the lead inspector.

Failing Infiltration Basins: Actions and Solutions

When asked to describe actions taken to address failing infiltration basins, several respondents said their agencies enlist the assistance of a geotechnologist or other soil professional and attempt to determine the reason for the failure. If the issue cannot be remedied with actions such as replacing geotextile or ripping the soil, an alternative stormwater method is considered.

Acquisition of Land for Stormwater Management

Agencies consider acquiring more land—through right of way or outright purchase—if needed to accommodate infiltration. Washington State DOT acquires new right of way for many projects, including new stormwater BMPs. Because Massachusetts has eminent domain, it acquires land when stormwater permits require infiltration and site constraints prevent the placement of an infiltration BMP within the right of way.

However, the majority of states responding to the survey considered it an alternative of last resort and prefer not to acquire more land when a stormwater method did not work as intended. Minnesota DOT's respondent noted that the agency argues for the infeasibility of that option when the possibility arises.

Appendix A

Infiltration Basins: Standards and Procedures to Ensure Performance: Survey Questions

The following survey was provided to 36 selected members of the AASHTO Standing Committee on the Environment. These members were from states in the northern half of the country and were expected to have some knowledge of infiltration basins and other stormwater practices.

Overview of Infiltration Basins

1. Approximately how many infiltration basins has your agency constructed in the last 10 years?
2. Approximately what percentage of these infiltration basins failed in the first two years after construction?
    - No failures
    - Approximately 1 to 15 percent failures
    - Approximately 15 to 30 percent failures
    - Approximately 30 to 50 percent failures
    - More than 50 percent failures
3. What are the understood or assumed causes of these infiltration basin failures?
4. Which jurisdiction or regulatory body oversees the construction standards for your agency's infiltration basins?
5. Does the regulatory body allow your agency to pursue other methods of stormwater management in difficult sites? If yes, please describe.

Protocols and Procedures for Constructing Infiltration Basins

6. Does your agency use standard contract specifications, protocols and/or procedures that apply to the stages of infiltration basin construction? If yes, please describe.
7. Which standard manuals or other established guidance (e.g., Minnesota Stormwater Manual, Maryland Stormwater Design Manual, Federal Highway Administration) does your agency follow to construct infiltration basins?
8. Does your agency perform tests to establish infiltration rates for proposed infiltration basins before initial construction?

    If yes, how? Specify the quantity of tests (e.g., number per acre) to establish infiltration rates.
9. Does your agency perform tests to establish infiltration rates for proposed infiltration basins during initial construction?

    If yes, how? Specify the quantity of tests to establish infiltration rates.
10. In the case of varying rates of infiltration across a site tested before construction, what is your agency's standard approach to determining a site's acceptability?
11. In the case of indications of infiltration insufficiency during construction, what corrective measures or alternative actions does your agency apply?

12. What quality assurance methods does your agency use during construction of infiltration basins?
    - Hold points (points in a process at which past tasks are examined for correctness and accuracy before work is allowed to continue)
    - Preactivity meetings
    - Checklists
    - Other quality assurance methods
13. How does your agency determine groundwater elevations? Please describe process.
14. How does your agency determine which years of groundwater elevation data include unusually dry or wet years? Please describe method.
15. How does your agency avoid compaction of the basin during construction?

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. What procedures does your agency use to maintain the site during construction of the infiltration basins (i.e., prevention of erosion and siltation, such as berm bypass, inlet bypass, lift station bypass)?
17. How does your agency facilitate the growth of stabilizing perennial plants on upgrades and generally promote plant establishment?
18. How does your agency deal with failing infiltration basins?
19. Does your agency seek additional land (right of way) to accommodate infiltration or any other stormwater management treatment method?
    - Yes
    - No
    - Sometimes

    Please describe the circumstances under which your agency would seek additional land (e.g., right of way) for infiltration or any other stormwater management treatment methods.

Wrap-Up

If you have further information or comments about your agency's standards and procedures regarding infiltration basins, please include them here.

Appendix B

Infiltration Basins: Standards and Procedures to Ensure Performance: Survey Results

The full text of each survey response is provided below. For reference, an abbreviated version of each question is included before the response. Responses have been edited for clarity.

Delaware

Contact: Vince Davis, Stormwater Engineer, Delaware Department of Transportation, 302-760-2180, Vince.Davis@state.de.us.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 12 infiltration basins, 10 trenches.
2. **Percentage of failures within two years of construction:** 1 to 15 percent.
3. **Reasons for failure:** Construction activities, primarily excessive sedimentation and/or compaction. Poor initial design could have been a factor for one as well.
4. **Regulatory body or jurisdiction:** DelDOT under the state EPA [Environmental Protection Agency]: [Department] of Natural Resources and Environmental Control (DNREC).
5. **Other allowed methods of stormwater management:** DNREC allows extended detention (48 [hours] vs. normal 24 [hours]) and we have a banking agreement that we can utilize.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** Detailed sequence of construction, facility construction checklist [see Appendix E], standard specifications for stormwater management facilities.
7. **Standard manuals and/or established guidance:** DelDOT Standard Specifications, DNREC Stormwater BMP [Best Management Practices] Manual. [See **Related Resources** below.]
8. **Infiltration tests before construction:** Yes. Determined by design engineer, but soon will have established criteria.
9. **Infiltration tests during construction:** No.
10. **Procedures in case of varying rates before construction:** Determined by the design engineer with concurrence from the stormwater engineer.
11. **Actions if signs of infiltration insufficiency during construction:** Corrective actions as needed to bring the facility back into compliance.
12. **Quality assurance methods:**
    - **Hold points:** Yes.
    - **Preactivity meetings:** Yes.
    - **Checklists:** Yes.
13. **Determining groundwater elevation:** As determined by the geotechnical engineer from Materials and Research section.

14. **Unusually wet or dry years noted:** As determined by the geotechnical engineer from Materials and Research section.

15. **Methods to avoid compaction:** No equipment is allowed within 1 foot of the designed basin bottom elevation.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** Detailed sequence of construction along with fairly detailed erosion and sedimentation (E&S) plan.

17. **Methods to facilitate establishment of perennial plants on basin:** Seeding specification.

18. **Actions taken to address failing infiltration basins:** We haven't had an issue yet with total failure.

19. **Acquisition of additional land for stormwater management:** If needed for project, then goes through our Real Estate section to acquire property.

Related Resources

Delaware Erosion and Sediment Control Handbook, Division of Watershed Stewardship, Delaware Department of Natural Resources and Environmental Control, March 2013.
http://www.dnrec.delaware.gov/swc/Drainage/Documents/Sediment%20and%20Stormwater%20Program/Technical%20Document/Latest%20Version%20of%20all%20Articles/3.06.1%20Delaware%20ESC%20Handbook.pdf
Chapter 3 of this handbook addresses standards and specifications for land management best management practices (BMPs).

Post Construction Stormwater BMP Standards and Specifications, Division of Watershed Stewardship, Delaware Department of Natural Resources and Environmental Control, April 2016.
http://regulations.delaware.gov/register/may2016/emergency/PostConstruction.pdf
This manual provides standards and specifications for stormwater management, beginning with stormwater infiltration practices.

Standard Specifications for Road and Bridge Construction, Delaware Department of Transportation August 2016.
https://deldot.gov/Publications/manuals/standard_specifications/pdfs/2016/2016_standard_specifications_08-2016.pdf
Section 900 of this manual (beginning on page 456 of the PDF) provides guidance for erosion, sediment and stormwater measures.

Massachusetts

Contact: Henry Barbaro, Stormwater Unit Supervisor, Massachusetts Department of Transportation, 857-368-8788, Henry.Barbaro@state.ma.us.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 250.

2. **Percentage of failures within two years of construction:** Approximately 15 to 30 percent (approximation based on available maintenance and inspection data).

3. **Reasons for failure:** Compaction during construction; inaccurate geotechnical data/assumptions of subsurface soil conditions.

4. **Regulatory body or jurisdiction:** Massachusetts Department of Environmental Protection; U.S. EPA Region 1.

5. **Other allowed methods of stormwater management:** Off-site mitigation for extraordinary circumstances only (variance); maximum extent practicable for constrained redevelopment projects.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** Special provision put in for managing infiltration areas added to every contract that has an infiltration BMP [best management practice]. [See Appendix D.] Use MassDEP Stormwater Handbook for regulatory guidance for constructing infiltration areas.

7. **Standard manuals and/or established guidance:** MassDEP Stormwater Handbook, MassDOT Stormwater Handbook, NACTO Urban Street Stormwater Guide, Hydrologic Engineering Center (HEC) releases of the Army Corps of Engineers. [See **Related Resources** below.]

8. **Infiltration tests before construction:** Yes. One per basin (minimum).

9. **Infiltration tests during construction:** No.

10. **Procedures in case of varying rates before construction:** Only take one measurement—in the case of varying rates, use the average or take new measurement, then reassess.

11. **Actions if signs of infiltration insufficiency during construction:** Before this happens, recommend constructing basin offline of drainage system if possible. Do not put online until fully vegetated. When it does not infiltrate, a combination of sediment removal (to remove fine earth fractions that may have accumulated during construction phase) and deep tilling to 18 inches. During construction, recommend using low ground pressure construction equipment for basins, prohibit "tracking," and fine grading should be done by hand.

12. **Quality assurance methods:**

    - **Hold points:** [No response.]
    - **Preactivity meetings:** Yes.
    - **Checklists:** [No response.]
    - **Other quality assurance methods:** Must observe drawdown within 72 hours of precipitation event before demobilization.

13. **Determining groundwater elevation:** Test pits, using redoximorphic features for seasonal high groundwater.

14. **Unusually wet or dry years noted:** It doesn't matter—we go with seasonal high groundwater; redox features are permanent.

15. **Methods to avoid compaction:** During construction, recommend using low ground pressure construction equipment for basins, prohibit "tracking," and fine grading should be done by hand.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** Construction offline when feasible. Clean out basin before vegetating.

17. **Methods to facilitate establishment of perennial plants on basin:** Construction contract contains a performance-based provision for seeding. The onus is on the contractor to figure out how to get vegetation to establish.

18. **Actions taken to address failing infiltration basins:** New geotechnologist to confirm soil conditions, deep tilling/scarification, revegetation, sediment removal.

19. **Acquisition of additional land for stormwater management:** We acquire land when stormwater permits require infiltration and site constraints prevent the placement of infiltration BMP [best management practice] within the right of way. We are an eminent domain state.

Related Resources

Massachusetts Stormwater Handbook, Volumes 1 and 2, Massachusetts Department of Environmental Protection, February 2008.
https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards
This handbook provides the regulations governing stormwater pollution management. Volume 1 presents the legal and regulatory framework; Volume 2 presents BMPs and other elements of stormwater management.

Storm Water Handbook for Highways and Bridges, Massachusetts Highway Department, May 2004.
http://www.massdot.state.ma.us/Portals/8/docs/environmental/wetlands/Stormwater_Handbook.pdf
The goal of this handbook is to provide guidance for complying with the Massachusetts Department of Environmental Protection stormwater management policy.

Urban Street Stormwater Guide, National Association of City Transportation Officials, undated.
https://nacto.org/publication/urban-street-stormwater-guide/
From the website: The Urban Street Stormwater Guide is a first-of-its-kind collaboration between city transportation, public works, and water departments to advance the discussion about how to design and construct sustainable streets. The Urban Street Stormwater Guide provides cities with national best practices for sustainable stormwater management in the public right-of-way, including core principles about the purpose of streets, strategies for building inter-departmental partnerships around sustainable infrastructure, technical design details for siting and building bioretention facilities, and a visual language for communicating the benefits of such projects. The guide sheds light on effective policy and programmatic approaches to starting and scaling up green infrastructure, provides insight on innovative street design strategies, and proposes a framework for measuring performance of streets comprehensively.

Michigan

Contact: Christopher Potvin, Stormwater Program Manager, Michigan Department of Transportation, 517-335-2171, PotvinC@michigan.gov.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 25.

2. **Percentage of failures within two years of construction:** No failures have been reported to me, but there is really a question about what the definition of what a "failure" is.

3. **Reasons for failure:** [No response.]

4. **Regulatory body or jurisdiction:** Construction standards, other than soil erosion, are not overseen by any agency.

5. **Other allowed methods of stormwater management:** Retention and detention could be used.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** We are in the process of developing new standards for basins. They are probably a year or so out.
7. **Standard manuals and/or established guidance:** Michigan Department of Transportation Drainage Manual, http://www.michigan.gov/stormwatermgt/0,1607,7-205--93193--,00.html. [See **Related Resource** below.]
8. **Infiltration tests before construction:** Yes. As defined in [the] Drainage Manual.
9. **Infiltration tests during construction:** No.
10. **Procedures in case of varying rates before construction:** MDOT does not have a policy covering this.
11. **Actions if signs of infiltration insufficiency during construction:** [No response.]
12. **Quality assurance methods:** None.
13. **Method of determining groundwater elevation:** Soil borings.
14. **Unusually wet or dry years noted:** No method used.
15. **Methods to avoid compaction:** Light equipment and avoidance of the area.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** [No response.]
17. **Methods to facilitate establishment of perennial plants on basin:** [No response.]
18. **Actions taken to address failing infiltration basins:** [No response.]
19. **Acquisition of additional land for stormwater management:** Purchasing right of way would be a last resort for project infiltration.

Related Resource
Drainage Manual, Michigan Department of Transportation, January 2006.
http://www.michigan.gov/stormwatermgt/0,1607,7-205--93193--,00.html
This manual provides guidance for designing drainage facilities that meet the stormwater BMPs of Michigan DOT's stormwater management program. Chapter 8 provides general design criteria for various stormwater storage facilities, including detention, retention, infiltration and basin sizing. Chapter 9 briefly addresses stormwater BMPs.

Minnesota

Contact: Dwayne Stenlund, Erosion Control Specialist, Minnesota Department of Transportation, 612-810-9409, Dwayne.Stenlund@state.mn.us.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** More than 100.
2. **Percentage of failures within two years of construction:** Approximately 15 to 30 percent failures.
3. **Reasons for failure:** Originally, poor location, understanding of soil type, too large an area in treatment, poor filter media. Now more likely [the reasons are] failure to isolate the basin from upgradient sediment loss, compaction during construction, subcontractor tracking and basin

phasing. We are still experimenting a bit with an optimal design, and getting groundwater data in a timely manner is problematic. Redox [redoximorphic features] has helped quite a bit.

4. **Regulatory body or jurisdiction:** Minnesota Pollution Control Agency (MPCA) and watershed districts (WSD), especially in the Metro District, and watershed management organizations.

5. **Other allowed methods of stormwater management:** Yes, if the sizing and infeasibility are defined in the MPCA permit, and with WSD criteria for new and redevelopment of parcels of land. If reasons are documented, the NPDES [National Pollutant Discharge Elimination System] permit allows options and is a very straightforward process. There are many different watershed regulations on infiltration, and infiltration is pushed and difficult to get around not implementing in many watershed areas.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** No.

7. **Standard manuals and/or established guidance:** A good synthesis can be found in the MnDOT design/build drainage document: Book 2 Section 12. [See Appendix F.] Note there is a design difference between filtration (active under-drain) and infiltration. Metro District also has a guidance document on infiltration [and] filtration.

8. **Infiltration tests before construction:** Yes. Variable, and mostly based on soil boring textural analysis. Some proposed projects have used pit tests.

9. **Infiltration tests during construction:** Yes. ASTM Double Ring infiltrometer, five tests on each layer unless [the site] is less than 0.4 acre; then two per layer (bottom pre-media, finished top fill).

10. **Procedures in case of varying rates before construction:** Use the lesser rate.

11. **Actions if signs of infiltration insufficiency during construction:** Basin construction will cease, design professional is contacted, water resource engineer is contacted, result may change media, method or initiate new design from infiltration, to filtration, and at last resort, to wet pond.

12. **Quality assurance methods:** Yes.

    - **Hold points:** Must meet infiltration/filtration special provisions before approval
    - **Preactivity meetings:** Discussion during preconstruction?
    - **Checklists:** [No response.]
    - **Other quality assurance methods:** Site management plan (contractor-submitted means and methods). Special provision.

13. **Determining groundwater elevation:** Soil borings, pit tests.

14. **Unusually wet or dry years noted:** Yes. Look for evidence of Redox, borings for perches, water lenses.

15. **Methods to avoid compaction:** Have not been able to avoid compaction on basins wider than an excavator bucket reach. Use deep tooth ripper on backhoe arm.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** Hit and miss. Attempt to build last after all upgradient vegetation is established; redundant perimeter controls. Unsure how to bypass large rain events.

17. **Methods to facilitate establishment of perennial plants on basin:** Mostly a luck of weather. The process of tillage, nutrient incorporation, and seeding are largely dependent on the knowledge and

skills of the lead inspector. Watering is incorporated into specifications.

18. **Actions taken to address failing infiltration basins:** It depends on when the basin fails to deliver an acceptable rate of water abstraction. If it is caught during construction, attempts are made to deliver success. Otherwise, it appears to be a function of maintenance supervisor, time and budget if restoration of function occurs. Inspections are performed after construction per permit requirements and repairs made.

19. **Acquisition of additional land for stormwater management:** In general, we attempt to avoid additional land. As the permit requires volume reduction by infiltration, attempts are made to document infeasibility [of] obtaining additional land. **Land is acquired to meet watershed requirements.**

Ohio

Contact: Jon Prier, Environmental Hydraulic Engineer, Ohio Department of Transportation, 614-644-1876, Jonathan.Prier@dot.ohio.gov.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 16 constructions on 2 sites.
2. **Percentage of failures within two years of construction:** More than 50 percent failures. Approximately 95 percent of Ohio soils are sandy clay loam or clay loam with silt clay (Hydrologic Soil Groups C or D). Infiltration is normally not a good practice unless [sited] near to a river basin with sandy soil.
3. **Reasons for failure:** Poor or nonexistent in situ soil infiltration rate tests. Poor stabilization of surrounding soil, leading to clogging of the aggregate.
4. **Regulatory body or jurisdiction:** ODOT ensures that infiltration practices are designed and built per ODOT's design requirements. Ohio EPA [Environmental Protection Agency] has regulatory authority over ODOT for post-construction BMPs [best management practices] that are required under the statewide Construction General Permit; however, Ohio EPA seldom oversees construction.
5. **Other allowed methods of stormwater management:** Yes. Ohio does not currently have a soil reduction requirement in the Construction General Permit. Construction activities that require post-construction BMPs may use extended detention basins, bioretention cells, retention basins or constructed wetland to get the same credit as infiltration practices.

Protocols and Procedures for Constructing Infiltration Basins

6. Standard contract specifications: Yes. ODOT specifies the aggregate material. ODOT also specifies that all contributing drainage areas are stabilized before the infiltration practice is completed (but that was not followed on our two infiltration practice sites).

   [Sample plan notes from Ohio DOT's Location and Design Manual, Volume 2: Drainage Design, page 226 of the PDF]:

   W102 INFILTRATION TRENCH (OR BASIN)
   This plan utilizes infiltration for post construction storm water treatment. Construct the completed infiltration trench(es) (and or basin(s)) after all contributing drainage areas are stabilized as shown in the contract plans and to the satisfaction of the engineer. Do not use infiltration devices as temporary sediment control facilities during construction. Do not operate heavy equipment within the perimeter of an infiltration device during excavation or backfilling of the facility.

Designer Note: This plan note shall be used on all projects that have infiltration trenches and or basins identified in the plan. Embankment work to create the impoundment will be constructed and paid for as Item 203 Embankment, using natural soils, 703.16.A.

7. **Standard manuals and/or established guidance:** ODOT has their own manual for post-construction stormwater BMPs: ODOT's Location and Design Volume 2 Manual: https://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Location%20and%20Design%20Volume%202/Pages/LandD-Vol-2.aspx. [See **Related Resource** below.]

8. **Infiltration tests before construction:** No. We don't currently, but we should as a condition of accepting the practice. Since the two sites we have aren't working well, we'll likely make some changes soon.

9. **Infiltration tests during construction:** No.

10. **Procedures in case of varying rates before construction:** We allow the designer (normally a consultant) to make the determination since they are the person stamping the drawings. We will question abnormally high assumed rates.

11. **Actions if signs of infiltration insufficiency during construction:** We do not measure infiltration during construction.

12. **Quality assurance methods:**
    - **Hold points:** [No response.]
    - **Preactivity meetings:** [No response.]
    - **Checklists:** Yes.
    - **Other quality assurance methods:** Yes. The ODOT site manager ensures the infiltration practice is built per the plans before the contractor is paid for that item.

13. **Determining groundwater elevation:** If groundwater elevations are reviewed, Ohio Department of Natural Resources keeps well information that is publicly available. The designer may also use soil borings from a single date.

14. **Unusually wet or dry years noted:** Generally not considered.

15. **Methods to avoid compaction:** Our specification calls for keeping heavy equipment outside of the infiltration practice.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** The contractor develops the Storm Water Pollution Prevention Plan (SWPPP). Infiltration practices are not allowed to be used as sediment basins.

17. **Methods to facilitate establishment of perennial plants on basin:** Our infiltration practices are covered with aggregate, and not planted.

18. **Actions taken to address failing infiltration basins:** If maintenance can be performed to bring the practice into operation, then ODOT will perform the maintenance. If the practice is not maintainable, ODOT will replace the BMP with a different BMP offering the same level of treatment per our National Pollutant Discharge Elimination System (NPDES) construction general permit requirements.

19. **Acquisition of additional land for stormwater management:** To my knowledge, ODOT has never acquired right of way for infiltration practices. However, ODOT has acquired right of way for other post-construction BMPs through normal means if the BMP is necessary to meet design requirements of the site.

Wrap-Up

Comments or additional information: At ODOT, infiltration practices are allowed based on the NPDES construction general permit, but we are recommending that they [be] avoided due to our normally low infiltration rates across the state. The infiltration rates at most sites range from 0.10 inch/hour to 0.01 inch/hour.

Related Resource

Drainage Design, Location and Design Manual, Volume 2, Ohio Department of Transportation, January 2018.
https://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Location%20and%20Design%20Volume%202/Pages/LandD-Vol-2.aspx
Volume 2 of the Location and Design Manual provides guidance for the hydraulic design of highway drainage facilities. Section 1115 (beginning on page 110 of the PDF) addresses post-construction stormwater BMPs.

Vermont

Contact: Jonathan Armstrong, Stormwater Engineer, Vermont Agency of Transportation, 802-828-1332, Jon.Armstrong@vermont.gov.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 3
2. **Percentage of failures within two years of construction:** No failures. Some performance concerns.
3. **Reasons for failure:** Upstream erosion caused some sedimentation on one, which needed to be partially reconstructed to function. One had some internal erosion, which has been stabilized.
4. **Regulatory body or jurisdiction:** VT [Vermont] Agency of Natural Resources Stormwater program.
5. **Other allowed methods of stormwater management:** Infiltration is promoted where possible, but documented and accepted constraints can justify using other practices. Infiltration is prohibited at hotspots and shallow water table or bedrock areas.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** No. Not a well-defined process at this time. Typically handled with project specific notes/narrative on practice details, drainage layout plans and/or on erosion prevention and sediment control plans.
7. **Standard manuals and/or established guidance:** [2017 Vermont Stormwater Management Manual Rule and Design Guidance; see **Related Resource** below.]
   http://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/2017%20VSMM_Rule_and_Design_Guidance_04172017.pdf
8. **Infiltration tests before construction:** Yes. Rates tested at basin location at proposed bottom elevation.
9. **Infiltration tests during construction:** No.
10. **Procedures in case of varying rates before construction:** Testing must be done at [the] location of practice, and typically most conservative results would be utilized as a basis for sizing.

11. **Actions if signs of infiltration insufficiency during construction:** We partially excavated one and removed geotextile. A sandier soil was placed.
12. **Quality assurance methods:** No.
13. **Determining groundwater elevation:** Not well defined at this time; similar to methods used for typical septic disposal requirements.
14. **Unusually wet or dry years noted:** [No response.]
15. **Methods to avoid compaction:** Notes on plans.

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** [No response.]
17. **Methods to facilitate establishment of perennial plants on basin:** Typically just low-mow seed mix with lime, fertilizer and mulch, or temp matting used.
18. **Actions taken to address failing infiltration basins:** Attempt to troubleshoot based on observation of likely failure mechanism.
19. **Acquisition of additional land for stormwater management:** Acquire additional land as needed to provide treatment necessary to meet VT [Vermont] Stormwater Manual pursuant to a jurisdictional VT post-construction [stormwater] permit.

Related Resource

2017 Vermont Stormwater Management Manual Rule and Design Guidance, Vermont Agency of Natural Resources, 2017.
http://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/2017%20VSMM_Rule_and_Design_Guidance_04172017.pdf
From the introduction: This Manual more fully integrates approaches for designing and sizing STPs [stormwater treatment practices] for water quality treatment, groundwater recharge, downstream channel protection, and flood protection under the umbrella of runoff reduction through the Hydrologic Condition Method to ensure runoff volumes delivered to local receiving waters after site development more closely mimics pre-development conditions. In addition, this Manual provides instruction on a range of site planning and green stormwater infrastructure design practices for minimizing the generation of runoff from the developed portions of Vermont's landscape, including requirements for restoring healthy soils as part of development activity.

Washington

Contact: Jana Ratcliff, Municipal Stormwater Permit Coordinator, Washington State Department of Transportation, 360-570-6649, RatcliJ@wsdot.wa.gov.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 111 infiltration ponds, 81 bio-infiltration ponds.
2. **Percentage of failures within two years of construction:** "Uncertain" or "no failures."
3. **Reasons for failure:** [No response.]
4. **Regulatory body or jurisdiction:** The Washington Department of Ecology approves the BMP [best

management practice] design specifications in WSDOT's Highway Runoff Manual (HRM). [See **Related Resources** below.] WSDOT engineers size BMPs to meet these standards and create the contract plans and specifications. WSDOT contractors build the BMPs per the plans and specifications.

5. **Other allowed methods of stormwater management:** Yes, we have other infiltration- type BMPs such as infiltration trenches, infiltration vaults, natural dispersion, engineered dispersion and dry wells. We also have other stormwater BMPs where partial infiltration is part of the stormwater treatment. These BMPs include compost-amended vegetated filter strips, compost-amended biofiltration swales, media filter drains and bioretention areas.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** WSDOT's Highway Runoff Manual (HRM) (Chapter 5) contains construction criteria for building infiltration BMPs. Designers can include this information into the contract Special Provisions to help tell the contractor how to construct the infiltration BMP. The Temporary Erosion and Sediment Control (TESC) Plan may also contain pertinent information. WSDOT's Temporary Erosion and Sediment Control Manual (TESCM) contains TESC Plan guidance. [See **Related Resources** below.] TESC Planning Element 13 is intended to protect permanent infiltration BMPs during construction.

7. **Standard manuals and/or established guidance:** See answer above.

8. **Infiltration tests before construction:** Yes. See WSDOT's HRM Appendix 4D for infiltration testing methods [see **Related Resources** below].

9. **Infiltration tests during construction:** No. The construction criteria in the HRM BMP write-up for infiltration BMPs (Chapter 5) [see **Related Resources** below] says, "Conduct the initial excavation to within 1 foot of the final elevation of the infiltration pond floor. Defer the final excavation to the finished grade until you stabilize or protect all disturbed areas in the upgradient drainage area. The final phase of excavation should remove all accumulated sediment. As with all types of infiltration facilities, you generally should not use infiltration ponds as temporary sediment traps during construction. If an infiltration pond is to be used as a sediment trap, do not excavate it to final grade until after the upgradient drainage area has been stabilized. Remove any accumulation of silt in the pond before the pond is put into service. Low-ground-pressure equipment is recommended for excavation to avoid compacting the floor of the infiltration pond. Consider the use of draglines and trackhoes. Flag or mark the infiltration area to keep equipment away." So the infiltration testing done before construction should still be OK to characterize the infiltration rate of the infiltration pond after construction if the above guidance is followed.

10. **Procedures in case of varying rates before construction:** See HRM Appendix 4D. [See **Related Resources** below.]

11. **Actions if signs of infiltration insufficiency during construction:** Because of the rigorous infiltration testing done prior to construction, field testing isn't required. If site conditions do change, the contractor and WSDOT can do a change order to figure out an alternative way to treat the stormwater with another stormwater BMP.

12. **Quality assurance methods:** Yes.

    - **Hold points:** [No response.]
    - **Preactivity meetings:** [No response.]
    - **Checklists:** Yes.
    - **Other quality assurance methods:** WSDOT builds stormwater BMPs per the construction

plan set and Special Provisions. WSDOT uses the Construction Manual (which includes many checklists) to aid project inspectors during the construction of the project. [See **Related Resources** below.]

13. **Determining groundwater elevation:** See the HRM Appendix 4D for directions on how to locate the groundwater table elevation. [See **Related Resources** below.] We need this to establish the hydraulic gradient when determining infiltration rates.

14. **Unusually wet or dry years noted:** A Washington State licensed professional engineer needs to stamp the geotechnical report that establishes the infiltration rates. That person uses engineering judgment to establish the length of piezometer monitoring to establish the groundwater table elevation.

15. **Methods to avoid compaction:** See HRM Chapter 5 for Infiltration Pond BMP construction criteria. [See **Related Resources** below.]

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** WSDOT uses the Temporary Erosion and Sediment Control Manual Element 13 [see **Related Resources** below] to protect infiltration ponds during construction.

17. **Methods to facilitate establishment of perennial plants on basin:** WSDOT landscape architects provide appropriate plant selection, spacing and site preparation methods (soil amendment) to facilitate plant growth. A minimum of three years is required to fund plant establishment. Plant establishment activities include (but [are] not limited to) weed control, supplemental watering, plant replacement, pruning, etc.

18. **Actions taken to address failing infiltration basins:** WSDOT's maintenance office would contact the Region Hydraulics office to figure out the cause of failure and find a solution. The solution might be to perform special maintenance, or as extreme as to replace the infiltration BMP with another type of stormwater BMP.

19. **Acquisition of additional land for stormwater management:** Sometimes. WSDOT acquires new right of way for many things, which may include area for new stormwater BMPs.

Related Resources

Highway Runoff Manual, Washington State Department of Transportation, February 2016.
Complete manual: https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf
Appendix 4D: http://www.wsdot.wa.gov/publications/fulltext/hydraulics/hrm/app4d_2014.pdf
The Highway Runoff Manual provides guidance for planning and designing stormwater management facilities, including details for integrating stormwater-related elements into the project development process. Appendix 4D, Infiltration Testing and Design (beginning on page 187 of the PDF), describes the "testing methods used to determine infiltration rates (and saturated hydraulic conductivities) used for stormwater design." Chapter 5 (beginning on page 217 of the PDF) provides "specific guidelines and criteria on the proper selection, design and application of stormwater management techniques."

Temporary Erosion and Sediment Control Manual, Washington State Department of Transportation, April 2014.
https://www.wsdot.wa.gov/publications/manuals/fulltext/M3109/TESCM.pdf
This guide outlines Washington State DOT's policies for complying with National Pollutant Discharge Elimination System (NPDES) requirements. Element 13 (page 25 of the report, page 35 of the PDF) describes low-impact development BMPs during construction activity.

Construction Manual, Washington State Department of Transportation, January 2018. https://www.wsdot.wa.gov/publications/manuals/fulltext/M41-01/Construction.pdf
From the foreword: This manual is provided for our construction engineering personnel as instruction for fulfilling the objectives, procedures, and methods for construction administration of Washington State transportation projects. … [T]he instructions prescribe detailed methods and procedures, or detailed performance measures, designed to assure the objective of a safe and adequate finished product.

West Virginia

Contact: Charles R. Riling Jr., Environmental Monitor, West Virginia Division of Highways, 304-558-9761, Charlie.R.Riling@wv.gov.

Overview of Infiltration Basins

1. **Number of infiltration basins constructed in last 10 years:** 15-20. The WVDOH [West Virginia Division of Highways] has installed a minimum number of permanent infiltration basins. Because of the long-term maintenance requirements, we only do when necessary. Temporary basins utilized during construction are not allowed to have infiltration, as stated in the WVDEP general construction stormwater permit (http://dep.wv.gov/WWE/permit/Pages/default.aspx). [See **Related Resources** below.]
2. **Percentage of failures within two years of construction:** No failures.
3. **Reasons for failure:** N/A.
4. **Regulatory body or jurisdiction:** WV Department of Environmental Protection (http://dep.wv.gov/WWE/permit/Pages/default.aspx). [See **Related Resources** below.]
5. **Other allowed methods of stormwater management:** When a permanent basin cannot be constructed we are permitted to mitigate in other areas of the watershed. This can include monetary payments.

Protocols and Procedures for Constructing Infiltration Basins

6. **Standard contract specifications:** WVDOH Standard Specifications and Supplementals, Erosion and Sediment Control Manual, Drainage Manual, Design Directive, etc. (http://transportation.wv.gov/highways/engineering/Pages/publications.aspx). [See **Related Resources** below.]
7. **Standard manuals and/or established guidance:**
   http://dep.wv.gov/WWE/permit/Pages/default.aspx. [See **Related Resources** below.]
8. **Infiltration tests before construction:** No.
9. **Infiltration tests during construction:** No.
10. **Procedures in case of varying rates before construction:** N/A.
11. **Actions if signs of infiltration insufficiency during construction:** [No response.]
12. **Quality assurance methods:** [No response.]
13. **Determining groundwater elevation:** [No response.]
14. **Unusually wet or dry years noted:** [No response.]
15. **Methods to avoid compaction:** [No response.]

Procedures for Site Maintenance During Construction of Infiltration Basins and for Failing Basins

16. **Methods to maintain site during construction:** [No response.]
17. **Methods to facilitate establishment of perennial plants on basin:** [No response.]
18. **Actions taken to address failing infiltration basins:** [No response.]
19. **Acquisition of additional land for stormwater management:** Sometimes. When the basin can't be constructed within the existing r/w [right of way], and the additional taking will only take vacant land.

Related Resources

Water and Waste Permits, West Virginia Department of Environmental Protection, undated.
http://dep.wv.gov/WWE/permit/Pages/default.aspx
This website provides access to the permitting section of the Division of Water and Waste Management, including stormwater permitting.

Standard Specifications: Roads and Bridges, 2017 edition, Division of Highways, West Virginia Department of Transportation, 2017.
https://transportation.wv.gov/highways/contractadmin/specifications/2017StandSpec/Documents/2017_Standard.pdf
Section 107.21.1 addresses contractor requirements in erosion and sedimentation control.

2018 Supplemental Specifications, Division of Highways, West Virginia Department of Transportation, 2018.
https://transportation.wv.gov/highways/contractadmin/specifications/2018%20Supplemental%20Specifications/Documents/2018%20%20Supplemental_20171207.pdf
This handbook accompanies the 2017 Standard Specifications: Roads and Bridges manual.

Erosion and Sediment Control Best Management Practice Manual, Division of Water and Waste Management, West Virginia Department of Environmental Protection, August 2016.
http://dep.wv.gov/WWE/Programs/stormwater/csw/Documents/E%20and%20S_BMP_2006.pdf
From the introduction: The purpose of this manual is to provide standardized and comprehensive erosion and sediment control management practices that can be implemented on construction projects throughout West Virginia.

Drainage Manual, Division of Highways, West Virginia Department of Transportation, December 2007.
https://transportation.wv.gov/highways/engineering/Manuals/Drainage/WVDOH%202007%20Drainage%20Manual%20with%20Addendum%201%20and%202.pdf
This edition of the Drainage Manual "provides the designer with the needed information and tools to perform drainage analysis and design for highway facilities."

Design Directives, Engineering Division, Division of Highways, West Virginia Department of Transportation, November 2016.
http://transportation.wv.gov/highways/engineering/DD/2014%20DD%20Manual%20MASTER.pdf
Section 506 of the design directives (page 338 of the PDF) addresses post-construction stormwater management for both new and existing highway system projects.

Appendix C

Infiltration Basins: Standards and Procedures to Ensure Performance: Contact Information

Below is the contact information for the individuals responding to the survey for this report.

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Appendix D

MANAGEMENT AND PREPARATION OF INFILTRATION AREAS

Contractor shall take extra precaution not to compact subsoil during construction or excavation. Where possible, excavation shall be performed from outside the footprint of the infiltration area. When access across an infiltration area is unavoidable during construction or excavation of material, low ground pressure type equipment shall be used to complete the work.

Subsoil at infiltration areas shall be tilled to a minimum depth of eighteen inches prior to placement of final dressing materials, such as loam borrow or compost topsoil. Soil tilling or ripping shall occur only when the subbase is in a friable condition, not muddy or hard.

Contractor shall take every effort possible to place infiltration media or final dressing materials in a way to minimize compaction of the subsoil, infiltration media, or final dressing materials. No construction vehicles shall be allowed in the infiltration area after the media is placed unless approved by the Engineer. Loose placement of infiltration media or final dressing materials shall be accomplished by dumping from the edges and spreading from outside of the infiltration area, or some other acceptable means determined by the Engineer. Any irregularities at the design finished grade shall be worked out with hand tools.

Following approval of infiltration media or final dressing material placement, seeding should occur as soon as possible to avoid erosion and the establishment of weeds. When site conditions allow, proposed infiltration areas shall remain offline until final site stabilization is achieved. As defined in the NPDES Construction Stormwater Permit dated February 16, 2017, final site stabilization shall be considered achieved when all soil disturbing activity is completed and the exposed soils have been stabilized with a perennial vegetative cover with a uniform density of at least 70 percent over the entire site and/or by permanent non-vegetative stabilization measures such as riprap, gravel, or equivalent means to provide effective cover and to prevent soil failure.

Prior to demobilizing from the site, Contractor shall remove all accumulated sediment and silt from the sediment forebays and drainage structures.

No separate payment will be made for the magement and preparation of infiltration areas, but all costs in connection therewith shall be included in the unit price bid for various items required to complete the work.

Appendix E

Infiltration Construction Checklist

This checklist has been designed for infiltration practices constructed in accordance with the Delaware Sediment and Stormwater Program's Post Construction Stormwater BMP Standards and Specifications

PROJECT INFORMATION

Project Name: _____

Location: _____

Contractor: _____

Construction Reviewer: _____

Date(s) / Time(s) of Inspections: _____

_____

_____

KEY:

✓	**Item meets standard**
X	**Item not acceptable**
N/A	**Item not applicable**

I. Pre-Construction

_____ A. Facility location staked out. Extents of infiltration practice (to include pre-treatment area) delineated and access by equipment prohibited to prevent compaction of existing soils.

_____ B. Upstream drainage area stabilized or effectively diverted.

_____ C. Materials on-site and dimensions and properties checked.

- _____ (1) Underdrain/discharge pipe
- _____ (2) Overdrain/discharge pipe
- _____ (3) Underdrain stone
- _____ (4) Geotextile fabric
- _____ (5) Sand
- _____ (6) Supplemental storage pipe
- _____ (7) Outfall pipe
- _____ (8) Riser pipe
- _____ (9) Observation ports

_____ D. Equipment on the site large enough to excavate infiltration area from the sides of the facility.

Project Name:_____

Construction Reviewer:_____

II. Excavation

_____ A. Facility excavated to dimensions and at location as per the approved plan.

_____ B. Stepwise excavation used for infiltration facilities.

_____ C. Facility excavated from the sides so as to not compact the existing soil.

_____ D. Groundwater not encountered during excavation.
(Note: If groundwater is encountered during the excavation process, construction of the facility must cease and the designer notified that a plan modification is necessary)

_____ E. Sides of infiltration trench excavation vertical.

_____ F. Bottom of excavation within design slope range.

_____ G. Bottom of trench excavation scarified prior to placement of sand.

_____ H. Geotextile fabric placed along the vertical sides of the trench, tuck into sand at the bottom for anchoring.

III. Structural Components

(For infiltration practices containing underdrains and/or overdrain pipe discharge components)

_____ A. Discharge pipe installed from overdrain to discharge point.

Discharge pipe diameter:_____

Discharge pipe material:_____

_____ B. Outlet protection provided at discharge point.

_____ C. Underdrain pipe material according to approved plan. *(Note: If underdrain pipe material is not specified, it shall be SDR 35 minimum)*
Underdrain pipe material:_____

_____ D. Underdrain pipe sizes according to approved plans.

Underdrain pipe diameter(s): _____

_____ E. Underdrain pipe perforations according to approved plans.
(Note: If not specified on the plan, three rows of 5/8" diameter perforations, 6" on-center, shall be provided)

_____ F. Underdrain piping lay flat or with positive slope toward outlet.

_____ G. Clean-outs and/or observation ports provided at endpoints of underdrain pipes or as shown on the approved Plan.

_____ H. Double-washed crushed aggregate, clean DE #57 stone, used for the underdrain gravel. Stone free of rock dust, fines and soil particles.

_____ I. Depth of stone over underdrain piping checked. ***Depth of stone:*** _____

Project Name:_____

Construction Reviewer:_____

IV. Grading

_____ A. Channel protection and/or level spreader provided at infiltration practice inlets as specified on the approved plan.

_____ B. Side slopes of infiltration basin no steeper than 3:1.

_____ C. Bottom of basin graded as per the Plan.

_____ D. Earth spillway constructed to design elevation and dimensions.

V. Vegetation

_____ A. Vegetation planted on the bottom and slopes of the basin as indicated on the vegetation spec on the Plan.

_____ B. For trenches, placement of topsoil and sod over the pea gravel, if this option is specified on Plan.

VI. Erosion and Sediment Control

_____ A. Installed matting in spillway as specified on Plan.

_____ B. For trenches, geotextile emerges from the sides of the trench and folds over stone to protect against sediment contamination during site construction.

Appendix F

From the MnDOT drainage section of Design/Build Book 2 Section 12:
CSAH 14 Design-Build Project SAP No. 02-614-34
http://www.dot.state.mn.us/designbuild/documents/online/ProcurementTemplates/book2/book2-section12-drainage.docx.

12.3.2.3 Infiltration Basins

At a minimum, runoff from a one-inch storm from impervious surfaces on the Project shall be infiltrated. Infiltration basins and wet ponds may both contribute to meeting the infiltration requirement.

Infiltration basins shall not be allowed within the one-year travel zone of any public well as defined by the applicable municipal wellhead protection plan.

Infiltration basins shall only be located in areas where in situ soils support infiltration. Each potential infiltration basin must be tested for the local infiltration rate before including that basin in the RFC Documents. The tests shall be conducted with a double-ring infiltrometer. A minimum of five tests per acre of infiltration basin and a minimum of five tests per infiltration basin are required. The results of the infiltration tests shall be used in the design of the infiltration basin.

All infiltration basins shall have pre-treatment according to the CCWDR to prevent clogging and ineffectiveness of the infiltration.

The filtration media shall consist of at least 3 feet of engineered soil composed of 80 percent fine-filter aggregate and 20 percent Grade 2 Compost. Rainfall shall be routed around the infiltration basin to the outfall during construction until all disturbed tributary areas have been restored and turf within the infiltration basin is fully established. An overflow shall be provided to limit water depth in the infiltration basin such that the water elevation is above the bottom for no more than 48 hours and a freeboard from the High Water Level (HWL) to the filtration basin berm crest of at least 2 feet is provided. Infiltration basins are not required to have emergency outlets if the basin can contain back-to-back, 24-hour, 100-year storms with at least 2 feet of freeboard to the crest of the basin.

All basins shall be tested for infiltration rates after they are completed. The tests shall be conducted with a double-ring infiltrometer, and the infiltration rates must meet or exceed the design infiltration rate used to size the basins. A minimum of five tests per acre of pond area or infiltration basin and a minimum of five tests per pond or infiltration basin are required. If the infiltration rates do not meet or exceed the design infiltration rate, the Contractor shall revise the basin design to meet the design rate. The Contractor shall acquire CCWD approval and Owner Approval of design revisions.

All infiltration areas shall be marked with an Approved sign identifying the area as “filtration area” or “infiltration basin.” These signs shall be placed on each end and at the center of the longest length of the filtration feature.

The Contractor shall take all measures necessary to prevent compaction of the underlying soils. After infiltration tests have been completed, the Contractor shall not allow any construction equipment or vehicles in the basin.