NS-641 - Time and Vegetation Effects on Infiltration and Filtration Performance: Literature Search

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Resources searched: ASCE Library, Transport Database, Library Catalog, TRID, Pooledfund.org, Web

Summary: Results are compiled from the databases named above. Links are provided for full-text, if applicable, or to the full record citation. I completed my searches using the following terminology: infiltration, filtration, performance, vegetation, time, stormwater, storm water. Results are categorized as most and least relevant below.

Most Relevant Results

Hagglund, Christopher; Shokri, Mohammad; Kibler, Kelly. Hydraulic Performance of Vegetated Filter Strips (VFS) during High-Intensity Runoff Events. World Environmental and Water Resources Congress 2020, American Society of Civil Engineers, 2020, pp 104-114
https://trid.trb.org/view/1706709

Abstract: Vegetated roadway shoulders equipped with engineered media (vegetated filter strips, VFS) may be an effective measure to treat contaminated stormwater runoff from roadways. However, when the infiltration capacity of the VFS is exceeded, untreated stormwater may bypass the VFS as surface runoff. Precipitation and runoff from 1-hour, high-intensity storms (1–3 in/hr) were simulated over two 1:1 scale physical models (treatment and control) of roadway shoulders and embankments. The treatment test bed contained a layer of engineered media, biosorption activated media (BAM) while the control test bed contained A-3 sandy soils. Hortonian surface flow generated near the shoulder edges during most tests; however surface flow consistently generated further along the treatment shoulder as compared to the control. Furthermore, by 20 ft from the shoulder edge, all surface flows had infiltrated into the control test bed, while respectively 22% and 35% of inflows bypassed the VFS as surface runoff in the treatment bed during the highest intensity simulations (2 and 3 in/hr). This may suggest that water infiltrates more readily into unaltered media.

https://trid.trb.org/view/1687076

Abstract: Dry detention basins (DDBs) are a type of stormwater control measure (SCM) designed to provide flood storage, peak discharge reduction, and some water quality improvement through sedimentation. DDBs are ubiquitous in the urban environment, but are expensive to maintain. In this study, two overgrown DDBs near Raleigh, NC, receiving highway runoff were monitored for up to one year to quantify their water quality and hydrologic performance. Both basins, B1 and B2, have not received vegetation maintenance since construction in 2007. Flow-weighted composite samples were collected during storm events and analyzed for nutrients (Total Phosphorus (TP), Ortho-phosphorus (OP), Ammonia-N (NH₃), NO₂⁻-N (NO₂⁻), and Total Kjeldahl Nitrogen (TKN)), total suspended solids (TSS), and total Cd, Cu, Pb, and Zn. An annual water balance was also conducted to quantify runoff volume reduction. Despite low influent concentrations from the highway, significant removal efficiencies were found for all constituents except NH₃ in B1. TP,
OP, NOₓ, TSS, and Zn were reduced in B2. Both basins achieved greater than 41% volume reduction through soil infiltration and evapotranspiration, resulting in significant pollutant load reductions for all detected constituents, between 59% and 79% in B1 and 35% and 81% in B2. This study provides evidence that overgrown and unmaintained DDBs can reduce pollutant concentrations comparable to those reported for maintained DDBs, while reducing more volume than standard DDBs. Moreover, carbon sequestration likely increases while maintenance costs decrease.

Zhang, Lei; Lu, Qing; Ding, Yongfu; Peng, Pan; Yao, Yu. Design and Performance Simulation of Road Bioretention Media for Sponge Cities. Journal of Performance of Constructed Facilities, Volume 32, Issue 5, 2018, 04018061
https://trid.trb.org/view/1517189

Abstract: Road bioretention is one of the promising low impact development (LID) best management practices (BMPs) for the construction of sponge cities. Design of the media used in the soil layer of a bioretention facility is critical to its performance regarding infiltration, filtration, and storage of a high volume of runoff from impervious areas. In this study, a coarse aggregate void filling (CAVF) method was adopted for the design of bioretention soil media. The key hydrological parameter of the bioretention media, the average matrix suction at its wetting front, was estimated through finite-element simulation of the rainfall infiltration process. Using the obtained parameter, a bioretention structure was designed, then modeled in the Storm Water Management Model (SWMM) software to analyze its potential hydrologic benefits in terms of reduction in both peak flow and total volume of surface runoff into storm drains in a rainfall event. It was found that the permeability of bioretention soil media is the key factor that affects outflow reduction ratio, peak flow reduction rate, and peak time of the system. The bioretention media composition design method adopted in this study seems promising for future use in the material and structural design of road bioretention facilities for sponge cities.

Optimizing Compost Application Rates for Vegetation Health, Maximal Stormwater Infiltration, & Runoff Quality.
https://trid.trb.org/view/1530118

Description: Soils disturbed by roadway construction often exhibit reduced soil porosity, precipitation storage capacity and infiltration rates, thereby yielding increased surface runoff. Poor performance of vegetation in these locations also leads to long-term aesthetic and erosion problems. Research has demonstrated that tillage can be used in conjunction with compost to improve soil conditions on disturbed, pervious areas. This year, NCDEQ formally recognized soil improvement as a stormwater best management practice (BMP). The soil improvement BMP has potential advantages to NCDOT with respect to lowering the cost of regulatory compliance while also contributing to goals such as beautification of the right-of-way via healthy landscape plantings, wildflower beds, and permanently stabilizing eroding areas caused by poor soil conditions. Given the broad applicability of soil improvement as a BMP throughout NCDOT’s transportation network, it is important to optimize soil improvement specifications to ensure the lowest-cost effective solution is achieved.

There has been very little research to specifically determine optimal compost application rates to concurrently improve stormwater infiltration and/or storage, limit potential for offsite losses of nutrients and metals, and aid in timely vegetation establishment. These are all potential benefits of soil improvement BMPs, and the addition of compost at a proper rate is anticipated to be the most costly consideration for BMP implementation. The proposed research is designed to determine optimum compost amendment rates for soil improvement BMPs in North Carolina. The project will include a series of complimentary activities: (1) A literature review on the performance of compost amendments, application rates and pollutant transport mechanisms. (2) Laboratory assessment of the effects of compost amendment rate on hydraulic properties of North Carolina soils. (3) Bench-scale testing of nutrient and metal losses from compost/soil blends in leachate waters at target amendment rates. (4) Greenhouse testing of vegetation establishment and performance with compost amendment at target incorporation rates. (5) Field evaluation of optimized compost amendment rate effects on runoff water quantity and quality, infiltration, and vegetation.
establishment. (6) Development of recommended specifications for optimizing compost amendment rates for soil improvement BMPs.

Abstract: The U.S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) was used to simulate upland runoff production and the subsequent performance of a downstream, ponded infiltration basin installed adjacent to a highway in suburban Maryland. The SWMM’s performance was evaluated with a unique, rich suite of in situ flow and water quality observations. The availability of these in situ observations creates a novel opportunity to explore the performance of SWMM across small scales in space and time. In order to systematically explore the ability of SWMM to leverage these observations, an automatic Monte Carlo–based calibration framework was developed and a multiparameter sensitivity analysis was conducted. As expected, the calibrated model showed better skill in terms of reproducing water quantity observations relative to water quality observations. An uncertainty analysis showed model predictions (flow and water quality) were consistent in the sense that the model was able to encapsulate the observations between 5 and 95% confidence intervals. Example code for use by other researchers to employ the techniques discussed in this paper is made publicly available with this manuscript.

Osouli, Abdolreza; Bloochian, Azadeh Akhavan; Nassiri, Sina; Marlow, Scott L. The Effects of Sediments on Bioswale and Infiltration Trench BMP Performance. Transportation Research Board 97th Annual Meeting, 2018, 6p https://trid.trb.org/view/1495702
Abstract: Best management practices (BMPs) are commonly used to reduce adverse effects of post-construction runoff. The BMP deterioration happens over time when they age and the infiltration rate decreases by sediment accumulation. The objective of this paper is to investigate the effect of sediment accumulation on the BMPs stormwater runoff reduction performances. The studied BMPs include bioswale and infiltration trench. Three different sedimentation accumulation configurations (i.e., new, 2-year-old, and 10-year-old BMP) were considered. To perform this research, both field tests and numerical simulations were conducted under five different rainfall events with a wide range of intensities and duration. The minimal sediment accumulation of 0.22 Kg/m 2/year was considered in this study. According to the results, the infiltration trench had 100% runoff reduction efficiency in any condition including the high intensity rain and 10-year-old age. The performance of the bioswale for the first two and ten year was deteriorated by about 55% and 70%, respectively.

Izevbekhai, Bernard Igbafen; Schroeder, Collin. Seven Year Performance of City of Shoreview’s Pervious Concrete Project. Minnesota Department of Transportation; Minnesota Department of Transportation, 2017, 62p https://trid.trb.org/view/1492805
Abstract: Stormwater runoff from the Woodbridge neighborhood of Shoreview had previously been drained to Lake Owasso. City of Shoreview built the Woodbridge neighborhood’s local roads using pervious concrete pavements in 2009. Pervious concrete pavements exhibit high hydraulic conductivity and sound absorption ability. To evaluate the functional performance of the City of Shoreview’s pervious concrete pavements researchers from Minnesota Department of Transportation (MnDOT) measured sound absorption, hydraulic conductivity, and ride quality periodically. This report assesses the seven year performance of Shoreview’s pervious concrete pavements using the above pavement performance metrics from data twice a year on average between 2009 and 2012. Sound absorption coefficient was found to be decreasing over time mainly due to clogging and traffic load impact. Ride quality was also observed to decrease through time as pavements clogging became increasingly observable over time. Clogging enhances freeze-thaw susceptibility that leads to various distresses. Traffic load impact also seemed to reduce the sound absorption and hydraulic conductivity of the pervious pavements. To improve the hydraulic conductivity of the pervious
concrete pavements, frequent vacuuming with appropriate equipment method is recommended. This research calculated the stormwater infiltration benefits and compared life cycle cost of pervious and non-pervious alternative, concluding that pervious concrete may still be a better alternative than storm water structures in that location.

https://trid.trb.org/view/1488772
Abstract: The estimation of hydraulic conductivity ($K_{sat}$) is a key step to assess the rate of infiltration, whether that estimate is for an infiltration pond or trench, if it is for a highway embankment, or if it is for natural dispersion in general. The focus of this research is to assess available methods for estimating $K_{sat}$, especially with regard to the ability of various methods to assess $K_{sat}$ in both a loose, uncompacted state as well as in a compacted state for embankments. $K_{sat}$ prediction for natural soils is also considered. To accomplish this, a series of relatively large diameter (i.e., 6 to 9 inch) saturated hydraulic conductivity tests were conducted both in a loose state and in a compacted state. Existing $K_{sat}$ prediction equations such as those developed by Hazen (1892), Slichter (1898), Terzaghi (1925), Chapuis (2004), and Massmann (2003) were evaluated and, using the $K_{sat}$ laboratory measurements gathered in this study, were empirically optimized to improve prediction performance. Those equations that included soil porosity, $\eta$, or void ratio, $e$, were given preference for further development, since $\eta$ or $e$ were determined to be the best parameters to address the effects of compaction on $K_{sat}$. The empirically optimized Slichter, Terzaghi, and Chapuis equations were found to provide the most accurate prediction performance. Since it may be difficult to obtain a measured porosity or void ratio at design time, a method to estimate the soil porosity using grain size parameters plus degree of soil compaction, or for natural soils, degree of over-consolidation, was developed, and could be used in the optimized equations with only minimal reduction in $K_{sat}$ prediction accuracy. The optimized Slichter Equation was used for several example infiltration facilities as was done by Massmann (2003) to determine what effect the use of this new equation would have on infiltration design and infiltration rate prediction accuracy.

Hydraulic Performance of a Residential Stormwater Infiltration Gallery
Journal of Environmental Engineering
March 2016 Volume 142, Issue 3Online publication date: December 01, 2015
Abstract
An increasing number of municipalities are encouraging homeowners to implement on-site residential stormwater management. In some communities, this encouragement takes the form of a stormwater utility fee or rain tax that may be reduced if homeowners take measures to reduce runoff. The most commonly cited techniques for reducing runoff are disconnecting downspouts or installing rain barrels, rain gardens, or permeable pavements. The analysis presented here examines the hydraulic performance of the less commonly recommended residential stormwater infiltration gallery designed to reduce off-site runoff from roof gutters. Case study simulation results based on a 10-year precipitation record for Cleveland, Ohio, indicate that a 30-m (100-ft) infiltration gallery sitting atop soil with a modest infiltration rate of 0.64cm/h (0.25in./h) could attain a single downspout roof service-area runoff reduction of 90%, and a 61-m (200-ft) gallery could attain a whole roof runoff reduction of more than 85%. This performance is superior to that expected from rain barrels or modest-size rain gardens, and the operation-free and low-maintenance gallery would address many of the concerns often expressed by homeowners about other stormwater-management options.

Evaluation of Infiltration Basin Performance on Coarse Soils
Journal of Hydrologic Engineering January 2016 Volume 21, Issue 1Online publication date: June 23, 2015
Abstract
Infiltration basins are commonly utilized to reduce or eliminate stormwater runoff and are commonly located on coarse soils due to relatively high infiltration rates. Forty infiltration basins in Florida were included in this field study to evaluate whether basin infiltration rates varied significantly from their designed infiltration rates. Basins were located among Leon, Alachua, and Marion counties in Florida, while watershed land uses were equally divided between Florida Department of Transportation and residential developments. Generally, six test sites within each basin were selected for infiltration rate measurement by double-ring infiltrometer (DRI). Also, a soil boring was collected from each test site for analyses, including soil texture, bulk density, and organic matter content. Infiltration rates were log-transformed and statistical analysis was used to determine if DRI measurements were significantly different from design rates. Basin soil textures were well distributed between sand, loamy sand, sandy loam, and sandy clay loam. Most (91%) bulk densities ranged between 1.30 and 1.80g/cm³ and organic matter percentages ranged from 0.1 to 48.5%, with 49% of soils having less than 3.0% organic matter. Nearly all bulk densities were not limiting to vegetation growth for the respective soil texture. Based on DRI rates, 16 (40%) basins had rates significantly less than their designed rates, 10 (25%) had rates equal to their designed rates, and 14 (35%) basins had rates significantly greater than their designed rates. Basins with coarser soils were also more likely to have DRI rates greater than designs. In addition, a higher proportion of basins located within Florida Department of Transportation watersheds had DRI rates greater than or equal to design rates, which may be related to vegetation size and diversity.

Least Relevant Results

Hachem, Anthony E; Zornberg, Jorge G. Enhanced Lateral Drainage Geotextile to Mitigate the Effects of Moisture Migration from a High Water Table. Eighth International Conference on Case Histories in Geotechnical Engineering (Geo-Congress 2019), American Society of Civil Engineers, 2019, pp 227-234
https://trid.trb.org/view/1594090
Abstract: Pavements founded on fine-grained subgrades subject to moisture increase are prone to severe distress shortly after construction. Moisture can reach the pavement foundation through various means including infiltration, capillary rise, lateral moisture transfer, and frost-thaw action. A recent advancement in the geotextile industry has led to the development of geotextiles with enhanced lateral drainage capabilities that can wick water out of the pavement section under unsaturated conditions. A laboratory test was conducted to quantify the moisture increase in the different pavement layers due to capillary rise from a nearby water table and to assess the ability of the wicking geotextile in decreasing the moisture from the system leading to an improved performance. Subgrade and base soil layers were compacted in a test box with acrylic sides. A hydraulic system was established to create a constant water level and allow for capillary rise. A laboratory testing program was conducted with conventional and wicking geotextiles installed at the layer interface and extended outside of the box. The moisture content was continuously monitored at different elevations using the time domain reflectometer technology. The results of this hydraulic setup showed a decreased moisture level in the pavement layers where the enhanced lateral drainage geotextile was installed.

Lin, Chuang; Zhang, Xiong; Han, Jie. Comprehensive Material Characterizations of Pavement Structure Installed with Wicking Fabrics. Journal of Materials in Civil Engineering, Volume 31, Issue 2, 2019, 04018372
https://trid.trb.org/view/1569609
Abstract: When a road is constructed, soils within the embankment are often compacted at the optimum water content to achieve the best performance. The postconstruction water content tends to increase with time due to capillary action, precipitation infiltration, and water condensation. Because soils are sensitive to water content variations, a slight water content increase will cause a significant reduction in soil moduli and a dramatic increase in permanent deformation under cyclic loading. Materials with large pores, such as granular materials and nonwoven geotextiles, are commonly used for the drainage of gravitational water under a saturated condition, but not for the drainage of capillary water under an unsaturated condition. Therefore, the excessive water in the soil accelerates the deterioration of the road with time. Recently, a new geotextile with wicking fibers, which can drain both gravitational and capillary water under saturated and unsaturated conditions, has been developed. Several field applications have proven its
effectiveness in dehydrating the road embankment. This paper aims to quantify the benefits of the new geotextile in terms of water removal. First, comprehensive laboratory tests were performed to characterize the properties of the soil, the new geotextile, and the soil-geotextile interactions. Second, the working mechanism and functional range of the new geotextile were determined and the drainage ability of the soil-geotextile system was quantified via numerical simulations. The wicking fabric functions as an effective drainage material to hold and transport capillary water in the in-plane direction. The soil-geotextile system is able to reduce the water content of the base course by 2.2% from the optimum value, and the corresponding resilient modulus can be increased by 2–3 times.

Bateni, Norazlina; Lai, Sai Hin; Putuhena, F J; Mah, Darrien Yau Seng; Mannan, Md Abdul; Chin, Ren Jie. Hydrological Performances on the Modified Permeable Pavement with Precast Hollow Cylinder Micro detention Pond Structure. KSCE Journal of Civil Engineering, Volume 23, Issue 9, 2019, pp 3951-3960
https://trid.trb.org/view/1646177
Abstract: In this study, a permeable pavement with an on-site subsurface micro-detention pond was developed. Common permeable pavements are typically composed of fine layered particles attributed with low porosity. The permeable pavement with micro-scale detention storage (PPDS) developed in this study is a modified type of interlocking block permeable pavement consisting of a hollow cylinder with a hexagonal cover at the top and bottom of the PPDS. The PPDS was designed with a void volume of 70% and a water storage capacity of 0.19 m³/m². A rainfall simulator was used to perform the tests on the profile of the hydrological pavement such as the storage capacity, detention period, permeability rates and infiltration performance over various storm events. The PPDS showed its ability to detain first flushes of rainfall within a 15-minutes period for a 100 year return period. Meanwhile, the permeability rate of the PPDS was subjected to the infiltration capacity of the subgrade soil following a linear relationship between the flow depths over time. The testing performances indicated that the PPDS has met the basic hydrological design considerations, as those in the typical permeable pavement, from the perspective of permeability rates, infiltration capacity, storage and detention capability.

Tao, Junliang; Li, Junhong; Huang, Sichuan; Liang, Robert; Ozdogan-Dolcek, Ayse; Likos, William. Performance Comparison of Abutment and Retaining Wall Drainage Systems. University of Akron; Ohio Department of Transportation; Federal Highway Administration, 2017, 200p
https://trid.trb.org/view/1507624
Abstract: Control of water infiltration and providing adequate drainage are critical to the performance of retaining walls and abutment walls. Current Ohio Department of Transportation (ODOT) practice for drainage of structures specifies the use of a two-foot porous backfill with filter fabric, which has a long performance history. ODOT is seeking alternative drainage systems that are more cost- and time-effective, durable, and at the same time, have comparable or superior drainage capability compared to current practice. A prefabricated composite drainage system (PCDS) is proposed in this research as an alternative structure drainage system. The current state of practice of drainage systems for retaining wall and bridge abutment structures is evaluated through a survey of county agencies in Ohio. Commercially available PCDS products as well as specifications for PCDS used by other state DOTs are also reviewed and synthesized. Laboratory testing and evaluation of select PCDS products are conducted to improve the understanding of their properties. It is found that tested values for some properties of some products do not match those listed by the manufacturers. Recommendations on the selection of proper standard testing methods and suggestions on the selection of factory of safety in design are discussed. Field performance of the PCDS system and the traditional drainage system are evaluated with in situ instruments including piezometers, tiltmeters and flumes. The data analysis suggests that the PCDS has comparable drainage capability to the traditional system. Field observation and feedback from the contractor reveal that installation of PCDS systems are less labor-intensive and more time-effective. Cost analysis from ODOT historical bidding data and the actual cost at the tested sites demonstrates that a PCDS system costs 40% less than the traditional process. Based on the findings, draft specifications were developed to specify the material and construction requirements for a PCDS system.
Barrett, Kirk R; Diallo, Mohamed. **Long-term Infiltration Capacity of Different Types of Permeable Pavements.** Manhattan College; University Transportation Research Center; Research and Innovative Technology Administration, 2017, 23p
https://trid.trb.org/view/1481383
Abstract: Permeable pavements such as porous asphalt (PA), pervious concrete (PC) and permeable interlocking concrete pavers (PICP) are relatively novel alternatives to conventional pavement that allow rain and snowmelt to infiltrate, thereby reducing runoff, flooding and nonpoint source pollution. A barrier to wider adoption of these runoff-reducing alternative pavements is uncertainty over their long-term performance. **Infiltration** capacity (IC) can decrease over **time** if pores in permeable pavement become clogged with particles. Indeed, several studies have found rapid reduction in **infiltration** from clogging, but other studied sites have maintained high IC for multiple years. The purpose of this project was to measure IC on three different types of permeable pavement: PA, PC and PICP. Combined with previous results, the results from this project provide further understanding of how IC changes over **time** in different types of permeable pavements.

Knappenberger, Thorsten; Jayakaran, Anand D; Stark, John D; Hinman, Curtis H. **Monitoring Porous Asphalt Stormwater Infiltration and Outflow.** Journal of Irrigation and Drainage Engineering, Volume 143, Issue 8, 2017, 04017027
https://trid.trb.org/view/1480622
Abstract: **Performance** of porous asphalt (PA) was evaluated on a parking lot of the Washington State University Puyallup campus that included three pavement treatments in triplicate: maintained impervious asphalt (MIA), maintained porous asphalt (MPA), and unmaintained porous asphalt (UPA). Maintained treatments were annually swept with a regenerative air street sweeper. **Infiltration** rates measured annually using an **infiltration** ring declined over the course of the study (2011–2015) from 118 to 39 mm/min for the MPA, and from 134 to 54 mm/min for UPA, respectively. Lower **infiltration** rates on maintained cells relative to unmaintained cells are ascribed to the air-blast and suction cycle that characterizes the type of street sweeper used. The authors hypothesize that particulate matter was forced deeper into the porous structure of the pavement wearing course, reducing **infiltration** rates in the maintained cells. Annual maintenance was shown to be too infrequent and did not prevent **infiltration** rates from declining, with parts of the pavement cells becoming clogged. However, **performance** of the pavement as a whole, measured by relating total storm inflow to storm outflow, did not decline over the study period with 99.5% of storm inflow infiltrating into the porous asphalt pavement surface. **Time**-series analysis showed that peak flow mitigation of **stormwater** was considerably superior with permeable pavements in comparison with impervious pavement surfaces.

https://trid.trb.org/view/1439860
Description: Low Impact Development (LID) techniques that are economical and appropriate for the highway environment are important tools for state departments of transportation (DOTs) faced with increasingly demanding water quality and hydrologic management requirements. Vegetated filter strips along highways, an accepted LID Best Management Practice (BMP), are a cost-effective alternative to hydraulically engineered BMPs. Their use is limited however, by site constraints such as limited right-of-way and steep side slopes, and their effectiveness may vary greatly depending on climate, soils, and other factors. Vegetated compost blankets (VCBs) can overcome some of these limitations by promoting **stormwater filtration**, retention of runoff, and **infiltration** of **stormwater** into the underlying soils—potentially removing pollutants and reducing flow volumes. VCBs have the potential to be relatively low
cost and low maintenance, which makes them attractive to state DOTs. VCBs also can be a relatively simple retrofit on a roadside embankment. Research is needed to evaluate hydrologic and water quality benefits of VCBs. This involves determining pollutant removal capability and capacity; the ability to detain and retain runoff; and the effect of climate, soils, compost composition, compost blanket thickness, and other parameters on performance. Design guidance will be needed in order to provide state DOTs with an effective and economical BMP that can be used in a wide variety of roadway settings.

The objectives of this research are to:

1. Develop performance curves for surface-applied, VCBs on slopes of 3:1 or flatter that (a) remove pollutants of concern, (b) control erosion, (c) reduce volume, and (d) support vegetation when placed on an existing roadway embankment.
2. Provide construction specifications, standard details, and a decision matrix that provides guidance on the use, limitations, design, and implementation of vegetated compost blankets on existing roadway embankments. The guidance is intended to be a practical manual for practitioners who select, design, and implement stormwater management facilities and should be broadly applicable to a wide range of conditions and geography.

Assessment of Surface Infiltration Performance and Maintenance of Two Permeable Pavement Systems in Louisville, Kentucky
Journal of Sustainable Water in the Built Environment
November 2017 Volume 3, Issue 4Online publication date: June 30, 2017
Abstract
This study presents the infiltration performance of two permeable pavement systems installed in the parking lanes of an urban neighborhood. Both systems were subject to large (12.9 and 9.8) impermeable drainage ratios and high sediment loadings from the surrounding environment. The surface infiltration performance of each system was monitored by conducting surface infiltration measurements and analysis of data collected using an array of embedded time domain reflectometers. The results indicated progression of clogging from the upgradient edge toward the downgradient edge on the surface of the permeable pavements, which limited the infiltration performance of the systems. This study conducted three different maintenance methods to restore the surface infiltration performance of the clogged permeable pavements. The developed monitoring techniques were used to ascertain the short-term and long-term efficiency of each surface maintenance treatment. The most effective maintenance treatment was determined to be a combination of hydro pressure washing and vacuuming to clean the permeable pavement surfaces. The research results indicate that the infiltration performance of permeable pavement systems, even those subjected to high hydraulic loadings and unsuitable environments, can be maintained with frequent application of a proper surface-maintenance method.

Vegetation and Media Characteristics of an Effective Bioretention Cell
Journal of Sustainable Water in the Built Environment February 2016 Volume 2, Issue 1Online publication date: September 23, 2015
Abstract
A seven-year-old bioretention cell in Silver Spring, Maryland was surveyed for vegetation and media characteristics 11 months after last maintenance. Volunteer plants constituted more than half of the cell vegetation. Eutrochium dubium (Joe Pye weed) had the most coverage of all plant species at 43%. Average longest root length for the three examined species was 29.1 cm, and was not statistically different among the species. E. dubium had the thickest roots, with its thickest root diameter averaging 2.2 cm, and an extensive root structure. E. dubium also had the tallest above-ground biomass, averaging 88.7 cm. Spatial Mehlich 3 phosphorus profiles indicated P accumulation in the top 6 cm of media and decreasing P concentrations with depth. No indication of breakthrough in regard to P saturation was found. Based on the findings of this study, E. dubium is recommended for bioretention vegetation due to its survivorship and
root structure. Additionally, the high percentage of volunteer species suggests the importance of vegetation maintenance planning.

Vegetated Swales for Managing Stormwater Runoff from Secondary Roads
Journal of Environmental Engineering
October 2018 Volume 144, Issue 10Online publication date: July 18, 2018
Abstract
Secondary roads play an important role for connecting local communities to principal county and state highways and, in some cases, may account for a large proportion of the state-maintained road systems. Existing swales alongside secondary roads can help mitigate the impact of roadway runoff. Limited information is available to characterize their runoff constituent concentrations and pollutant reduction potentials. Consequently, three secondary roadway segments typical of low-to-medium traffic volumes were monitored within the Piedmont region of North Carolina. Event mean concentrations (EMCs) of monitored constituents were found to be substantially lower than those reported for North Carolina primary roads and the national highway runoff data derived from the Federal Highway Administration. In general, secondary road runoff exhibited site-average EMCs of 32mg/L total suspended solids (TSS), 0.65mg/L total nitrogen (TN), and 0.13mg/L total phosphorus (TP). Roadside swales are effective to attenuate the inflow EMCs to 15mg/L TSS and 0.48mg/L TN, achieving EMC removal efficiencies of 53% TSS and 25% TP. There was essentially no change in TP EMCs as runoff passing through the swale. Pollutant-load reductions for runoff moving through roadside swales were 77% for TSS, 67% for TN, and 33% for TP. Runoff attenuation through infiltration in vegetated swales accounts for all or most of the load reductions and points to the importance of maximizing infiltration rates in roadside swales. As a result, state agencies can incorporate the water quality benefits of swale treatment with secondary roads when developing their watershed strategies for nutrient load reductions.