



California Stormwater Quality Association[®]

Dedicated to the Advancement of Stormwater Quality Management, Science and Regulation

Removing Barriers to Low Impact Development (LID)

Proposition 84 Grant 12-421-550

LID Technical Standards Review

**Technical Memorandum #3
Future Efforts Related to LID**

May 2017

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California Stormwater Quality Association

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Preface

The California Stormwater Quality Association (CASQA) is a professional member association dedicated to the advancement of stormwater quality management through collaboration, education, implementation guidance, regulatory review, and scientific assessment. CASQA has been a leader since 1989 when the field of stormwater management was in its infancy. CASQA's membership is comprised of a diverse range of stormwater quality management organizations and individuals, including cities, counties, special districts, industries, and consulting firms throughout the state. A large part of CASQA's mission is to assist California stormwater permittees in developing, implementing, and maintaining effective stormwater quality management programs by drawing upon the collective experiences of its individual members, to share successes and avoid the pitfalls.⁶

CASQA was awarded a Proposition 84 Stormwater Grant (Grant) to provide Low Impact Development (LID) implementation support to municipalities throughout California. As part of the Grant, CASQA provided technical support to municipalities including developing LID technical resources and using existing LID details and standards, developed by others, including details and standards for bioretention and permeable paving. Subsequently, CASQA entered an agreement with a team of specialists to provide review of the LID details and standards to verify that the materials being used are comprehensive, technically accurate, and identify areas of technical uncertainty or where differences in technical opinion exist.

The team of specialists include CASC Engineering and Consulting, Inc. as the project manager and technical specialist, EOA, Inc. as a technical specialist, and the Interlocking Concrete Pavement Institute as a technical specialist. The team brings together Jeff Endicott, PE, BCEE, Jill Bicknell, PE, and David Smith from these respective organizations.

This Technical Memorandum #3 provides recommendations related to future LID engineering details and standards including research needs, importance of statewide consistency or when tailoring details and standards to a region is appropriate, and recommendations for development of additional LID measure details and standards. Jeff Endicott is the primary author of Technical Memorandum #3, with technical and editorial review provided by Jill Bicknell, David Smith, Darla Inglis, and Daniel Apt.

The review team recognizes that CASQA and its predecessor organization the Stormwater Quality Task Force (SQTF) have served key roles in the dissemination of information regarding stormwater source control and treatment control best management practices (BMPs) since 1993, first through the SQTF's Stormwater Best Management Practices Handbook (1993), then through CASQA's four-volume set of Stormwater Best Management Practice Handbooks (2003), and now through CASQA's BMP Handbook Web Portal.⁷ Additionally, LID specific information is available on the California LID Portal⁸ on the CASQA website including the LID technical resources developed as part of the Removing Barriers to LID Grant inclusive of the updated LID details and standards and the technical memorandums No.1, No.2, and No.3 associated with the updated LID details and standards. . Many agencies and professionals throughout California have come to view and utilize the CASQA recommendations as standards of practice in their communities and work. The review team highly recommends that the products and recommendations of this LID Technical Standards Review be incorporated into CASQA's Handbooks and the BMP Handbook Web Portal.

⁶ <https://www.casqa.org/about>

⁷ <https://www.casqa.org/resources>

⁸ <https://www.californialid.org>

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Introduction

CASQA was awarded a Proposition 84 Stormwater Grant (Grant) to provide Low Impact Development (LID) implementation support to municipalities throughout California. As part of the Grant, CASQA provided support to municipalities including developing LID technical resources and using existing LID details and standards, developed by others, including details and standards for bioretention and permeable paving. Subsequently, CASQA entered an agreement with a team of specialists to provide review of the LID details and standards developed originally by LIDI and modified by the Grant Project Team to verify that the materials being used are comprehensive, technically accurate, and identify areas of technical uncertainty or where differences in technical opinion exist.

The team of specialists have been assigned three major tasks, including:

- Task 1 – Bioretention Details and Standards Review;
- Task 2 – Pervious Pavement Details and Standards Review; and
- Task 3 – Future Efforts Related to LID.

Task 1 and Task 2 each include several defining subtasks.

This Technical Memorandum #3 provides recommendations related to future LID engineering details and standards including research needs, importance of statewide consistency or when tailoring details and standards to a region is appropriate, and recommendations for development of additional LID measure details and standards.

It is our understanding that products from the Proposition 84 Grant will be made available to the stormwater practitioner community through the CASQA LID Portal. Part of the purpose of the LID Technical Standards Review effort is to verify that the standards and details are comprehensive, technically accurate, and generally suitable for use throughout the state especially when it comes to common design elements. However, the review team acknowledges the diverse climatic, environmental, demographic, economic, regulatory, and political conditions that define California, and recognizes that the standards and details may be adapted by users to accommodate local or regional requirements. It is intended that the LID Technical Standard Review products will provide a sound starting point for such use. Furthermore, while the review team brings many years of experience in LID design to the project, the team recognizes that the practice is evolving, and that additional research is needed to gain additional information and knowledge that may lead to future updates and optimization of the LID standards and details.

Scope of Work

The work performed under Task 1 included the following subtasks:

Task 3 – Future Efforts Related to LID

This Technical Memorandum #3 provides recommendations for future research and provides recommendations for development of additional LID details and standards, all geared towards improving and expanding the LID tools available to stormwater professionals.

Research Needs

When Low Impact Development (LID) measures first started to appear in new development and redevelopment projects, the designs and installations were commonly based on field experience and engineering judgment, or information from the East Coast, often without solid research or documented track records of performance to back up the design criteria and details or the expected performance of the LID measures. As interest in LID measures increased, and especially when *voluntary* use of LID measures began to transition to *mandated* use to meet new development requirements adopted by

land use authorities in response to requirements in their Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) permits, interest increased in investigating and documenting the design and performance of LID measures.

A significant amount of LID measure research has been conducted and much is currently underway nationally at universities, government agencies, industry organizations, and businesses from coast to coast, and internationally. The results of this research often is publicly available, and it is not uncommon for current research efforts to begin with a literature review to identify prior research projects and results in an effort to help define the starting point for the current research effort.

A challenge in using the results of existing research comes down to the issue of adaptability and scalability. For example, will the results of amazing research into bioretention design and performance conducted at North Carolina State University in Raleigh, North Carolina where the average temperature is 60.8°F and annual rainfall averages 46.58" translate to Palm Springs, California where the average temperature is 74.6°F and annual rainfall averages 4.85"?⁹ Another challenge is that some MS4 Permits in California specify design criteria for some LID measures, and these specific criteria may differ from those validated through research.¹⁰

In this Technical Memorandum #3, research is recommended based on the authors' perceived value that said research can provide in furthering the effective use of LID measures in California. The authors recommend that prior to undertaking any LID measure research effort, the effort be preceded by an expert review of the literature to identify work that has already been completed and where the most effective use of research dollars may be applied.

Bioretention and Biofiltration

Use of Trees

Observation and experience has shown that use of trees in bioretention and biofiltration/biotreatment systems can be problematic. First, some engineered Biotreatment Soil Media (BSM) may not retain sufficient moisture or nutrients to support tree growth and survival. Second, trees planted in BSM may not develop sufficient root mass and strength to prevent trees from toppling in the wind.

The Bay Area Stormwater Management Agencies Association's (BASMAA's) Development Committee Soil Specifications Work Group commissioned a literature review and conducted a roundtable meeting of experts to revise or develop new specifications to address the soil moisture and soil nutrient issues with the BASMAA BSM.¹¹ Key factors discussed at the roundtable for the success of tree installations were providing sufficient soil volumes and allowing the roots access to native soil. The experts did not come to consensus on design, and work groups are continuing to explore these issues. To guide design development, another literature review was prepared for BASMAA to compile existing design details for bioretention systems with trees.¹²

The City of Fremont convened a workgroup to evaluate the use of trees in bioretention facilities, and concluded a "soil pedestal" was needed to support the weight of trees and to allow trees to root into soil capable of supporting the tree during winds. The City constructed several full-scale test units, and

⁹ <http://www.usclimatedata.com>

¹⁰ Water Quality Order No. 2013-0001-DWQ, National Pollutant Discharge Elimination System General Permit No. CAS000004, Waste Discharge Requirements for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (Phase II Small MS4 General Permit), Section E.12.e.ii.f.

¹¹ BASMAA, Biotreatment Soil Media and Specification: Current Research on Trees and Water Quality Treatment, Literature Review, San Francisco Bay Area, CA. Prepared by WRA Environmental Consultants. September 2016.

¹² BASMAA, Bioretention Design for Tree Health: A Literature Review, San Francisco Bay Area, CA. Prepared by WRA Environmental Consultants. September 2016.

several years ago commenced testing. Because trees grow slowly, it may be another few years before a final evaluation of the City of Fremont Tree Well Filters can be concluded.

Recommendation: Conduct research relative to the use of trees in bioretention and biofiltration/biotreatment facilities, including suitable BSM and configurations for tree rooting.

Designer BSM

The BSM used in bioretention and biofiltration/biotreatment facilities typically contains a mixture of primarily sand and compost, and some specifications call for 5-10% clay. BSM is commonly designed to provide for a high flux of influent stormwater and for fast drainage, characteristics that may reduce the pollutant removal capabilities of the BSM. “Designer BSMs” are BSMs that typically meet the flux and drainage requirements and address critical target pollutants by including special materials in the makeup of the BSM. Special materials have included activated alumina and soils with a low p-index to reduce phosphorus and phosphorus export to name a few.

Recommendation: Conduct research relative to the use and effectiveness of “designer BSMs” in bioretention and biofiltration/biotreatment facilities to target specific pollutants of concern such as nitrogen, phosphorus, metals, bacteria, oil and grease, etc.

Role of Plants

Bioretention and biofiltration/biotreatment LID measures typically have a plant component to them, with the plant materials often being the differentiator between a “bio” LID measure (e.g., bioretention) and a “physical or mechanical” LID measure (e.g., sand filter). Much of the available research on “bio” LID measures focuses on the combined BSM and plant “system” and its ability to remove pollutants, with little or no information to differentiate the pollutant removal and other benefits specifically of the plant materials. However, it is generally believed that the plants help trap pollutants on the surface of the facility, aerate the soil and support its biological functions, maintain porosity and infiltration rates, and uptake pollutants. Depending on the situation plants also assist with volume reduction through evapotranspiration.

In arid and desert areas of California where landscape plants must be periodically irrigated to survive, and in drought areas of the state where outdoor irrigation is increasingly restricted and regulated, interest in no water use landscaping is gaining interest. With bioretention and biofiltration/biotreatment LID measures often being incorporated into site landscaping, use of irrigation water to support these facilities is likewise coming into question. Municipalities are also concerned about long-term maintenance costs and funding sources for maintenance of these systems, making it important to understand the quantify the benefits provided by the plant component.

If plants are an essential component of bioretention and biofiltration/biotreatment systems, better understanding of plant function will also help inform selection of plants for site-specific and potentially pollutant-specific applications.

Additionally, there is an important plant distinction that is often overlooked in the slope-sided bioretention designs where the “stormwater functional” plants are those located within the stormwater functional area and will receive periodic ponding. In contrast, plants located along the higher elevation perimeter may not experience stormwater ponding and this planting zone does not require bioretention-specific vegetation.

Recommendation: Conduct research into the specific role of plants in bioretention and biofiltration/biotreatment facilities to quantify the benefits of plants and determine if the plants are necessary functional components of these systems and under what circumstances facilities can function adequately without plants. Research is also recommended to evaluate the effect of irrigation of vegetation on the treatment and flow regime management capabilities of bioretention and biofiltration/biotreatment LID measures. Outreach is needed to educate landscape architects and

contractors regarding the difference in the vegetation design that may result from the existence of a functional planted zone that receives stormwater and areas within the facility that do not receive stormwater (e.g., perimeter zones).

Volume and Flow Reduction

MS4 permits are now including hydromodification control requirements that require projects to maintain the pre-development runoff flow regime after development. Bioretention and biofiltration/biotreatment LID measures include features that may reduce runoff volumes, reduce peak flows, and increase times of concentration or combinations of these hydrologic variables. Research in its early stage at the Riverside County Flood Control and Water Conservation District's LID Demonstration Facility indicated that lined biofiltration facilities had achieved up to 50% reduction in runoff volume, and other reports quote values of 20-30% but do not always indicate whether the value is for a lined or unlined facility. Projects that implement these LID measures can further benefit from them if credit could be claimed for contributions to flow regime management, thus a better understanding of these LID measures with respect to flow regime management is needed. There are several hydrologic models being used to quantify volume and flow reductions and determine designs that will achieve specified volume and flow control criteria in MS4 permits; however, these models use varying approaches to represent the hydrologic/hydraulic processes within these systems that are often not calibrated to actual performance.

Recommendation: Conduct research into the flow regime management capabilities and hydrologic benefits of bioretention and biofiltration/biotreatment facilities. Specifically, it would be beneficial to better understand the flow regime management capabilities and hydrologic benefits of both unlined and lined facilities and facilities without and with underdrains. In addition, it would be beneficial to better understand how well the various hydrologic models replicate field conditions and how to best use the models to optimize the design of bioretention and biofiltration/biotreatment LID measures.

Maintenance Requirements

Intuitively, it is recognized that bioretention and biofiltration/biotreatment facilities must be maintained to continue to be effective at pollutant reduction and flow regime management. The level and frequency of maintenance recommended in existing guidance manuals and performed by maintenance crews varies considerably, as do the mechanisms to accomplish the maintenance. Questions related to maintenance include:

- Does the organic matter in the BSM need to be replaced, and if so, how often?
- Are other actions needed to maintain long-term BSM performance, such as soil replacement and use of biological amendments, and if so, how often?
- Under what conditions should the entire facility be reconstructed?
- What does the role of maintenance frequency and what types of maintenance affect pollutant removal and volume reduction (e.g. infiltration, evapotranspiration)?

Recommendation: Conduct research to identify and quantify the type and frequency of maintenance needed to keep bioretention and biofiltration/biotreatment facilities functional.

Permeable Pavements

There is a plethora of information on water volume and pollutant reductions, design and material options to address specific pollutants, surface clogging mechanisms and surface maintenance methods, ASTM test methods, and life cycle cost analyses. In addition, there are proven ways to increase deicer resistance of pervious concrete, surface stability of porous asphalt and of jointing materials within permeable interlocking concrete pavements. The Technical Memorandum #2 presents much of that information.

Life Cycle Analysis

A recent and comprehensive analysis of research needs for permeable pavements is a 2015 jointly funded, US DOT, Caltrans, and Minnesota DOT report titled, “The Application of Permeable Pavement with Emphasis on Successful Design, Water Quality Benefits, and Identification of Knowledge and Data Gaps.”¹³ The report notes that all LID measures and permeable pavements in particular should examine energy use, as well as water and pollutant flows. For California, urban areas are being retrofitted with LID measures including permeable pavements; these should be viewed as an impermeable-to-permeable urban surface evolution.

California’s surface and ground waters can only benefit from re-introduction of runoff to the earth. Additionally, permeable pavements have broader benefits by providing a cooler, cleaner, quieter, and healthier urban environment. The referenced report characterizes the interrelationship of these pavement benefits in terms of total life cycle assessments (LCAs), an analysis framework examining relevant pollutant impacts from extraction, manufacture, construction, use, and end-of-life actions. Conventional pavement LCAs are being spearheaded by UC Davis and the University of Illinois for the Federal Highway Administration through its sustainable pavements program. LCAs should be developed and articulated for permeable pavements as well as for other LID measures.

Recommendation: Develop pavement LCAs specifically for permeable pavement types. This can be used by designers and agencies in assessing and comparing pollutant emissions, water use/re-use, and especially carbon emissions from all life phases. This can better position permeable pavement benefits against lesser benefits from cheaper, institutionalized, and easily-used conventional pavements.

Structural Load Testing

In 2008 and 2010, UC (Davis) Pavement Research Center (UCPRC) conducted research on pervious concrete and porous asphalt as road shoulders. At about \$1 million, this work for these two reports was funded by the Caltrans Department of Environmental Assessment (DEA). The deliverables included base thickness design tables and a life cycle cost analysis. This work developed mechanistic models to predict rutting in porous asphalt and cracking in pervious concrete as a function of Caltrans Traffic Index (TI), soil subgrade strength, surface and base thickness.

No full-scale structural load testing was done at UCPRC for Caltrans. This testing is needed to validate (or adjust) the base thicknesses in the design tables in the deliverables. At this point, they are only theoretical and therefore not useful to designers. Full-scale load testing to failure is essential to validate structural performance. Similar load testing is done regularly for Caltrans for conventional highway pavement materials by UCPRC in Davis. Other state highway agencies conduct pavement load testing regularly such as DOTs in Alabama, Florida, Louisiana, Illinois and Washington.

In 2014, UCPRC was hired by the Interlocking Concrete Pavement Institute Foundation for Education and Research (ICPIF) to conduct full-scale load testing of permeable interlocking concrete pavement. This [report](#) validated design tables for subbase thickness published in 2011 by the Interlocking Concrete Pavement Institute (ICPI). Those design tables were originally developed from the 1993 AASHTO *Guide for Design of Pavement Structures*, a source document for conventional pavement design. The UCPRC thickness tables for PICP (slightly modified) were included in the [Caltrans Pervious Pavements Design Guide](#). The maximum allowable traffic index is TI = 9 which represents residential streets and residential collector roads. This represents a promising start.

In the conclusions of its research for ICPIF, UCPRC also noted that substantially higher loads (expressed as higher TIs) could be achieved by placing a 6-inch thick layer of pervious concrete directly on the soil

¹³ Kayhanian, Masoud; Weiss, Peter; Guilliver, John; and Khazanovich, Lev: [The Application of Permeable Pavement with Emphasis on Successful Design, Water Quality Benefits, and Identification of Knowledge and Data Gaps](#) (National Center for Sustainable Transportation, June 2015).

subgrade. This rigid, pervious subgrade platform confines and stiffens an open-graded aggregate subbase/base placed above it, thereby allowing designs with TIs greater than 9. This enables wider use in municipal roads such as collectors and low-speed thoroughfares.

The unique aspect is that UCPRC design method for permeable interlocking concrete pavement is based on the number of days per year water stands in the subbase. The number of days can be estimated using rainfall data on the Caltrans website or from weather service websites. The cutting-edge aspect of the UCPRC research is it provides a method to design pavements in saturated subgrade conditions, a practice that civil and geotechnical engineers may not be exposed to in traditional training or in practice. This lack of knowledge solidifies reluctance to use permeable pavements in municipal roadways. Addressing this aspect via research and full-scale load testing is essential to building confidence in permeable pavements by consulting and municipal engineers.

Conventional pavements are well known as a pollutant source and in many cities, streets occupy 25% or more of the land and can represent 40% or more of impervious cover. A primary barrier to adoption of permeable pavements by municipal road agencies as a standard pavement presents a technology gap. Well-intended stormwater agencies recognize roads as a pollutant source and permeable pavements as a solution, but they do not have effective design tools validated by pavement researchers (such as those at UCPRC) for municipalities to adopt permeable pavements as a standard street design. Generating validated structural design and performance information are keys to overcoming this barrier to adoption. This would enable permeable pavements as the stormwater conveyance system (with some infiltration) rather than solely relying on piped systems, some of which are operating at capacity. This road-system-as-stormwater-management approach can address local flooding and provide a more resilient road infrastructure. Moreover, this research would accelerate the impermeable-to-permeable urban surface evolution.

Recommendation: UCPRC recently proposed additional permeable pavement structural testing to Caltrans DEA. CASQA should make a similar request as a stakeholder interested in seeing highway runoff pollution reduced. The UCPRC research should include structural testing of pervious concrete, porous asphalt and a hybrid system of permeable interlocking concrete pavement that includes a pervious concrete base and/or subbase. The approximate cost for full-scale load testing research of all of three permeable pavement systems would be \$2 to \$3 million. Deliverables from this effort would be structural design guides, as well as guide construction specifications for California municipalities. These could then be promulgated through CASQA.

The research deliverables would be applicable to road shoulders which would provide Caltrans with LID tools for infiltrating and treating highway runoff, especially in highly urbanized areas where no space exists for detention facilities, and where high amounts of impervious pavement may preclude the use of bioretention. While outside Caltrans' sphere, the research deliverables could be easily adopted for municipal use which would have a tremendous benefit to California's incorporated cities as well as county road agencies.

ASCE/ANSI Design Standard

Later in 2017, ASCE will publish a standard guide for design, construction, and maintenance of permeable interlocking concrete pavements. At this writing, the ASCE national standard is being balloted, about 120 pages (Keith Lichten, from the San Francisco Regional Water Quality Control Board, is on the ASCE committee responsible for the development of this standard).

Recommendation: CASQA should consider reviewing, referencing this standard in online/printed documents, and possibly adopting this standard for permeable interlocking concrete pavements.

Development of Additional LID Measure Details and Standards

One challenge in the development of bioretention and biofiltration details and standards is communicating the flexibility that is inherent in some design elements but not other elements whereby deviation from the detail may result in facility failure. LID designs that include plants, specialized soils and often unique configurations can be especially problematic as our technical understanding of the critical components and their interrelationship is still an emerging. Future design guidance documents should provide practitioners with a better understanding of how facility design can deviate from the engineering detail and standards without compromising system pollutant removal and hydrologic performance or the structural integrity of the facility or adjacent infrastructure. The review team has identified several additional LID measure details and/or standards that we believe will contribute value to the LID measure toolbox.

Plan View and Longitudinal Sections

In TM #1, the review team noted that a better understanding of bioretention and biofiltration/biotreatment facilities could be achieved by providing plan view and longitudinal sections to supplement the cross-section details already provided.

Recommendation: Develop plan view and longitudinal sections for bioretention and biofiltration/biotreatment facilities.

Vegetated Swales

Vegetated swales continue to be a common practice in development, and research indicates that swales provide benefits that parallel bioretention and biofiltration/biotreatment facilities, including surface filtration, plant uptake, and infiltration, though perhaps at a reduced level.

Recommendation: Develop cross-section, plan view, and longitudinal section details for vegetated swales to maximize their LID benefits.

Underdrain and Underdrain Outlet Details

The standards reviewed in TM #1 provided details that included outlets and underdrains. Outlets and underdrains are key features of bioretention and biofiltration/biotreatment facilities and warrant added details and options.

Recommendation: Develop additional details for underdrains and outlets for bioretention and biofiltration/biotreatment facilities. Include underdrains details for near the bottom, middle, and top of the storage layer, including details that allow provide for retention when the underdrain is located near the bottom of the storage layer (e.g., inverted "J").

Residential Street Bump Outs and Bump Ins

Bioretention and biofiltration/biotreatment facilities can be located to address runoff from streets, and can provide benefits such as narrowed path of crossing for pedestrians and traffic calming in addition to the more conventional LID measure benefits. Bump Outs have the treatment area encroach into what is commonly the parking shoulder of the street, and Bump Ins have the treatment area located out of the street but adjacent to the curb. Details and standards are needed to give land use authorities, engineers, and developers the confidence to use this type of LID measure.

Recommendation: Develop details for residential street Bump Outs and Bump Ins to accommodate bioretention and biofiltration/biotreatment facilities as part of street improvements. The recommendation is currently limited to residential streets because thoroughfares and arterial streets are much more complicated and should have site-specific designs.

Side Loaded Bioretention and Biofiltration/Biotreatment

The City of Fremont developed bioretention and biofiltration/biotreatment LID measures that introduced stormwater into the facility via the side as opposed to the surface, thus preventing surface ponding. The Fremont Tree Well filters have been flow tested twice, with tests about a year apart, and the flow performance exceeded expectations. Side loaded facilities may provide more flexible deployment of bioretention and biofiltration/biotreatment facilities where surface water is an issue.

Recommendation: Develop details and standards for side loaded bioretention and biofiltration/biotreatment facilities. The City of Fremont details could provide a good starting point for development of the recommended details and standards.

Alternative Curb Openings

Open curb cuts are perhaps the most common method deployed to introduce stormwater into bioretention and biofiltration/biotreatment facilities. Concerns have been raised regarding vehicles getting tires and wheels stuck in these openings, tripping, and issues with street sweepers.

Recommendation: Develop details and standards for alternative means to convey stormwater into bioretention and biofiltration/biotreatment facilities. Include details for cored curbs, cast-iron inlets, grates, and steel or iron bridged openings.

Sediment & Trash Management

Bioretention and biofiltration facilities are designed to remove particulate matter. However, sediment input can adversely impact bioretention and biofiltration function due to clogging of bioretention media soils. Bioretention and biofiltration facilities have the capacity to capture and retain trash, however maintenance and collection of trash in bioretention and biofiltration may be a concern. Designs for these facilities generally do not provide guidance on pre-treatment sedimentation/trash features whether located within the facility or just adjacent.

Recommendation: Develop details and standards for pre-treatment sediment/trash capture function for bioretention and biofiltration facilities to reduce clogging of BSM soils and reduce maintenance requirements.