



Using Green Infrastructure in Highway Roadside Stormwater Management

Requested by
Jennifer Taira, Landscape Architecture

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Executive Summary

Background

Current stormwater management practices of state departments of transportation (DOTs) have been chiefly limited to traditional approaches that employ single-purpose gray stormwater infrastructure—defined by U.S. Environmental Protection Agency as conventional piped drainage and water treatment systems—and other types of hardscaping. These approaches are expensive and can contribute to flooding and stormwater pollution as a result of improper design, construction and/or maintenance practices.

Stormwater solutions that employ low-impact development (LID) and other green infrastructure (GI) techniques are being explored as cost-effective and resilient alternatives to traditional methods. LID and other GI practices, which work with natural processes, include water harvesting, landform grading and micro-catchment basins in arid regions, and the implementation of large watershed actions as components of transportation development projects and operations. Information about LID and other GI designs will help Caltrans create a resource that will include effective practices and design guidance, facilitating the implementation of these practices on a larger scale.

To gather information about these alternative stormwater management solutions, CTC & Associates distributed an online survey to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Design and the AASHTO Committee on Environment and Sustainability. Consultations with other researchers along with design guidance provided by survey participants supplemented the survey findings.

Summary of Findings

This Preliminary Investigation gathered information in three areas:

- Survey of practice.
- Consultation with researchers.
- Design guidance.

Survey of Practice

Eighteen state transportation agencies participated in the online survey. Key findings from respondents are highlighted below.

Agency Approach to Stormwater Management Design

Survey respondents were asked to characterize the stormwater management program in their agencies by describing the approach taken to apply LID or other GI techniques to roadside stormwater management design. More than half of the agencies participating in the survey apply LID and other GI techniques on a project-by-project basis to meet individual project needs. While North Carolina is the only agency currently using a holistic approach, five other states—Connecticut, Maryland, Oregon, Utah and Virginia—are moving toward a holistic approach. Three states—Alaska, Kansas and Oklahoma—don't apply LID or GI techniques to roadside stormwater management design.

Green Infrastructure Stormwater Management Techniques

Respondents were asked to indicate which of 15 LID and other GI techniques their agencies use to manage roadside stormwater. Wet basins, bioretention areas, dry detention basins and infiltration basins were the most commonly used techniques among survey participants. Stormwater tree trenches, submerged gravel wetlands, water harvesting and infiltration berms were used the least frequently. Washington State and Virginia DOTs used the greatest number of techniques (15 and 11, respectively), while Alaska and Tennessee DOTs used the fewest (two). Other GI stormwater management practices and techniques used by participating agencies included bioslopes, swales and vegetated areas.

Use of Compost and Other Soil Enhancements

Eight states—Connecticut, Florida, Kansas, New Jersey, North Carolina, Oregon, Virginia and Washington—use compost or other soil enhancements to increase the water-holding capacity and organic content in the soil for the plant materials used in GI projects.

The allowable distance to the roadway that these soil enhancements are incorporated into the soil profile varied considerably among respondents. In Washington, these products are allowed 1 to 3 feet from the pavement edge; in Oregon, the allowable distance is 12 feet. Currently North Carolina DOT is evaluating the optimal distance for incorporating compost for plant growth and stormwater infiltration; the agency plans to develop a practice specification based on the findings.

The depth that soil enhancements are incorporated into the existing soil profile also varied among respondents. In Connecticut, the recommended depth for soil enhancements is 2 to 6 inches for turf establishment and 6 to 12 inches for tree plantings; in Florida, the depth averages 1 to 3 feet, depending on the existing soils and groundwater conditions. In North Carolina, where the depth is approximately 6 to 8 inches, the respondent noted that agency research indicates that “deeper tillage does not substantively improve infiltration performance.” Only two states—Connecticut and Oregon—change the depth that these materials are incorporated in the areas closer to the roadway.

Case Studies

Highlights of six successful roadside stormwater management projects are provided as case studies beginning on page 13. Estimated costs for these projects ranged from \$1 million to more than \$87 million. Only one state—Maryland—provided cost-benefit information related to the project’s life cycle. The respondents from Connecticut and Virginia DOTs noted that it was too early in the project life cycle to assess these factors.

Consultation With Researchers

Follow-up contacts with members of the AASHTO Technical Committee on Hydrology and Hydraulics and the Transportation Research Board (TRB) Standing Committee on Stormwater supplemented the survey findings:

- Scott Taylor, senior vice president at Michael Baker International, recommended two National Cooperative Highway Research Program (NCHRP) projects in progress:
 - NCHRP 14-39: Using Vegetated Compost Blankets to Achieve Highway Runoff Volume and Pollutant Reduction.
 - NCHRP 25-51: Limitations of the Infiltration Approach to Stormwater Management in the Highway Environment.

Taylor also provided a compendium of resources related to stormwater management research that was developed by the Standing Committee on Environment.

- Nick Wark, hydraulics engineer at Vermont Agency of Transportation and member of the Technical Committee on Hydrology and Hydraulics, reported that the committee is currently evaluating more traditional stormwater best management practices, not GI and LID design.
- Other researchers recommended resources and programs from Georgia, Maryland, North Carolina and South Carolina transportation agencies.

Design Guidance

Most of the respondents provided design guidance and documentation related to the 15 stormwater management techniques listed in the survey. DOT and other state agency documentation provided by participants includes design, construction, inspection and maintenance criteria. Other general guidance provided by survey participants follows the individual practice guidance.

Gaps in Findings

Portions of the survey received a limited response from survey participants, specifically related to successful roadside stormwater management projects. Follow-up inquiries with the six states that listed projects could provide more specific detail related to project specifications, costs and maintenance practices. Additionally, follow-up inquiries with the remaining survey participants could produce additional projects of interest. Also, while survey respondents provided numerous design manuals and other guidance, additional contact with Connecticut, North Carolina, Utah and other DOTs could produce useful guidance.

Next Steps

Moving forward, Caltrans could consider:

- Examining in detail the design guidance for GI and LID stormwater management techniques provided by survey participants and other researchers.
- Contacting selected survey respondents for supplementary information:
 - Connecticut and North Carolina DOTs and Maryland DOT State Highway Administration for additional agency documents related to GI practices and projects.
 - Utah DOT for the 2018 standards for LID long-term stormwater controls on projects that disturb 1 or more acres of ground or discharges to waters of the state.
 - North Carolina DOT about its research into developing a practice specification about the optimal distance for incorporating compost for plant growth and stormwater infiltration.
- Following the progress of NCHRP 14-39 and NCHRP 25-51 projects.

Detailed Findings

Survey of Practice

Survey Approach

Caltrans is seeking information from other state transportation agencies about alternatives to traditional, single-purpose gray stormwater infrastructure to manage roadside stormwater. Of particular interest are stormwater management solutions that use low-impact development (LID) and other green infrastructure (GI) techniques that work with natural processes, such as water harvesting, landform grading and micro-catchment basins in arid regions, and that implement large watershed actions as components of transportation development projects and operations.

To gather information about alternative stormwater management solutions, CTC & Associates distributed an online survey to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Design and the AASHTO Committee on Environment and Sustainability. The survey questions are provided in [Appendix A](#). The full text of survey responses is presented in a supplement to this report.

In addition to the survey results, this Preliminary Investigation includes:

- Findings from consultations with members of the AASHTO Technical Committee on Hydrology and Hydraulics and the Transportation Research Board (TRB) Standing Committee on Stormwater to gather additional information about alternatives to roadside stormwater management.
- Design guidance and other resources provided by survey respondents, which are provided in **Design Guidance** beginning on page 22.

Summary of Survey Results

The survey received 20 responses from 18 state transportation agencies:

- Alaska.
- Arkansas.
- Connecticut.
- Florida (2 responses).
- Georgia.
- Hawaii.
- Kansas.
- Kentucky.
- Maryland.
- Montana.
- New Jersey.
- North Carolina.
- Oklahoma.
- Oregon.
- Tennessee.
- Utah.
- Virginia (2 responses).
- Washington.

Survey results are summarized below in the following topic areas:

- Agency approach to stormwater management design.
- Green infrastructure stormwater management techniques.
- Use of compost and other soil enhancements.
- Case studies.
- Other agency practices.

Agency Approach to Stormwater Management Design

Survey respondents were asked to characterize the stormwater management program in their agencies by describing the approach taken to apply LID or other GI techniques to roadside stormwater management design. Respondents were asked to choose the options below that described the program:

- Our agency does not apply LID or other GI techniques to roadside stormwater management design.
- Our agency has made limited use of LID and other GI techniques to manage roadside stormwater.
- Our agency applies LID and other GI techniques on a project-by-project basis to meet individual project needs.
- Our agency uses a broad-based watershed approach to applying LID and other GI techniques to roadside stormwater management design.
- Our agency is moving toward a holistic approach that includes guidance on design, construction and maintenance.
- Our agency has adopted a holistic approach that includes guidance on design, construction and maintenance.
- Our agency takes a different approach than those described above.

More than half of the respondents indicated that their agencies apply LID and other GI techniques on a project-by-project basis to meet individual project needs. Six state respondents said their agencies use LID or GI techniques on a limited basis while three said their agencies use a broad-based watershed approach. North Carolina Department of Transportation (DOT) is the only agency that has adopted a holistic approach, but five other states—Connecticut, Maryland, Oregon, Utah and Virginia—are moving toward a holistic approach. Respondents from Alaska, Kansas and Oklahoma said their agencies don't use LID or GI techniques.

Two states—Georgia and Kentucky—use a different approach:

- Georgia DOT has two permits that may require LID or GI techniques beyond those that are naturally inherent to a DOT project: the municipal separate storm sewer system (MS4) permit, which requires the agency to look at each outfall for the placement of a structure on a state route within an MS4 area, and the construction stormwater permit, which may be required when the agency encroaches on a stream buffer.
- Kentucky Transportation Cabinet has a karst/groundwater protection policy that incorporates enhanced best management practices (BMPs) in sensitive areas, such as the Mammoth Cave catchment basin.

Survey responses are summarized in the table below.

Agency Stormwater Management Program							
State	No Use of LID or GI Techniques	Limited Use of LID or GI Techniques	Project-by-Project Basis	Broad-Based Watershed Approach	Moving Toward Holistic Approach	Adopted a Holistic Approach	Other Approach
Alaska	X	X					
Arkansas		X		X			
Connecticut		X			X		
Florida 2		X	X				
Georgia							X
Hawaii		X					
Kansas	X						
Kentucky							X
Maryland			X	X	X		
Montana			X				
New Jersey			X				
North Carolina			X			X	
Oklahoma	X						
Oregon			X		X		
Tennessee			X				
Utah		X	X		X		
Virginia 1			X		X		
Washington			X	X			

Green Infrastructure Stormwater Management Techniques

Respondents were asked to indicate which of the following 15 LID and other GI techniques their agencies use to manage roadside stormwater:

- Bioretention areas.
- Catch basin inserts.
- Dry detention basins.
- Infiltration basins.
- Infiltration berms.
- Infiltration trenches.
- Landform grading.
- Manufactured treatment devices.
- Rain gardens.
- Stormwater tree trenches.
- Stormwater wetlands.
- Submerged gravel wetlands.
- Water harvesting.
- Wet basins.
- Other practices.

Among the states surveyed, the most common techniques used were wet basins (15), bioretention areas and dry detention basins (14) and infiltration basins (13). The least frequently used techniques were stormwater tree trenches (three), submerged gravel wetlands (three), water harvesting (three) and infiltration berms (two). Washington State and Virginia DOTs reported using the widest range of techniques (15 and 11, respectively). Alaska and Tennessee DOTs reporting using the fewest techniques (two). The table below summarizes survey responses.

Green Infrastructure Stormwater Management Techniques															
State	Bioretention Areas	Catch Basin Inserts	Dry Detention Basins	Infiltration Basins	Infiltration Berms	Infiltration Trenches	Landform Grading	Manufactured Treatment Devices	Rain Gardens	Stormwater Tree Trenches	Stormwater Wetlands	Submerged Gravel Wetlands	Water Harvesting	Wet Basins	Other
Alaska									X						X
Arkansas				X							X			X	X
Connecticut	X		X			X			X					X	
Florida 1	X	X		X		X		X			X		X	X	X
Florida 2				X		X		X	X		X			X	
Georgia	X		X	X		X					X			X	X
Hawaii	X	X	X					X							
Kansas	X		X ¹								X ²			X	
Kentucky	X	X	X				X								
Maryland	X		X	X		X					X	X		X	X
Montana	X		X	X				X						X	X

Green Infrastructure Stormwater Management Techniques															
State	Bioretention Areas	Catch Basin Inserts	Dry Detention Basins	Infiltration Basins	Infiltration Berms	Infiltration Trenches	Landform Grading	Manufactured Treatment Devices	Rain Gardens	Stormwater Tree Trenches	Stormwater Wetlands	Submerged Gravel Wetlands	Water Harvesting	Wet Basins	Other
New Jersey	X		X	X				X			X	X		X	X
North Carolina	X		X	X			X		X		X		X	X	X
Oregon	X		X	X			X	X	X					X	X
Tennessee						X					X				
Utah			X	X		X		X						X	X
Virginia 1	X		X	X	X	X		X		X	X			X	X
Virginia 2	X	X	X	X		X	X	X	X	X	X			X	
Washington	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

- 1 Very limited use.
- 2 As required by Federal Highway Administration.

Other Green Infrastructure Practices

Several survey respondents described other GI stormwater management practices and techniques used by their agencies, including bioslopes (also known as media filter drains) (Georgia and Oregon); swales (Maryland, New Jersey, North Carolina, Oregon, Utah and Virginia); and vegetated areas (Arkansas, Oregon and Utah). Survey responses are summarized in the table below.

Additional Green Infrastructure Stormwater Management Techniques		
Techniques and Practices	State	Description
Bioslopes (Media Filter Drains)	Georgia, Oregon	<i>Georgia.</i> Sections of filter material are embedded in a shoulder slope that has an underdrain to transport water to a roadside ditch.
Swales	Maryland, New Jersey, North Carolina, Oregon, Utah, Virginia 1	<i>Maryland.</i> Bioswales, wet swales and grass channels/swales. <i>New Jersey.</i> Bioretention swales. <i>Oregon.</i> Compost-amended bioswales. <i>Utah.</i> Vegetated swales. <i>Virginia 1.</i> Wet swales and dry swales.

Additional Green Infrastructure Stormwater Management Techniques		
Techniques and Practices	State	Description
Vegetated Areas	Arkansas, Oregon, Utah	<p><i>Arkansas.</i> Most DOT right of way consists of vegetated ditch, which allows for some infiltration.</p> <p><i>Oregon.</i> Compost-amended roadside filter strips.</p> <p><i>Utah.</i> Vegetated filter strips.</p>
Other Practices	Florida 1, Montana, New Jersey, North Carolina, Utah, Virginia 1, Washington	<p><i>Florida 1.</i> Amendments are used to capture soluble nutrients such as nitrogen and phosphorus.</p> <p><i>Maryland.</i> Micro-bioretenion.</p> <p><i>Montana.</i> Hydrodynamic separators (proprietary devices).</p> <p><i>New Jersey.</i> Constructed wetlands and sand filters.</p> <p><i>North Carolina.</i> Level spreaders and preformed scour holes.</p> <p><i>Utah.</i> Asphalt open-graded surfaces and catch basin sumps.</p> <p><i>Virginia 1.</i> Pollution prevention and nutrient management.</p> <p><i>Washington.</i> Dispersion.</p>

Additional Information

Below are further details about agency practices and guidance provided by respondents:

Bioretention Areas

- The Connecticut DOT respondent reported that guidance for using bioretention areas includes working with wet soils and native plants, and coordinating efforts with the state Department of Energy and Environmental Protection (DEEP).
- Kansas DOT designs stormwater detention basins when more than 10 acres of disturbed area leave the site at one point.

Catch Basin Inserts

- While North Carolina DOT has researched catch basin inserts, it doesn't use them routinely because of excessive maintenance requirements.
- The Virginia DOT 1 respondent reported that this technique is used for pollution prevention on maintenance facilities, but not for roadside stormwater management.

Dry Detention Basins

- Connecticut DOT primarily uses dry detention basins for facility designs. Turf surface is used only for maintenance.
- The Florida 2 DOT respondent noted that the agency typically follows the rules and guidelines specified by the permitting agency (the water management district). The

respondent provided an example from the St. John River Water Management District (see **Design Guidance**, which begins on page 22).

Infiltration Basins

- The Florida 2 DOT respondent noted that the agency typically follows the rules and guidelines specified by the permitting agency (the water management district). The respondent provided an example from the St. John River Water Management District (see **Design Guidance**).

Infiltration Trenches

- Connecticut DOT generally uses wrapped storage areas below ground, with vegetated swales above ground.
- Tennessee DOT uses standard design details.

Landform Grading

- The North Carolina DOT respondent indicated that various agency guidance documents might be helpful for landform grading design. (*Note: Follow-up requests for these documents were unanswered.*)

Manufactured Treatment Devices

- Florida DOT uses SunTree products for baffles, trashceptors and upflow filters using bioactivated media.
- Montana DOT uses manufactured treatment devices mostly within MS4 areas.
- North Carolina DOT has researched a few manufactured treatment devices but does not routinely use them on projects due to maintenance issues.
- In Oregon, Filterra is currently the only manufactured treatment device on the agency's qualified products list. The DOT follows the manufacturer's recommendations.

Rain Gardens

- Connecticut DOT uses rain gardens in areas where community stakeholders agree to perform the maintenance.
- While Florida DOT has used rain gardens in conjunction with local governments, the agency does not have design standards.
- North Carolina DOT has used rain gardens informally as a stewardship practice rather than a regulatory compliance practice, most often at rest areas. Design guidance is similar to infiltration basins but without the outlet structure.

Stormwater Wetlands

- Kansas DOT designs stormwater wetlands when required by the Federal Highway Administration.
- Tennessee DOT uses standard design details for this technique.

Water Harvesting

- Florida DOT typically follows the rules and guidelines specified by the permitting agency (the water management district). The respondent provided an example from the St. John River Water Management District (see **Design Guidance**).
- North Carolina DOT has used water harvesting (cisterns) informally as a stewardship practice rather than a regulatory compliance practice, most often at rest areas. The agency typically follows design guidance provided by North Carolina State University.

Wet Basins

- Connecticut DOT uses wet basins in areas with highly organic soils, with native plants or for habitat development.
- Florida typically follows the rules and guidelines specified by the permitting agency (the water management district). The respondent provided an example from the St. John River Water Management District (see **Design Guidance**).
- Oregon DOT rarely uses wet basins. The ODOT Hydraulics Manual does not include them in its design guidance.

Use of Compost and Other Soil Enhancements

Respondents from eight states—Connecticut, Florida, Kansas, New Jersey, North Carolina, Oregon, Virginia and Washington—reported that their agencies use compost or other soil enhancements to increase the water-holding capacity and organic content in the soil for the plant materials used in GI projects.

The allowable distance to the roadway that these soil enhancement products are permitted varied considerably among respondents: from 1 to 3 feet (Washington) to 12 feet (Oregon) from the pavement edge. In Florida, these products are allowed as close as the sodded portion of the actual roadway paved shoulder, which is 4 to 6 feet from the edge of the travel lane. In Connecticut and Virginia, soil amendments may be added to the area outside the clear zone of the roadway. Soil amendments have very limited use in Kansas (only when top soil is unavailable).

The Oregon DOT respondent noted that in special circumstances, amended soil-filled geogrids may be used closer than 12 feet to provide necessary support that prevents vehicles leaving the pavement from sinking in the soil. North Carolina DOT currently is conducting research on the optimal compost incorporation rates for plant growth and stormwater infiltration; the agency will develop a practice specification when the research is completed.

The depth that soil enhancements are incorporated into the existing soil profile also varied among respondents. In Connecticut, the depth is 2 to 6 inches for turf establishment and 6 to 12 inches for tree plantings in compacted or clay soils. In Florida, the depth is 1 to 3 feet on average, depending on the existing soils and groundwater conditions. In North Carolina, where the depth is approximately 6 to 8 inches, the respondent noted that agency research indicates that “deeper tillage does not substantively improve infiltration performance.”

Only two states—Connecticut and Oregon—change the depth that these materials are incorporated in the areas closer to the roadway. The Oregon DOT respondent said the proximal

face of the cut for placement of amended soil has a 1-to-1 slope, so the depth would change after approximately the first 8 inches of the road.

Responses from all survey participants are summarized in the table below.

Use of Compost and Other Soil-Enhancement Products

State	Distance to the Roadway	Depth of Incorporation into Existing Soil Profile	Change in Depth Closer to the Roadway
Connecticut	Outside the clear zone or areas for maintenance trucks.	<ul style="list-style-type: none"> • Turf: 2"-6" • Trees: 6"-12" 	Depending on the cross section. No incorporation on embankment that supports highway infrastructure.
Florida	4'-6' from pavement edge.	1'-3', depending on existing soils and groundwater conditions.	No.
Kansas	N/A (very limited)	6"	N/A.
New Jersey	N/A.	N/A.	N/A.
North Carolina	N/A.	6"-8"	No.
Oregon	12' from pavement edge. May use soil-filled geogrid closer to roadway.	8"	Approximately 8" from roadway.
Virginia	Outside the clear zone.	10"-12"	No.
Washington	1'-3' from pavement edge.	3"	N/A.

Case Studies

The following case studies describe a roadside stormwater management project that respondents considered successful:

- Connecticut DOT (Farmington Canal Trail).
- Georgia DOT (grade separation of State Route (SR) 316 and SR 20).
- Hawaii DOT (erosion control on Oahu).
- Kansas DOT (South Lawrence Trafficway).

- Maryland DOT State Highway Administration (SHA) (grass channels and median bioswales).
- Virginia DOT (truck climbing lane on Interstate 81 (I-81) Southbound).

Each case study includes the following information (when provided by the respondent):

- Project description.
- Maintenance practices.
- Project specifications.
- Cost–benefit life-cycle information.
- Project estimate.

Some of the case studies are followed by a **Supporting Documents** section that includes manuals and guidance provided by the respondent.

These case studies lack details when a survey respondent provided limited information or did not respond to a question. For example, only the respondent from Maryland DOT SHA provided cost–benefit information related to the project’s life cycle. The respondents from Connecticut and Virginia DOTs said it was too early in the project life cycle to determine these factors.

In addition to the specific details of these projects, the respondents from Arkansas, North Carolina and Tennessee DOTs provided general information about projects that their agencies consider to be successful. The Arkansas DOT respondent noted that the Cave Springs recharge area basins are unintentionally GI. The respondent from Tennessee DOT said the agency includes stormwater management designs in roadway and bridge construction projects, but does not perform stand-alone stormwater projects. The respondent from North Carolina DOT reported that the agency had completed successful projects (follow-up emails to the respondent for more information were unanswered).

Connecticut Department of Transportation

Success Story: Farmington Canal Trail, Cheshire

Project Description	Captured stormwater in rain gardens with both below-ground storage in stone, as well as the depressed cross section, and an overflow system.
Project Specifications	Furnished and placed compost rain garden (complete with all materials).
Project Estimate	Approximately \$4 million.
Maintenance Practices	None by the agency. Trail adopted by municipality and stakeholders.
Cost–Benefit Life-Cycle Information	N/A (too early in the project life cycle).

Supporting Document

Stormwater Pollution Control Plan: Farmington Canal Heritage Trail Extension, Cheshire, CT, Connecticut Department of Transportation District 1, July 2016.

http://www.ct.gov/deep/lib/deep/water_regulating_and_discharges/stormwater/construction/Farmington_Canal_Trail_Cheshire_SWPCP.pdf

This document describes the rain gardens proposed for the Farmington Canal Trail project.

From page 10 of the PDF:

Two rain gardens are proposed on the northern extents of the project limits to retain and collect stormwater flow from the proposed parking lot and sidewalks. The parking lot will utilize minimal curbing to ensure stormwater flow is directed towards the rain gardens, as one garden will be located directly to the north of the lot and the other directly to the south. Sidewalks will be graded towards the rain gardens as they traverse the surrounding area to safely direct pedestrians to and from the parking lot and the multi-use trail. The rain gardens will be composed of a 24" deep top layer of special soil preparation and a 36" deep layer of processed aggregate wrapped in filter fabric on top of graded subsoil. Both rain gardens combined will cover 1232 square feet of plantable area. Refer to the Landscaping Plans in Appendix C for planting details.

Georgia Department of Transportation

Success Story: Grade Separation of State Route (SR) 316 and SR 20

Project Description	Placed enhanced dry swales, which can be described as bioretention basins aligned with a ditch.
Project Specifications	Used engineering drawings from the 2001 Georgia Stormwater Management Manual.
Project Estimate	\$77 million (itemized cost for the dry swales not available).
Maintenance Practices	Inspection and maintenance procedures in the state's Stormwater System Inspection and Maintenance Manual.
Cost-Benefit Life-Cycle Information	N/A.

Supporting Document

Stormwater System Inspection and Maintenance Manual, Georgia Department of Transportation, April 2015.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/1%20and%20M%20Manual.pdf>

Inspection and maintenance procedures for dry swales are provided on pages 5-21 through 5-24 of the manual (pages 53 through 56 of the PDF). An inspection checklist (Form B-3) begins on page 169 of the PDF. Inspection and maintenance procedures for bioretention basins are provided in Section 5.10.2 (beginning on pages 5-88 of the manual, page 120 of the PDF). An inspection checklist (Form B-10) begins on page 190 of the PDF.

Hawaii Department of Transportation

Success Story: Erosion Control on Oahu

Project Description	Installed erosion control measures along cut sections of the highway at various locations. Also installed inlet inserts and baffle boxes.
Project Specifications	Advertised on a biennial basis to meet the state department of health requirements for MS4 and National Pollutant Discharge Elimination System.
Project Estimate	\$1 million to \$4 million per location.
Maintenance Practices	Maintenance procedures in the Storm Water Permanent Best Management Practices Manual or as recommended by the manufacturer for proprietary products.
Cost-Benefit Life-Cycle Information	N/A.

Supporting Document

Storm Water Permanent Best Management Practices Manual, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Inspection and maintenance procedures are discussed in Section 8, beginning on page 8-1 of the manual (page 99 of the PDF).

Kansas Department of Transportation

Success Story: South Lawrence Trafficway, Lawrence

Project Description	Installed several wetlands to manage stormwater runoff.
Project Specifications	N/A.
Project Estimate	\$2 million.
Maintenance Practices	Maintenance provided by Baker Wetlands and Discovery Center, Baker University.
Cost-Benefit Life-Cycle Information	N/A.

Supporting Document

Baker Wetlands Restoration, Federal Contract Opportunity, GovTribe Inc., August 2013.

<https://govtribe.com/opportunity/federal-contract-opportunity/baker-wetlands-restoration-ag6215s130010>

This web site provides links to bid-related documents for the Baker Wetlands Restoration project. The site includes this description of the project:

SUMMARY: This project is for the restoration of wetlands through the Wetlands Research Program in Labette County, Kansas. Work will include mobilization and demobilization,

planting and mulching, earthfill, excavation, depression zones, structure for water control, range planting, chemical weed control and tree planting.

QUANTITIES: The project will consist of an estimated 9,362 cubic yards of excavation, 8,735 cubic yards of earthfill, 7.0 acres of depression zones, 40.0 acres of mowing, 4.0 acres of planting and mulching, 29.0 acres of chemical weed control, 29.0 acres of range planting, planting of 116 root production method trees, 2.4 acres of nut planting, 30 linear feet of sediment control measure, 1 structure for water control, and 60 linear feet of 8-inch plastic pipe.

Maryland Department of Transportation State Highway Administration

Success Story: Grass Channels and Median Bioswales

Project Description	Installed grass channels and median bioswales for watershed restoration or roadway improvement projects.
Project Specifications	Designed to treat runoff from untreated impervious surfaces.
Project Estimate	\$2 million to \$3 million.
Maintenance Practices	Maintenance includes mowing, trash removal, media replacement, erosion stabilization and reseeding vegetation (turf) establishment.
Cost–Benefit Life-Cycle Information	Incorporated into typical roadside maintenance.

Virginia Department of Transportation

Success Story: Truck Climbing Lane on Interstate 81 (I-81) Southbound

Project Description	Added one truck climbing lane and full-width shoulders on two-lane I-81 to improve safety in mountainous area with slow-moving trucks (beginning near Mile Marker (MM) 120 to approximately MM 125). Integrated management practices used for stormwater management in new lanes.
Project Specifications	Used runoff-reducing practices and higher efficiency BMPs to meet water quality goals in a narrow corridor on steep slopes.
Project Estimate	\$87.4 million.
Maintenance Practices	Preventive maintenance: BMP inspection and monitoring with some landscape and roadside management.
Cost–Benefit Life-Cycle Information	N/A (too early in the project life cycle).

Other Agency Practices

Four respondents provided information about current agency practices and activities along with future plans:

- *Connecticut*. The respondent noted that the agency is working to coordinate LID practices with other environmental and community enhancement goals. It has established a working group to explore how its design, hydraulics and drainage can incorporate these trends without compromising safety.
- *Maryland*. Stormwater management laws and regulations that became effective in 2007 dictate that the agency use nonstructural LID practices in environmental site design to the maximum extent practicable before implementing structural practices (traditional stormwater management facilities) such as ponds and basins. These regulations have resulted in an exponential increase in stormwater infrastructure inventory.
- *Utah*. In June 2018, Utah DOT created standards for LID long-term stormwater controls on projects that disturb 1 or more acres of ground or discharges to waters of the state.
- *Virginia*. Virginia DOT's stormwater management program builds upon the Virginia Department of Environmental Quality's program, which includes BMP standards and specifications at the Virginia Stormwater BMP Clearinghouse (see **Design Guidance**, which begins on page 22).

Consultation With Researchers

To supplement the survey results, CTC contacted members of the AASHTO Technical Committee on Hydrology and Hydraulics and the TRB Standing Committee on Stormwater to gather additional information about alternatives to roadside stormwater management. Below are summaries of email queries posed to selected members of these committees along with references to relevant resources.

Delaware Department of Transportation

Steve Sisson, Sussex County review coordinator at Delaware DOT, pointed us to the stormwater management programs at North Carolina and South Carolina DOTs, and at Maryland DOT SHA. Much of the work at these agencies, he said, is driven by regulatory necessity. (*Note:* Both North Carolina DOT and Maryland DOT SHA participated in the survey for this Preliminary Investigation. Citations for Chapter 3 of the 2000 Maryland Stormwater Design Manual and for North Carolina DOT's Stormwater Best Management Practices Toolbox are included throughout this report.)

Contact: Steve Sisson, Sussex County Review Coordinator, Delaware Department of Transportation, 302-354-0979, steven.sisson@state.de.us.

Related Resource:

Storm Water Management Program, South Carolina Department of Transportation, undated.

<https://www.scdot.org/business/storm-water.aspx>

This web site includes links to resources related to stormwater quality management and to sediment and erosion control.

Iowa State University

Mike Perez, an assistant professor in the Department of Civil, Construction and Environmental Engineering at Iowa State University, recommended Georgia DOT's Drainage Design for Highways manual. Chapter 10, he noted, addresses post-construction stormwater management concepts. (*Note:* Citations to this manual are provided throughout this Preliminary Investigation.)

Contact: Mike Perez, Assistant Professor, Department of Civil, Construction and Environmental Engineering, Construction Stormwater Studio Research Laboratory, Iowa State University, 515-294-2700, perez1@iastate.edu.

Michael Baker International

Scott Taylor, senior vice president at Michael Baker International, recommended the following National Cooperative Highway Research Program (NCHRP) projects in progress and also provided a compendium of resources related to stormwater management research (see *Related Resources* below):

- NCHRP 14-39, Using Vegetated Compost Blankets to Achieve Highway Runoff Volume and Pollutant Reduction: According to Taylor, who is a member of this project panel, NCHRP 14-39 is reviewing the runoff volume reduction that can be gained by installing a compost blanket on the roadside shoulder. The blanket is placed directly over the existing soil or vegetation, with little or no preparation required to the shoulder. Taylor

said that this alternative appears to be a fairly inexpensive and easy way to significantly increase runoff retention, thus providing load reduction in stormwater pollutants.

- NCHRP 25-51, Limitations of the Infiltration Approach to Stormwater Management in the Highway Environment: The expected completion date for this project is January 2019.
- Standing Committee on Environment (SCOE) Research Update: Stormwater Management Resources.

Contact: Scott Taylor, Senior Vice President, Michael Baker International, staylor@mbakerintl.com.

Related Resources:

Research in Progress: NCHRP 14-39: Using Vegetated Compost Blankets to Achieve Highway Runoff Volume and Pollutant Reduction, National Cooperative Highway Research Program, start date: April 2017, expected completion date: April 2021.

Project description at

<http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4196>

From the project description: Vegetated compost blankets (VCBs) can overcome some of [the] limitations [of vegetated filter strips] 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.

Research in Progress: NCHRP 25-51: Limitations of the Infiltration Approach to Stormwater Management in the Highway Environment, National Cooperative Highway Research Program, start date: August 2015, expected completion date: January 2019.

Project description at

<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.

Standing Committee on Environment (SCOE) Research Update: Stormwater Management Resources, Joint Meeting of the Natural Resources Subcommittee and Technical Committee on Hydrology and Hydraulics, Joint Meeting of the AASHTO Standing Committee on Environment and Subcommittee on Design 2017 Annual Meeting, July 2017. See [Attachment B](#).

This compendium of resources is a comprehensive listing of field guides, manuals, reports and research projects related to stormwater management.

Vermont Agency of Transportation

Nick Wark, a hydraulics engineer at Vermont Agency of Transportation and member of the Technical Committee on Hydrology and Hydraulics, reported that the committee is currently evaluating more traditional stormwater BMPs, not GI and LID design. While these alternatives are mentioned from time to time, he said, they are not a priority.

Contact: Nick Wark, Hydraulics Engineer, Vermont Agency of Transportation, nick.wark@vermont.gov.

Design Guidance

The resources below include design guidance and documentation provided by survey respondents. Manuals and guidance are organized by GI practice:

- Bioretention areas.
- Catch basin inserts.
- Dry detention basins.
- Infiltration basins.
- Infiltration berms.
- Infiltration trenches.
- Landform grading.
- Manufactured treatment devices.
- Rain gardens.
- Stormwater tree trenches.
- Stormwater wetlands.
- Submerged gravel wetlands.
- Water harvesting.
- Wet basins.
- Other practices.

The documents include design, construction, inspection and maintenance considerations. Other general guidance provided by survey participants follows the individual practice guidance.

State Guidance

Bioretention Areas

Connecticut

Stormwater Management, Department of Energy and Environmental Protection, State of Connecticut, undated.

https://www.ct.gov/deep/cwp/view.asp?a=2721&q=325702&deepNav_GID=1654

DEEP's stormwater management web page describes how stormwater is regulated and provides links to guidance documents, including the state's 2004 Stormwater Quality Manual.

Georgia

Section 10.6.7: Bioretention Basin, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

Design criteria for bioretention basins begin on page 10-129 of the manual (page 383 of the PDF) and include a discussion of design, maintenance and LID/GI considerations. Also provided is an example calculation (beginning on page 10-140 of the manual, page 394 of the PDF).

Hawaii

Bioretention, *Storm Water Permanent Best Management Practices Manual*, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Design, construction and maintenance considerations begin on page 7-21 of the manual (page 57 of the PDF).

Maryland

Section 3.4: Stormwater Filtering Systems, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Section 3.4 (page 3.31 of the report, page 33 of the PDF) provides performance criteria for bioretention areas based on general feasibility, conveyance, pretreatment, treatment, environmental/landscaping and maintenance factors.

M-6: Micro-Bioretention, Chapter 5, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf>

Design guidance for micro-bioretention practices begins on page 5.96 of the manual (page 98 of the PDF).

New Jersey

Section 9.1: Bioretention Systems, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.1.pdf

This section provides design criteria and considerations, example designs and maintenance practices.

North Carolina

Media Filters, Chapter 11, *Stormwater Best Management Practices Toolbox*, Hydraulics Unit, North Carolina Department of Transportation, April 2014.

https://connect.ncdot.gov/resources/hydro/HSPDocuments/2014_BMP_Toolbox.pdf

Chapter 11 (beginning on page 11-1 of the report, page 103 of the PDF) provides design criteria along with construction, inspection, maintenance and safety considerations for bioretention basins and filtration basins.

Oregon

Appendix C: Media Filtration Facilities, Chapter 14, *ODOT Hydraulics Manual*, Oregon Department of Transportation, April 2014.

https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14-C.pdf

Section 2 of this appendix (page 14-C-1 of the report, page 1 of the PDF) presents details about bioretention facilities, including design criteria and step-by-step design procedures for two bioretention ponds.

Virginia

Stormwater Management, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Design elements and procedures for establishing bioretention areas are discussed throughout this chapter. Bioretention practices are also discussed in Section 11.1 of Appendix 11A-1 (beginning on page 217 of the appendix, page 386 of the PDF) and Section 7.1 of Appendix 11A-2 (beginning on page 75 of the appendix, page 554 of the PDF).

Washington

Section RT.08: Bioretention Area, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Section RT.08 (beginning on page 5-91 of the manual, page 315 of the PDF) addresses design, maintenance and other considerations, and rates the capital and operations and maintenance costs.

Catch Basin Inserts

Hawaii

Proprietary Non-LID BMPs, *Storm Water Permanent Best Management Practices Manual*, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Catch basin inserts are discussed briefly on page 7-59 of the manual (page 95 of the PDF).

Washington

Section RT.08: Bioretention Area, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Treatment requirements for catch basins are addressed in Chapter 4 (page 4-44 of the manual, page 140 of the PDF), and design criteria and considerations are addressed throughout Chapter 5 (beginning on page 225 of the PDF). Table 5-16 provides maintenance standards for catch basins (page 5-244 of the manual, page 468 of the PDF).

Dry Detention Basins

Florida

Permit Information Manual, St. Johns River Water Management District, June 2018.

<https://www.sjrwmd.com/static/permitting/PIM-20180601.pdf>

Design and performance criteria for dry detention basins are provided in Chapter 12 (beginning on page 12-2 of the manual, page 97 of the PDF), Chapter 22 (beginning on page 22-1 of the manual, page 273 of the PDF) and Chapter 28 (beginning on page 28-1 of the manual, page 354 of the PDF).

Georgia

Section 10.6.8: Dry Detention Basin, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

Design criteria for dry detention basins begin on page 10-144 of the manual (page 398 of the PDF) and include a discussion of design, maintenance and LID/GI considerations. An example calculation begins on page 10-154 (page 408 of the PDF).

Hawaii

Storm Water Quality BMP Design, Chapter 6, *Storm Water Permanent Best Management Practices Manual*, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Detention-based treatments are discussed in this chapter.

Maryland

Performance Criteria for Urban BMP Design, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Detention-based treatments are discussed in this chapter.

Montana

Section A12.0: Detention Basins, *Permanent Erosion and Sediment Control Design Guidelines*, Montana Department of Transportation, January 2018.

https://www.mdt.mt.gov/publications/docs/manuals/pesc_manual.pdf

Limited design information for dry detention basins is available in this section (beginning on page A12-1 of the report, page 46 of the PDF).

New Jersey

Section 9.4: Extended Detention Basins, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.4.pdf

This section provides design criteria and considerations, total suspended solids removal rates and maintenance practices.

North Carolina

Dry Detention Basin, Chapter 5, *Stormwater Best Management Practices Toolbox*, Hydraulics Unit, North Carolina Department of Transportation, April 2014.

https://connect.ncdot.gov/resources/hydro/HSPDocuments/2014_BMP_Toolbox.pdf

Design criteria along with construction, inspection, maintenance and safety considerations begin on page 5-1 of the toolbox (page 47 of the PDF).

Oregon

Appendix D: Density Separation Facilities, Chapter 14, *ODOT Hydraulics Manual*, Oregon Department of Transportation, April 2014.

https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14-D.pdf

Design criteria and step-by-step design procedures for dry detention ponds are provided in this appendix.

Utah

Section 4.2.5: Detention Basin, *Stormwater Quality Design Manual*, Utah Department of Transportation, June 2018.

<https://www.udot.utah.gov/main/uconowner.gf?n=39517213266675103>

This section provides design criteria and considerations for detention basins beginning on page 4-16 of the report (page 38 of the PDF). Additional considerations and examples are provided in Appendix A.3.5 (page A-21 of the report, page 75 of the PDF).

Virginia

Appendix 11-A1 and Appendix 11-A2: Part IIC Best Management Practices, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Appendix 11-A1: Design considerations are available in Section 2 (beginning on page 5 of the appendix, page 174 of the PDF) and Section 3 (beginning on page 57 of the appendix, page 226 of the PDF). *Appendix 11-A2*: Additional design guidelines and examples are available in Section 13.1 (page 193 of the appendix, page 672 of the PDF).

Washington

Section 5-4.2.3: Detention BMPs, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

This section (beginning on page 5-187 of the manual, page 411 of the PDF) provides design, construction and maintenance considerations.

Infiltration Basins

Florida

Section 23.0: Methodology and Design Examples for Retention Systems, *Permit Information Manual*, St. Johns River Water Management District, June 2018.

<https://www.sjrwmd.com/static/permitting/PIM-20180601.pdf>

Infiltration processes are discussed beginning on page 23-1 of the manual (page 282 of the PDF).

Georgia

Section 10.6.4: Infiltration Trench, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

References to design criteria for infiltration basins are made throughout this section, which begins on page 10-89 of the manual (page 343 of the PDF).

Hawaii

Infiltration Basin, *Storm Water Permanent Best Management Practices Manual*, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Design, construction and maintenance considerations begin on page 7-17 of the manual (page 53 of the PDF).

Maryland

Section 3.3: Stormwater Infiltration, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Infiltration basins are discussed in this section, beginning on page 3.25 of the manual (page 27 of the PDF).

Montana

Permanent Erosion and Sediment Control Design Guidelines, Montana Department of Transportation, January 2018.

https://www.mdt.mt.gov/publications/docs/manuals/pesc_manual.pdf

Infiltration basins are discussed in Section A13, beginning on page A14-1 of the report (page 49 of the PDF).

New Jersey

Section 9.5: Infiltration Basins, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.5.pdf

Design criteria and considerations along with maintenance practices are included in this section.

North Carolina

Infiltration Basin, Chapter 10, *Stormwater Best Management Practices Toolbox*, Hydraulics Unit, North Carolina Department of Transportation, April 2014.

https://connect.ncdot.gov/resources/hydro/HSPDocuments/2014_BMP_Toolbox.pdf

Design criteria along with construction, inspection, maintenance and safety considerations begin on page 10-1 of the toolbox (page 95 of the PDF).

Utah

Section 4.2.3: Retention Basin, *Stormwater Quality Design Manual*, Utah Department of Transportation, June 2018.

<https://www.udot.utah.gov/main/uconowner.gf?n=39517213266675103>

Design information for infiltration basins can be found in this section (page 4-10 of the report, page 32 of the PDF). Additional information is available in Section A.3.3 (page A-14 of the report, page 68 of the PDF).

Virginia

Appendix 11-A1 and 11-A2: Part IIC Best Management Practices, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Appendix 11-A1: Design considerations are available in Section 9 (page 192 of the appendix, page 361 of the PDF) and Section 3.1 (page 57 of the appendix, page 226 of the PDF).

Appendix 11-A2: Additional design guidelines and examples are available in Section 6 (page 56 of the appendix, page 535 of the PDF).

Washington

Section 4-5: Infiltration Design Criteria and LID Feasibility, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

This section (beginning on page 4-28 of the manual, page 124 of the PDF) provides design, construction and maintenance considerations. Additional design information is available on page 5-168 (page 392 of the PDF).

Infiltration Berms

Virginia

7.3.4 Pervious Berm, Appendix 11-A1 and 11-A2: Part IIC Best Management Practices, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Pervious berms are discussed on page 167 (page 336 of the PDF) of Appendix 11-A1 and on page 18 (page 497 of the PDF) of Appendix 11-A2.

Washington

Stormwater Best Management Practices, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Berms are discussed throughout this chapter, which begins on page 217 of the PDF.

Infiltration Trenches

Florida

Section 22.0: Filtration Design and Performance Criteria, *Permit Information Manual*, St. Johns River Water Management District, June 2018.

<https://www.sjrwmd.com/static/permitting/PIM-20180601.pdf>

Design and performance criteria for filter trenches begin on page 22-1 of the manual (page 273 of the PDF).

Georgia

Section 10.6.4: Infiltration Trench, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

Design, construction and maintenance criteria begin on page 10-89 of the manual (page 343 of the PDF).

Maryland

Section 3.3: Stormwater Infiltration, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Infiltration trenches are discussed in this section, beginning on page 3.25 of the manual (page 27 of the PDF).

Virginia

Appendix 11-A1 and 11-A2: Part IIC Best Management Practices, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Appendix 11-A1: Design considerations are available in Section 8 (beginning on page 178 of the appendix, page 347 of the PDF). *Appendix 11-A2*: Additional design guidelines and examples are available in Section 6 (page 56 of the appendix, page 535 of the PDF).

Washington

IN.03: Infiltration Trench, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Design, construction and maintenance considerations are provided in this section beginning on page 5-140 of the manual (page 364 of the PDF).

Landform Grading

Washington

Stormwater Best Management Practices, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

BMPs are discussed throughout this chapter, which begins on page 217 of the PDF.

Manufactured Treatment Devices

Hawaii

Proprietary Non-LID BMPs, *Storm Water Permanent Best Management Practices Manual*, Highways Division, Hawaii Department of Transportation, April 2015.

See [Attachment A](#).

Hydrodynamic devices and other manufactured treatment devices are discussed briefly on page 7-59 of the manual (page 95 of the PDF).

Montana

Section 5.9: Proprietary Treatment Devices, *Montana Post-Construction Storm Water BMP Design Guidance Manual*, Montana Department of Environmental Quality, September 2017.

<https://www.bozeman.net/home/showdocument?id=5325>

Design, construction and maintenance considerations are discussed in this section, which begins on page 5.9-1 of the manual (page 139 of the PDF).

New Jersey

Section 9.6: Manufactured Treatment Devices, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.6.pdf

Design criteria and considerations along with maintenance practices are included in this section.

Utah

Section 4.2.8: Hydrodynamic Separators and Oil Water Separators, *Stormwater Quality Design Manual*, Utah Department of Transportation, June 2018.

<https://www.udot.utah.gov/main/uconowner.qf?n=39517213266675103>

Manufactured treatment devices are discussed briefly in this section (page 4-27 of the manual, page 49 of the PDF).

Virginia

Stormwater Management, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Design elements and procedures for manufactured treatment devices are discussed in Section 11.5 (beginning on page 11-33 of the manual, page 37 of the PDF) and Section 10 of Appendix 11A-1 (beginning on page 124 of the appendix, page 603 of the PDF).

Washington

Stormwater Best Management Practices, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Proprietary treatment devices are discussed through this chapter, beginning on page 5-1 of the manual (page 225 of the PDF).

Rain Gardens

Oregon

Appendix C: Media Filtration Facilities, Chapter 14: Water Quality Facilities, *ODOT Hydraulics Manual*, Oregon Department of Transportation, April 2014.

https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14-C.pdf

For rain gardens, Oregon DOT follows the bioretention facilities guidelines in Section 2 of this appendix (page 14-C-1 of the report, page 1 of the PDF).

Washington

Section RT.08: Bioretention Area, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Section RT.08 (beginning on page 5-91 of the manual, page 315 of the PDF) addresses design, maintenance and other considerations for rain gardens, and rates the capital and operations and maintenance costs.

Stormwater Tree Trenches

Virginia

Stormwater Management, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Section 11.4 (page 228 of the manual, page 397 of the PDF) addresses trees in bioretention facilities.

Washington

Stormwater Best Management Practices, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Trees in detention ponds and infiltration facilities are discussed through this chapter, beginning on page 5-1 of the manual (page 225 of the PDF).

Stormwater Wetlands

Georgia

Section 10.6.10: Stormwater Wetlands, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

Design, construction and maintenance criteria begin on page 10-174 of the manual (page 428 of the PDF).

Maryland

Section 3.2: Stormwater Wetlands, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Design and construction criteria begin on page 3.16 of the manual (page 18 of the PDF).

New Jersey

Section 9.2: Standard Constructed Wetlands, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.2.pdf

Design criteria and considerations along with maintenance practices are included in this section.

Virginia

Appendix 11-A1 and 11-A2: Part IIC Best Management Practices, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Appendix 11-A1: Design considerations are available in Section 5 (beginning on page 112 of the appendix, page 281 of the PDF). *Appendix 11-A2*: Additional design guidelines and examples are available in Section 6 (page 56 of the appendix, page 535 of the PDF) and Section 11 (beginning on page 143 of the appendix, page 622 of the PDF).

Washington

RT.13: Constructed Stormwater Treatment Wetland, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Design, construction and maintenance considerations are provided in this section, beginning on page 5-110 of the manual (page 334 of the PDF).

Submerged Gravel Wetlands

Maryland

Section 3.4: Stormwater Filtering Systems, Chapter 3, *2000 Maryland Stormwater Design Manual*, Volumes I and II, Water Management Administration, Maryland Department of the Environment, May 2009.

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter3.pdf>

Design criteria for filtering systems begins on page 3.31 of the manual (page 33 of the PDF).

New Jersey

Section 9.13: Subsurface Gravel Wetlands, Chapter 9, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.13.pdf

Design criteria and considerations along with maintenance practices are included in this section.

Water Harvesting

Florida

Permit Information Manual, St. Johns River Water Management District, June 2018.

<https://www.sjrwm.com/static/permitting/PIM-20180601.pdf>

Section 21 (page 21-1 of the manual, page 267 of the PDF) provides design criteria for water harvesting. Section 29 (page 29-1 of the manual, page 360 of the PDF) provides methodology and design examples.

Wet Basins

Florida

Section 22.0: Filtration Design and Performance Criteria, *Permit Information Manual*, St. Johns River Water Management District, June 2018.

<https://www.sjrwmd.com/static/permitting/PIM-20180601.pdf>

Wet basins are discussed in Section 22.0 (page 22-1 of the manual, page 273 of the PDF).

Georgia

Section 10.6.9: Wet Detention Pond, *Drainage Design for Highways*, Georgia Department of Transportation, August 2018.

<http://www.dot.ga.gov/PartnerSmart/DesignManuals/Drainage/Drainage%20Manual.pdf>

Design, construction and maintenance criteria begin on page 10-157 of the manual (page 411 of the PDF).

Montana

Section A12.0: Detention Basins, *Permanent Erosion and Sediment Control Design Guidelines*, Montana Department of Transportation, January 2018.

https://www.mdt.mt.gov/publications/docs/manuals/pesc_manual.pdf

Design information for wet basins is available in this section, which begins on page A12-1 of the report (page 46 of the PDF).

New Jersey

Section 9.11: Wet Ponds, *New Jersey Stormwater Best Management Practices Manual*, Division of Watershed Management, New Jersey Department of Environmental Protection, February 2016.

https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.11.pdf

Design criteria and considerations along with maintenance practices are included in this section.

Utah

Section 4.2.7: Wet Pond, *Stormwater Quality Design Manual*, Utah Department of Transportation, June 2018.

<https://www.udot.utah.gov/main/uconowner.gf?n=39517213266675103>

Design information can be found in this section beginning on page 4-24 of the manual (page 46 of the PDF). Additional design information is available in Section A.3.7 (page A-25 of the manual, page 79 of the PDF).

Virginia

Stormwater Management, Chapter 11, *VDOT Drainage Manual*, Virginia Department of Transportation, July 2017.

<http://www.virginiadot.org/business/resources/LocDes/DrainageManual/drain-manual-chapter-11.pdf>

Design elements and procedures for wet basins are discussed in Section 11.6 (beginning on page 11-99 of the manual, page 103 of the PDF) and Section 11.7.3 (beginning on page 11-109 of the manual, page 113 of the PDF). A summary of design criteria are provided in Table 11-8 (page 11-106 of the manual, page 110 of the PDF).

Washington

Section RT.12: Wet Pond, Chapter 5, *Highway Runoff Manual*, Washington State Department of Transportation, February 2016.

<https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

Design, construction and maintenance considerations begin on page 5-93 of the manual (page 317 of the PDF).

Other Practices

Bioswales and Filter Strips

Oregon

Appendix B: Biofiltration Facilities, Chapter 14, *ODOT Hydraulics Manual*, Oregon

Department of Transportation, April 2014.

https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14-B.pdf

Design criteria and step-by-step design procedures for bioswales and filter strips are provided in this appendix.

Media Filter Drains (Bioslopes)

Oregon

Appendix C: Media Filtration Facilities, Chapter 14, *ODOT Hydraulics Manual*, Oregon

Department of Transportation, April 2014.

https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14-C.pdf

Design criteria and step-by-step design procedures for bioslopes are provided in this appendix.

Other State Resources

Maryland

Maryland Stormwater Management Guidelines for State and Federal Projects, Maryland Department of the Environment, April 2010.

<http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/State%20and%20Federal%20SWM%20Guidelines%20final.pdf>

This manual provides design, inspection and maintenance criteria for stormwater management.

Note: The following additional guidance recommended by the respondent was not available at the time of publication of this Preliminary Investigation:

- Construction-related specifications and special provisions.
 - National Pollutant Discharge Elimination System standard procedures for inspections, assessments and maintenance.
-

Montana

Low Impact Development (LID) Practice Analysis, Environmental Engineering Section, Montana Department of Transportation, August 2018.

See [Attachment C](#).

This form is used to evaluate the applicability of LID practices for projects in MS4 areas.

New Jersey

Stormwater in New Jersey, New Jersey Department of Environmental Protection, undated.

www.njstormwater.org

This web page provides links to state stormwater management resources, including BMPs and other guidance.

North Carolina

NCDOT Post-Construction Stormwater Program Post-Construction Stormwater Controls for Roadway and Non-Roadway Projects, Hydraulics Unit, North Carolina Department of Transportation, April 2014.

https://connect.ncdot.gov/resources/hydro/HSPDocuments/2014_PCSP_Guidance_Final.pdf

This document includes descriptions of minimum measures that may qualify as LID/GI practices.

Related Resource:

Post Construction Stormwater Program (PCSP), Highway Stormwater Programs, North Carolina Department of Transportation, undated.

<https://connect.ncdot.gov/resources/hydro/Pages/HSPProgramPages.aspx?PGM=PCSP>

This web page includes links to other post-construction stormwater program resources.

Tennessee

Stormwater Storage Facilities, Chapter 8, *Drainage Manual*, Design Division, Tennessee Department of Transportation, August 2012.

https://www.tn.gov/content/dam/tn/tdot/roadway-design/documents/drainage_manual/DM-Chapter_08.pdf

From the introduction: This chapter will present the analysis methods and design requirements to safely incorporate stormwater storage facilities into highway projects.

Virginia

Virginia Stormwater Best Management Practice Clearinghouse, Virginia Water Resources Research Center, Virginia Department of Environmental Quality, undated.

<https://www.swbmp.vwrrc.vt.edu/>

This web page includes links to the 2013 draft design specifications for GI and LID techniques and to other approved practices.

Virginia Runoff Reduction Method, Virginia Stormwater Best Management Practice Clearinghouse, Virginia Water Resources Research Center, Virginia Department of Environmental Quality, undated.

<https://www.swbmp.vwrrc.vt.edu/vrrm/>

From the web page: The Virginia Stormwater Management Program (VSMP) regulation requires use of the Virginia Runoff Reduction Method (VRRM) or another equivalent methodology

approved by [Virginia Department of Environmental Quality] for compliance with the Part IIB water quality criteria.

Washington

Water Resources Policies and Procedures, Washington State Department of Transportation, undated.

<http://www.wsdot.wa.gov/environment/technical/disciplines/water-erosion/policies-procedures/water>

This web page includes links to state environmental policies and procedures for stormwater runoff and erosion control.

Contacts

CTC contacted the individuals below to gather information for this investigation.

State Agencies

Alaska

Erik Norberg
Stormwater Program Manager
Alaska Department of Transportation &
Public Facilities
907-465-6964, erik.norberg@alaska.gov

Arkansas

Stephen Sichmeller
Roadway Design Division/Staff Engineer
Arkansas Department of Transportation
501-569-2336, stephen.sichmeller@ardot.gov

Connecticut

Susan Fiedler
Highway Design/Transportation Landscape
Designer
Connecticut Department of Transportation
860-594-2086, susan.fiedler@ct.gov

Florida

Catherine Earp
Drainage Engineer
Florida Department of Transportation
850-414-4171, catherine.earp@dot.state.fl.us

Carlton Spirio
Drainage/Stormwater Group
Florida Department of Transportation
850-414-4351, carlton.spirio@dot.state.fl.us

Georgia

Brad McManus
State Roadway Hydraulics Engineer,
Division of Engineering,
Georgia Department of Transportation
404-631-1630, bmcmamus@dot.ga.gov

Hawaii

Curtis Matsuda
Acting Design Branch Head, Highways
Hawaii Department of Transportation
808-692-7559, curtis.matsuda@hawaii.gov

Kansas

Scott Shields
Administrator, Environmental Programs
Kansas Department of Transportation
785-296-4149, scott.shields@ks.gov

Kentucky

Danny Peake
Director, Division of Environmental Analysis
Kentucky Transportation Cabinet
502-782-5027, danny.peake@ky.gov

Maryland

Dana Havlik
Division Chief, Highway Hydraulics
Maryland Department of Transportation
State Highway Administration
410-545-8418, dhavlik@sha.state.md.us

Montana

Mark Young
Statewide Environmental Engineering
Specialist, Environmental Services Bureau
Montana Department of Transportation
406-444-6395, mayoung@mt.gov

New Jersey

Sandra Blick
Bureau of Landscape and Environmental
Solutions
New Jersey Department of Transportation
609-963-1102, sandra.blick@dot.nj.gov

North Carolina

Andrew McDaniel
Manager, Hydraulics Unit
Highway Stormwater Program
North Carolina Department of Transportation
919-707-6737, ahmcdaniel@ncdot.gov

Oklahoma

Rachel Hanigan
Manager, Environmental Permit and Mitigation
Engineering
Oklahoma Department of Transportation
405-521-2676, ghanigan@odot.org

Oregon

William Fletcher
Water Resources Program Leader Emeritus,
Geo/Environmental Section
Oregon Department of Transportation
503-731-3024,
william.b.fletcher@odot.state.or.us

Tennessee

Christian Saxe
Office Manager, Environmental Compliance
Office
Tennessee Department of Transportation
615-253-8815, christian.saxe@tn.gov

Utah

Jeff Erdman
Hydraulic Engineer
Utah Department of Transportation
801-965-4024, jerdman@utah.gov

Virginia

Jeff Hancock
Location and Design Division
Virginia Department of Transportation
504-786-4364, jeff.hancock@vdot.virginia.gov

Chris Swanson
MS4 Program Manager, Location and Design
Division
Virginia Department of Transportation
804-615-9753,
chris.swanson@vdot.virginia.gov

Washington

Julie Heilman
State Hydraulic Engineer, Development
Washington State Department of
Transportation
509-577-1703, heilmaj@wsdot.wa.gov

Appendix A: Survey Questions

The following survey was distributed to members of the AASHTO Committee on Design and the AASHTO Committee on Environment and Sustainability to gather information about the use of alternatives to traditional, single-purpose gray stormwater infrastructure to manage roadside stormwater.

Green Infrastructure Stormwater Management Techniques

1. Please indicate below the types of low-impact development (LID) and other green infrastructure (GI) techniques your agency has used to manage roadside stormwater. Select all that apply.
 - Bioretention areas.
 - Catch basin inserts.
 - Dry detention basins.
 - Infiltration basins.
 - Infiltration berms.
 - Infiltration trenches.
 - Landform grading.
 - Manufactured treatment devices.
 - Rain gardens.
 - Stormwater tree trenches.
 - Stormwater wetlands.
 - Submerged gravel wetlands.
 - Water harvesting.
 - Wet basins.
 - Other practices (please describe).
2. Please describe your agency's design guidance or design tools related to the stormwater management techniques listed below. Include links to relevant documentation or send any files not available online to chris.kline@ctcandassociates.com.
 - Bioretention areas.
 - Catch basin inserts.
 - Dry detention basins.
 - Infiltration basins.
 - Infiltration berms.
 - Infiltration trenches.
 - Landform grading.
 - Manufactured treatment devices.
 - Rain gardens.
 - Stormwater tree trenches.
 - Stormwater wetlands.
 - Submerged gravel wetlands.
 - Water harvesting.
 - Wet basins.
 - Other practices (please describe).
3. Does your agency use compost incorporation or other types of soil enhancement on GI projects to increase water holding capacity and organic content in soil for the plant materials used in these projects?
 - No (please move to Question 7).
 - Yes (please respond to Questions 4 through 6 below).
4. How close to the roadway are these soil enhancement products permitted?
5. How deep are these soil enhancements incorporated into the existing soil profile?

6. Does the depth of incorporation change as you get closer to the roadway?
- No.
 - Yes (please identify the distances from the roadway and the depths allowed for incorporation).

Describing a Successful Green Infrastructure Project

7. Please provide details below of a successful roadside stormwater management project that applied LID or other GI techniques.
- Project description.
 - Project specifications.
 - Project estimate.
 - Maintenance practices.
 - Cost–benefit life cycle information.

Characterizing Your Agency's Stormwater Management Program

8. How would you describe your agency's approach to applying LID and other GI techniques to roadside stormwater management design? Select all that apply.
- Our agency does not apply LID or other GI techniques to roadside stormwater management design.
 - Our agency has made limited use of LID and other GI techniques to manage roadside stormwater.
 - Our agency applies LID and other GI techniques on a project-by-project basis to meet individual project needs.
 - Our agency uses a broad-based watershed approach to applying LID and other GI techniques to roadside stormwater management design.
 - Our agency is moving toward a holistic approach that includes guidance on design, construction and maintenance.
 - Our agency has adopted a holistic approach that includes guidance on design, construction and maintenance.
 - Our agency takes a different approach than those described above (please provide details below).

Wrap-Up

9. Please provide links to documentation associated with your agency's use of LID and other GI techniques for roadside stormwater management that you have not already provided, including documents related to design, construction and maintenance. Send any files not available online to chris.kline@ctcandassociates.com.
10. Please use this space to provide any comments or additional information about your previous responses.

Addendum

Caltrans Green Infrastructure/Low Impact Development Stormwater BMP Related Links

- [Best Management Practices for Guidance Documents, Specifications, and Example Plans](#)
Note: The link above uses JavaScript. The suggested web browsers are Microsoft Internet Explorer, Firefox, and Microsoft Edge.
- [Design Pollution Prevention Infiltration Area Design Guidance](#)
- [Specifications for the Design Pollution Prevention Infiltration Areas](#)
- [Summary and Examples of the Design Pollution Prevention Infiltration Area Design Guidance](#)