Treatment BMP Technology Report

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California Department of Transportation
Division of Environmental Analysis
1120 N Street, Sacramento, California 95814

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1.0 INTRODUCTION

The Treatment BMP Technology Report represents part of the California Department of Transportation (the Department) BMP identification, evaluation, and approval process as described in Section 4 of the Storm Water Management Plan (SWMP) (CTSW-RT-15-316.05.1; Caltrans 2016). This report satisfies the requirement for a New Technology Report contained in the State Water Resources Control Board Order No. 2012-0011-DWQ. This report consolidates information for post-construction technologies in a standardized manner by using a fact sheet format. The BMP fact sheets summarize available design, construction, and performance information. The fact sheets result from a desktop evaluation of BMPs. Usually, a full-scale field evaluation (pilot testing) is required to collect sufficient information to determine if a BMP should be approved and under what conditions (siting constraints). The Department uses the fact sheets as a preliminary screening tool for selection of pilot BMPs when approved BMPs cannot meet project-specific treatment requirements due to siting constraints. BMPs selected for pilot testing are not automatically approved for statewide use. The SWMP includes procedures to (a) identify the need for Pilot BMPs and (b) propose them. Refer to the Caltrans Storm Water Quality Handbook: Project Planning and Design Guide (PPDG) (CTSW-RT-16-314.11.1) for comprehensive information on this issue (Caltrans 2016).

Department-Approved Treatment BMPs:

- Biofiltration Systems
- Infiltration Devices
- Detention Devices
- Traction Sand Traps
- Dry Weather Flow Diversion
- Gross Solids Removal Devices (GSRDs)
- Media Filters
- Multi-Chambered Treatment Train
- Wet Basins

2.0 PURPOSE OF TREATMENT BMP TECHNOLOGY REPORT

This document is used by the Department to identify and evaluate treatment BMP technologies for potential use in the highway environment only. The Department does not evaluate BMPs for other situations or entities. This document is intended for internal use by the Department. Unless stated otherwise, vendor products discussed in this document are not approved for use by the Department and are not endorsed by Caltrans or the State of California.

3.0 IDENTIFYING AND EVALUATING NEW TECHNOLOGY

The Department prepares fact sheets based on an initial evaluation of identified treatment technologies. The Department may identify technologies in the course of performing reconnaissance studies for specific treatment needs, including non-proprietary BMPs used by other state departments of transportation. To identify proprietary treatment technologies, the Department relies on manufacturers to submit product information. To introduce products to the Department, manufacturers must contact the New Product Coordinator at (916) 227-7073 for submittal instructions. Fact sheets are updated when new information is submitted to the New Product Coordinator before the end of the reporting period (June 30th).

The Department evaluates identified technologies using several criteria (discussed in Section 3.1) and develops fact sheets of the BMPs for this report.

3.1 Evaluation Criteria and Fact Sheet Content

BMP fact sheets are developed using a standard format to facilitate comparison among BMPs. Each fact sheet addresses a standard series of topics, including design, operations, maintenance, construction, treatment, advantages, and constraints. The Department, with input from universities, consultants, regulators, third parties, and manufacturers, continually reviews BMP information reported in literature. Appendix A describes the content of the fact sheets and the evaluation criteria for performance.

3.2 Fact Sheet Organization and Treatment BMP Technology Approval

Completed BMP fact sheets are presented in Appendices B and C. Section 4 provides an alphabetical list of all the BMP categories to aid in locating fact sheets for specific types of BMPs.

Appendix B contains fact sheets for BMPs that are not approved by the Department. Favorable evaluations of BMPs can lead to pilot studies to gather cost and performance data. In most cases, a group of similar BMPs are represented on a single fact sheet.

Appendix C contains fact sheets for approved BMPs. Consult the PPDG for more details on the implementation of approved BMPs (Caltrans 2016).

4.0 CATALOG OF TREATMENT BMPS

This alphabetical list includes all BMP technologies. Proprietary BMPs are listed on each fact sheet. The page numbers correspond to the location of the fact sheets in Appendices B and C.

Table 1. List of Treatment BMPs in Appendices

BMP Category	Stormwater Technology	Page No.
Bioretention		B-3
	Linear Bioretention Trench	B-5
	Tree Box Filter	B-7
Biofiltration		
	Strip	C-3
	Swale	C-5
Detention/Sedimentation		
Chemical Treatment		B-9
Electrocoagulation		B-11
Permanent Pool		B-13
	Wet Basin/Pond	C-27
	Vegetated Rock Filter	B-15
Plate and Tube Settlers		B-17
Temporary Pool		B-19
	Detention Basin	C-7
	Double Barrel	C-25
	Hold and Release	B-21
	Infiltration Chambers	B-23
	Skimmer	B-25
Disinfection		
Chemical Treatment		B-27
Ultraviolet		B-29
Drain Inlet Insert		
Baffle Box		B-31
Basket/Box	Baffled Filtration Box	B-33
	GSR Basket (Mechanically Removed)	B-35
Fabric		B-37
Media		B-39
Screen		B-41
Skimmer		B-43
Dry Weather Flow Diversion		C-9
Filtration		
Bed		B-45
	Austin Filter with Alternative Media	B-47
	Delaware Sand Filter	C-13
	DC Sand Filter	B-49
	Infiltration Chambers	B-51
	Linear Filter Trench	B-53
	Media Filter Drain	B-55

5.0 REFERENCES

Caltrans 2016. *Statewide Storm Water Management Plan* (SWMP). Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-16-316.05.1.

Caltrans 2016. *Storm Water Quality Handbooks, Storm Water Planning and Design Guide*. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-16-314.11.1

Caltrans 2009. *Summary of Reports Prepared for the Monitoring and Research Program*. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-13-239-15.01D.

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APPENDIX A: BMP FACT SHEET DESCRIPTION AND FORMAT

This appendix describes the content of the fact sheets in Appendices B and C. It also describes evaluation criteria for performance assessments. Each fact sheet is divided into a standard series of topics, which are described below in the order in which they occur in the fact sheets.

A.1 Header Information: BMP Category, Name and Quick Reference Symbols

The left side of the header contains a broad BMP category and more specific subcategory. If necessary, a more specific name is found on the right side. Reference symbols are located in the upper right corner of fact sheets. The symbols and the attributes they represent follow:

Special material handling requirements or potential toxicity

Power is required for this technology

Vactor equipment recommended for maintenance

Vector concern because of standing water

A.2 BMP Description

The BMP description provides a summary of the configuration of the BMP and a general overview of the treatment process, how the BMP operates, and considerations that need to be addressed to promote maximum treatment effectiveness and functionality.

A.3 Constituent Removal

This section identifies the constituents expected to be removed by the BMP when present at levels typical of Caltrans stormwater runoff. The groups of constituents examined were previously identified as pollutants of concern (Caltrans 2016).

A.3.1 Constituent Groups

Estimates of the technology's performance removal abilities are made for each of the following constituent groups:

- Sediment (total suspended solids [TSS])
- Total nitrogen

- Total phosphorus
- Pesticides
- Total metals
- Dissolved metals
- Microbiological (including pathogens)
- Litter
- Biochemical oxygen demand (BOD)
- Total dissolved solids (TDS)

A.3.2 Constituent Removal

Unapproved BMPs

The fact sheets for BMPs that are not approved (Appendix B) report whether removal is expected for each of the 10 constituents (or constituent groups) listed in A.3.1. For a given constituent:

- A check mark is used if the removal efficiency is statistically significant or expected to be based on best professional judgment.
- A blank cell is used if there is insufficient data or the removal efficiency is not statistically significant.

Approved BMPs

The fact sheets for approved BMPs (Appendix C) report both constituent removal and level of confidence. The level of confidence reflects the certainty that the reported performance is applicable to typical Caltrans conditioning (e.g., influent concentrations). The level of confidence is based on the quality of monitoring studies. To ensure that data is of the highest quality, stormwater monitoring must be conducted according to scientific procedures, such as those listed in the *Stormwater Monitoring Protocols* (Caltrans 2016a), or equivalent protocols. The level of confidence assessments are defined as:

High: The constituent removal information came from either the Department's research or a study that met the Department's quality assurance and quality control monitoring protocols. Test conditions were typical of the Department's facilities and all of the following criteria were met:

- Full-scale field testing of a stabilized (erosion-free) post-construction transportation-related impervious drainage area
- Sampling and analysis in accordance to the *Guidance Manual: Stormwater Monitoring Protocols* (Caltrans 2016a), or other recognized protocol, such as that required for the International BMP Database (www.bmpdatabase.org)
- Testing at flow rates and volumes typical of Caltrans' drainage areas (areas vary, but usually are between 0.1 and 15 acres. Flow and volumes can be found by using Caltrans' Basin Sizer [www.owp.csus.edu/research/stormwatertools/])

- Mean influent concentrations below the 90th percentile of statewide characterization data (see Table A-1)
- At least eight storm events over a minimum period of two years, but data must also demonstrate a statistically significant removal ($p \leq 0.1$), which may require monitoring additional storm events
- Particle size distribution (PSD) similar to the proposed field conditions (e.g., state whether or not traction sand was applied)
- A mean removal estimate that corroborates the performance claim

Further, the study report must include the following:

- Rainfall record for the study area or its vicinity during the evaluation period
- Operation and maintenance records and costs for the evaluation period

Table A-1. The 90th Percentile Concentrations of Select Constituents.

Constituent	Units	90th percentile*	Constituent	Units	90th percentile*
TDS	mg/L	200	Ammonia nitrogen	mg/L as N	1.4
TSS	mg/L	300	Total Kjeldahl Nitrogen (TKN)	mg/L as N	4.4
Oil & Grease	mg/L	6.6	Nitrate	mg/L as N	2
Copper (dissolved)	µg/L	30	Phosphorus (dissolved)	mg/L as P	0.37
Copper (total)	µg/L	80	Phosphorus (total)	mg/L as P	0.84
Lead (dissolved)	µg/L	7	Orthophosphate	mg/L as P	0.3
Lead (total)	µg/L	100	Diazinon	µg/L	0.4
Zinc (dissolved)	µg/L	140	Diuron	µg/L	11
Zinc (total)	µg/L	400	Glyphosate	µg/L	50
			Pyrene	µg/L	0.96

* 90th percentile is the concentration at which 90% of all measurements are below. These values were estimated from Appendix B of the *Caltrans Discharge Characterization Study Report,* CTSW-RT-06-065 (Caltrans 2003b).

Alternatively, a high score is assigned to infiltration or reuse BMP technologies that provided "no discharge" to surface waters under design conditions. Constituent removal was assumed to be 100 percent removal although it was recognized that certain large storm events would not receive full treatment, and that infiltration may not provide complete removal of constituents for discharge to groundwater or subsequent re-entry to surface waters.

Medium: The criteria for a high level of confidence were not completely met; however, one of the following must apply:

- Statistically significant (p-value $\leq$ 0.1) constituent removal was established from independent stormwater field monitoring for at least one year
- Removal efficiency based on best professional evaluation of unit operations and processes that are well established for treatment of other waters
- Load reduction of nutrients or BOD due to partial infiltration
- Statistically significant (p-value $\leq$ 0.1) constituent removal was established from independent laboratory testing that follows the Technology Assessment Protocol – Ecology (TAPE) from Washington State (ECY 2008), and testing used a volume of water equivalent to one year of runoff for a typical installation. Alternatively, a laboratory loading using actual stormwater could be used as with the Tahoe Small Scale Research Facility (http://www.dot.ca.gov/hq/env/stormwater/ongoing/tahoe/index.htm).

Low: There are no available data or available data do not meet the above criteria for medium level of confidence assessment. For example, a manufacturer's performance claim, without supporting data, would get a low score.

Notes:

This section gives a brief explanation, if necessary, of the logic used to score approved BMP technologies for both removal efficiency and level of confidence.

A.4 Caltrans Evaluation Status [Appendix C Only]

This section documents the BMP's stage in the evaluation process.

A.5 Schematic

If appropriate, a schematic figure is provided to depict a typical installation, design plan, or a cross-section that identifies major components of the BMP.

A.6 Key Design Elements

This section identifies important design considerations that have been highlighted by vendors or discovered through testing. Ancillary facilities to be used in conjunction with each technology are also listed in this section. An example would be including a detention basin downstream of a chemical treatment technology to capture flocculated particles.

A.7 Advantages and Constraints

These sections list additional advantages and constraints of the BMP that are not covered in the previous sections. Information presented may include impacts from hydrologic characteristics and weather conditions in California, experiences from actual installations, and expansion of particular points discussed in previous sections of the fact sheet.

A.8 Cost Effectiveness Relative to Detention Basins [Appendix C Only]

This section provides an assessment of cost and pollutant removal effectiveness of approved BMPs relative to that for detention basins. Use this section for general comparisons of overall cost effectiveness but not for cost effectiveness comparison for treatment of an individual constituent. Detention basins were chosen because they are common BMPs that have relatively well-established cost and performance information. Relative cost assessments include the cost to build, operate, and maintain each BMP. Two pieces of information are provided on BMP costs:

- General assessment of the BMP's overall costs compared to detention basins
- Level of confidence in the available data

A.8.1 Cost Effectiveness Assessment

The cost for each BMP was assessed in terms of its 20-year, present worth cost relative to detention basins. The baseline cost of a detention basin is $\$673/m^3$ of water quality volume (1999 dollars), as reported in Appendix D of the *BMP Retrofit Pilot Program* (Caltrans 2004, p. 14-14). The effectiveness of each BMP was also assessed in terms of its overall constituent removal expectations relative to a detention basin. A four-quadrant system was used as a tool to rate each BMP (e.g.,). One of the four quadrants is shaded based on the rating key (see Figure A-1). If the overall constituent removal was greater than that for detention basins, then the BMP was marked as having a greater benefit. Because of a multitude of constituents, this assessment is often based on the best professional judgment rather than on an overall numeric efficiency score.

Benefit ↑ **Cost** ↓	**Benefit** ↑ **Cost** ↑
Benefit ↓ **Cost** ↓	**Benefit** ↓ **Cost** ↑

Figure A-1. Rating Key for Cost Effectiveness.

Due to a lack of cost data for BMPs constructed in the highway environment, the relative cost to detention basins was estimated based on the size and complexity of the technology compared to a detention basin sized for the same drainage area. If annual cost data are available, the 4% discount rate over 20 years results in an annual cost multiplication factor of 13.59. The resulting 20-year, present worth cost is the average annual cost times the 13.59 multiplication factor plus the construction cost. Planning, design, and right-of-way costs are not included.

A.8.2 Level of Confidence

The level of confidence in the costs to build and operate a BMP depends on the type and quantity of information found in the literature. Use of cost information developed for municipal stormwater programs was not considered to be directly relevant to the Department's facilities.

The right-of-way costs and construction costs of major highway transportation projects are typically much greater than the typical suburban street or arterial road that might be constructed by a municipal public works department. Furthermore, operations and maintenance costs of facilities along major freeways are typically much more expensive than similar municipal facilities because of limited access and the need for traffic control. The level of confidence was assessed in terms of being high, medium, or low. The criteria applied for defining the confidence level of the cost estimates were:

- *High:* Unit cost information was available from a facility constructed by the Department or a similar state's department of transportation.
- *Medium*: Cost information was available from several similar facilities constructed under municipal stormwater programs or conservative costs estimates indicate an obvious unit cost difference compared to a detention basin.
- *Low*: No cost information was available from a similar BMP facility that could be independently verified. Construction costs were extrapolated from available pricing information.

The level of confidence only applies to cost since the level of confidence in the benefit of the BMP is evaluated in the "Constituent Removal" section of the fact sheets.

A.9 Issues and Concerns

This section presents issues and concerns to be considered when evaluating the appropriateness of a BMP for any of the Department's facilities. This information is divided into two categories: maintenance and project development. Within each category is a standard set of topics.

A.9.1 Maintenance Issues

- *Requirements:* Summarizes major maintenance tasks required to keep the BMP functional.
- *Special Training:* Identifies special or unusual training required to perform the maintenance, if applicable.

A.9.2 Project Development Issues

- *Right-of-Way Requirements:* Identifies relative space required to install the BMP.
- *Siting Constraints:* Identifies unique siting considerations and limitations, such as soil types, slope of the land, distance from existing infrastructure or other natural features, power requirements, and regulatory requirements. Common siting constraints, such as maintenance access, are not listed.
- *Construction:* Identifies unique construction precautions and requirements, such as unwanted soil compaction, if applicable.

A.10 Design, Construction, Maintenance, and Cost Sources

This section lists design, construction, maintenance, and cost sources.

A.11 Performance Demonstration Literature Sources [Appendix C Only]

This section provides the references from which performance was evaluated for approved BMPs. It also contains a limited number of additional performance references.

A.12 Certifications, Verifications, or Designations [Appendix C Only]

This section lists the abbreviated names of selected state or federal agencies or cooperatives that issue statements of performance based on third-party review of test results. Agency abbreviations that are used in the fact sheets are defined below, along with a brief explanation of the performance statements typically made by each agency.

TAPE: Technology Assessment Protocol, Ecology

The Washington State Department of Ecology (Ecology) uses TAPE to designate levels of allowed BMP use based on performance. The three designated use levels described below relate to the confidence that Ecology has in a technology's ability to meet various performance goals.

- PULD: The "pilot use level designation" allows limited installations of promising technologies for the purpose of data collections.
- CULD: The "conditional use level designation" allows widespread use within a time period in which testing must be completed to make a determination for GULD.
- GULD: The "general use level designation" indicates that the technology has been proven compliant with TAPE's performance goals.

There are six performance goals that could apply to the designated use level. Brief summaries follow:

- *Basic treatment*: Requires 80% removal of influent TSS between 100 and 200 mg/L and an effluent limit of 20 mg/L for influent TSS less than 100 mg/L.
- *Enhanced treatment or metals treatment*: Requires performance levels to be significantly higher than basic treatment. Influent metals must fall within 0.003 to 0.02 mg/L for dissolved copper and between 0.02 to 0.3 mg/L for dissolved zinc.
- *Phosphorus treatment*: Requires 50% reduction of phosphorus with an influent range of 0.1 to 0.5 mg/L.
- *Oil treatment*: Requires no discharge of visible sheen or of concentrations above 10 mg/L (composite) or 15 mg/L (grab).
- *Pretreatment*: Requires 50% reduction of TSS influent between 100 and 200 mg/L and an effluent limit of 50 mg/L for TSS influent below 100 mg/L.

ETV: Environmental Technology Verification, Environmental Protection Agency

The ETV verifies performance under specific conditions and explicitly states that performance under any other condition may be different. ETV reviews are performed by cooperative agreement with the National Sanitation Foundation (NSF International).

NJCAT: New Jersey Corporation for Advanced Technology

NJCAT provides technical review of field studies and provides performance verification statements. NJCAT works with the Technology Acceptance and Reciprocity Partnership (TARP), which has been endorsed by the states of California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia.

NJDEP: New Jersey Department of Environmental Protection

NJDEP certifies TSS removal based on NJCAT verification reports.

LA RWQCB: Los Angeles Regional Water Quality Control Board

LA RWQCB issues Full Capture Certifications for trash TMDL compliance.

TCEQ: Texas Committee on Environmental Quality

TCEQ approves BMPs that are appropriate for the protection of sole-source groundwater resources.

References

Caltrans 2016a. *Caltrans Comprehensive Protocols Guidance Manual*. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-105.51.42.

Caltrans 2016b. *Discharge Characterization Study Report*. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-065.

Caltrans 2004. *BMP Retrofit Pilot Program Final Report*. Sacramento: Caltrans, Division of Environmental Analysis. p. 14-14. CTSW-RT-01-050.

Caltrans 2017. *Storm Water Quality Handbooks, Storm Water Planning and Design Guide*. Sacramento: Caltrans, Office of Storm Water Management, Division of Design. CTSW-RT-17-314.24.1

Department of Ecology (ECY), Washington State. 2008. *Guidance for Evaluating Emerging Stormwater Treatment Technologies*. Publication number 02-10-037. Retrieved January 17, 2009 from http://www.ecy.wa.gov/pubs/0210037.pdf.

APPENDIX B: TECHNOLOGY FACT SHEETS

This appendix presents fact sheets for technologies that have *not* been approved by the Department. Evaluation of these technologies is ongoing and may be revised in future reports. The evaluations presented were derived from a review of available information and best professional judgment was used where information was lacking.

TABLE OF CONTENTS

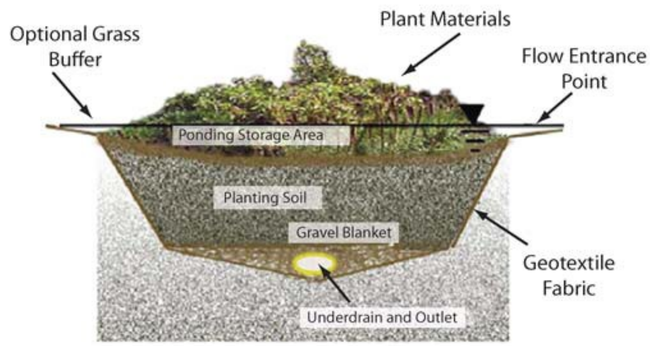
BMP Fact Sheet

Bioretention

Description

Bioretention cells consist of vegetated depressions that treat runoff by filtering through mulch and soil-based media. Physical straining, biological and chemical reactions in the mulch, root zone, and soil matrix, and infiltration into the underlying subsoil are the main treatment processes. Bioretention cells reduce peak discharge and runoff volume by detaining water through surface ponding and storage in soil and gravel layers, and by allowing it to infiltrate into the subsoil or dissipate through evapotranspiration.

Schematic



Source: Maryland Water Resources Research Center

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	

* Based on performance of conventional bioretention systems or best professional judgment. Blank cells indicate data not available or poor treatment performance. Small bioretention systems operating at relatively high loading rates and/or with shallow media or soil depth may not provide treatment as indicated.

Key Design Elements

- Bioretention area and depth
- Water quality flow
- Ponding depth
- Underground drain system
- Vegetation
- Bioretention media
- Liner, if high seasonal groundwater

Advantages

- Pollutant removal effectiveness is typically high
- Can provide an aesthetic vegetated appearance
- Reduces peak discharge and runoff volume
- Can fit into narrow right-of-way

Constraints

- In areas with prolonged dry periods, vegetation may require irrigation
- Vegetation may develop slowly in a biorentention facility, though filtering still occurs

Bioretention

Maintenance Issues

Requirements:

- Periodic replacement of mulch and planting media
- Maintenance of irrigation system, if used in dry areas

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Linear biotrench configuration is designed to fit narrow right-of-way

Siting Constraints:

May need irrigation in dry areas, depending on plant selection

Construction:

- Plant establishment period may be required
- Water should bypass until construction is complete and the BMP is stabilized

Design, Construction, Maintenance, and Cost Sources

US EPA. 1999. Stormwater Technology Fact Sheet: Bioretention. EPA 832-F-99-012.

Caltrans. 2003. SR-73 Stormwater BMP Replacement Project at CSF System 1149L Bioretention Area: Basis of Design Report. Division of Environmental Analysis. CTSW-RT-03-006.51.39.

Center for Watershed Protection. 2000. Bioretention as a Stormwater Treatment Practice. The Practice of Watershed Protection, Article 110, 548-550.

Engineering Technologies Associates (ETA). Design Manual for Use of Bioretention in Stormwater Management. Prepared for Prince George's County, Department of Environmental Resources, Maryland.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Available Vendor Products

The names of vendor products that appear here are for information only. The vendor products listed below are NOT APPROVED FOR USE by the California Department of Transportation. Their appearance here IS NOT AN ENDORSEMENT OF THE PRODUCTS BY CALTRANS OR THE STATE OF CALIFORNIA.

- DeepRoot® Silva Cell
- TreePod® Biofilter
- Filterra® Bioretention System
- UrbanGreen™ Biofilter

Alternative Designs

- Bioretention Basin
- Linear Bioretention Trench

BMP Fact Sheet

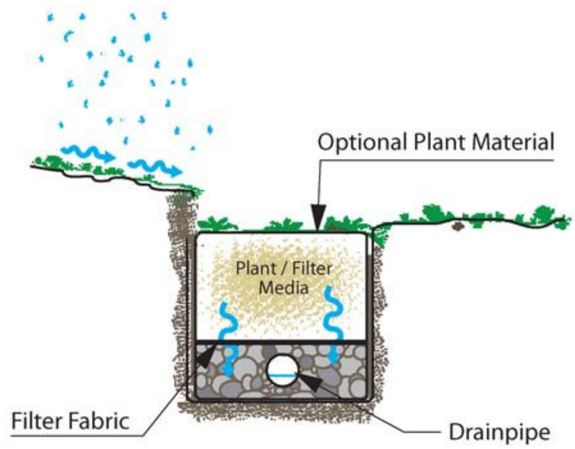
Bioretention

Linear Bioretention Trench

Description

Bioretention cells consist of vegetated depressions that treat runoff by filtering through mulch and soil-based media. Physical straining, biological and chemical reactions in the mulch, root zone, and soil matrix, and infiltration into the underlying subsoil are the main treatment processes. A linear bioretention trench is an adaptation of existing biofiltration designs, consisting of a trench that filters sheet flow runoff through vegetation and a planting soil. It is designed for the narrow right-of-way typical of roadside areas. Removal mechanisms include filtration, infiltration, and plant uptake. Biofiltration strips can be used as pretreatment.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	

* Based on performance of conventional bioretention systems or best professional judgment. Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Bioretention area and depth
- Water quality flow
- Ponding depth
- Underground drain system
- Vegetation
- Bioretention media
- Liner, if high seasonal groundwater

Advantages

- Fits in a narrow right-of-way
- Pollutant removal effectiveness is typically high
- Can provide an aesthetic vegetated appearance
- Reduces peak discharge and runoff volume

Constraints

- Vegetation may require irrigation in areas with prolonged dry periods
- Vegetation may develop slowly in a bioretention facility, though filtering still occurs
- If media clogs, resulting standing water may create mosquito habitat
- Avoid high groundwater
- Although narrow, could be a large footprint BMP depending on design constraints
- Maintenance activities may require traffic control

Linear Bioretention Trench

Maintenance Issues

Requirements:

- Periodic replacement of mulch or planting media
- Maintenance of irrigation system, if used in dry areas

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Designed to fit in a narrow right-of-way

Siting Constraints:

- May need irrigation in dry areas, depending on plant selection
- Minimum head requirement of two feet

Construction:

- Vegetation establishment period may be required
- Water should bypass until construction is complete and the BMP is stabilized

Design, Construction, Maintenance, and Cost Sources

US EPA. 1999. Stormwater Technology Fact Sheet: Bioretention. EPA 832-F-99-012.

Caltrans. 2003. SR-73 Stormwater BMP Replacement Project at CSF System 1149L Bioretention Area: Basis of Design Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-006.51.39.

Center for Watershed Protection. 2000. Bioretention as a Stormwater Treatment Practice. The Practice of Watershed Protection, Article 110, 548-550.

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NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

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Alternative Designs

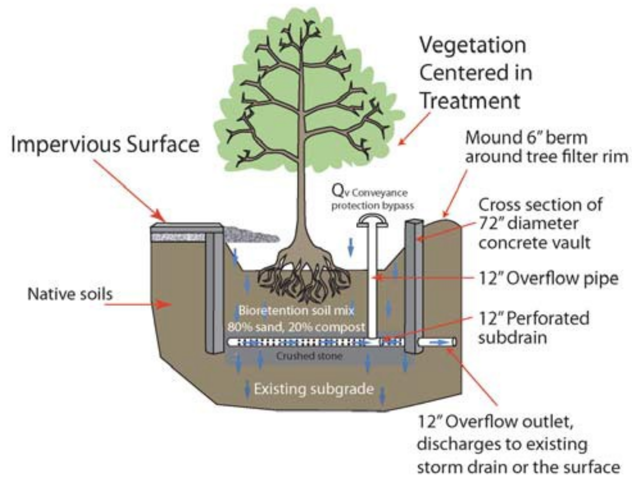
Bioretention

Tree Box Filter

Description

Bioretention cells consist of vegetated depressions that treat runoff by filtering through mulch and soil-based media. Physical straining, biological and chemical reactions in the mulch, root zone, and soil matrix, and infiltration into the underlying subsoil are the main treatment processes. Bioretention cells reduce peak discharge and runoff volume by detaining water through surface ponding and storage in soil and gravel layers, and by allowing it to infiltrate into the subsoil or dissipate through evapotranspiration. Tree box filters are mini bioretention systems that are typically installed along urban sidewalks.

Schematic



Source: University of New Hampshire Stormwater Center

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance of conventional bioretention systems or best professional judgment. Blank cells indicate data not available or poor treatment performance. Small bioretention systems operating at relatively high loading rates and/or with shallow media or soil depth may not provide treatment as indicated.

Key Design Elements

- Bioretention area and depth
- Water quality flow
- Ponding depth
- Underground drain system
- Vegetation
- Bioretention media

Advantages

- Pollutant removal effectiveness is typically high
- Can provide an aesthetic vegetated appearance
- Reduces peak discharge and runoff volume
- Can fit into narrow right-of-way
- Small footprint bioretention devices such as tree box filters are most applicable in urban settings

Constraints

- In areas with prolonged dry periods, vegetation may require irrigation
- Vegetation may develop slowly in a biorentention facility, though filtering still occurs

Tree Box Filter

Maintenance Issues

Requirements:

- Periodic replacement of mulch and planting media
- Maintenance of irrigation system, if used in dry areas

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Tree box filters are small footprint devices that fit in sites where available space is limited

Siting Constraints:

May need irrigation in dry areas, depending on plant selection

Construction:

- Plant establishment period may be required
- Water should bypass until construction is complete and the BMP is stabilized

Design, Construction, Maintenance, and Cost Sources

US EPA. 1999. Stormwater Technology Fact Sheet: Bioretention. EPA 832-F-99-012.

Caltrans. 2003. SR-73 Stormwater BMP Replacement Project at CSF System 1149L Bioretention Area: Basis of Design Report. Division of Environmental Analysis. CTSW-RT-03-006.51.39.

Center for Watershed Protection. 2000. Bioretention as a Stormwater Treatment Practice. The Practice of Watershed Protection, Article 110, 548-550.

Engineering Technologies Associates (ETA). Design Manual for Use of Bioretention in Stormwater Management. Prepared for Prince George's County, Department of Environmental Resources, Maryland.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of New Hampshire (UNH). 2008. Tree Box Filter. University of New Hampshire Stormwater Center. Http://www.unh.edu/erg/cstev/fact_sheets/tree_filter_fact_sheet_08.pdf (accessed January 20, 2010).

Available Vendor Products

The names of vendor products that appear here are for information only. The vendor products listed below are NOT APPROVED FOR USE by the California Department of Transportation. Their appearance here IS NOT AN ENDORSEMENT OF THE PRODUCTS BY CALTRANS OR THE STATE OF CALIFORNIA.

- DeepRoot® Silva Cell
- TreePod® Biofilter
- Filterra® Bioretention System
- UrbanGreen™ Biofilter

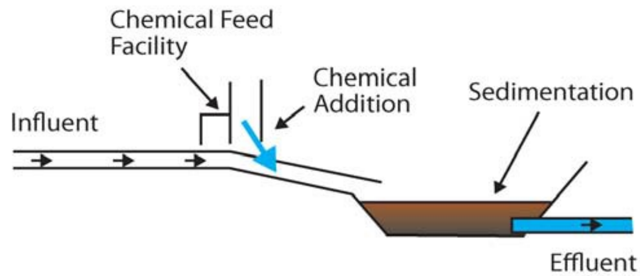
Alternative Designs

Chemical Treatment

Description

Adding chemical coagulants to stormwater influent can enhance removal of particulates, associated contaminants, and dissolved nutrients in a detention system. Chemical treatment results in floc formation, which increases the settling velocity of particles and improves sedimentation removal efficiencies. The effectiveness of this system largely depends on the type of chemical added, time allowed for sedimentation, and the particle size, density, and settling velocity of the floc that is produced. Typical chemicals used include alum, chitosan, and polyacrylamide (PAM). These chemicals are added either in liquid form upstream of the detention or as a solid (gel block) that is placed in the flow path.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on expected improvement over conventional dry detention basin performance. Blank cells indicate data not available or poor treatment performance. Small systems with relatively short detention times may not provide treatment as indicated.

Key Design Elements

- Chemical dose
- Chemical feed and storage facilities
- Chemical mixing facilities
- Capture volume and depth
- Drain time
- Debris screen to protect effluent control
- Maintenance access
- High flow routing

Advantages

- Increases performance of existing detention basins
- The accumulation rate of floc in sediments of quiescent receiving waters can be low due to floc consolidation over time and incorporation of floc into existing sediment
- Chemical treatment can remove nutrients, heavy metals, and fecal coliforms
- Dry alum sludge has chemical characteristics suitable for general land or agricultural application
- Construction costs for stormwater treatment feed systems are largely independent of the drainage area to be treated and depend primarily upon the number of outfalls to be retrofitted

Constraints

- Treated waters may require pH adjustment
- Safety issues related to the chemical storage facility need to be considered
- Alum forms voluminous metal hydroxides that are difficult to dewater
- Appropriate mixing must be provided at the point of chemical addition
- Sludge removal method and frequency need to be considered
- The optimum dose may vary with each storm
- Potential toxicity due to overdosing
- Requires higher level of operator observation than for other BMPs

Chemical Treatment

Maintenance Issues

Requirements:

- Chemical storage and dosing equipment must be inspected and maintained on a regular basis
- Effluent pH monitoring system must be maintained on a regular basis
- Sludge removal

Special Training:

- Training is required for maintenance of chemical addition and storage system
- Chemical handling

Project Development Issues

Right-of-Way Requirements:

- Small footprint for chemical addition system
- Downstream detention requirement increases footprint
- Other requirements as listed on the Detention Basin fact sheet (see Appendix C)

Siting Constraints:

- May require electrical power supply
- Space for a central housing unit and storage tank
- Need enough head for mixing
- Other requirements as listed on the Detention Basin fact sheet (see Appendix C)

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Harper H.H. Current Research and Trends in Alum Treatment of Stormwater Runoff. Environmental Research & Design, Inc.

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None identified

Alternative Designs

None identified

Electrocoagulation

Description

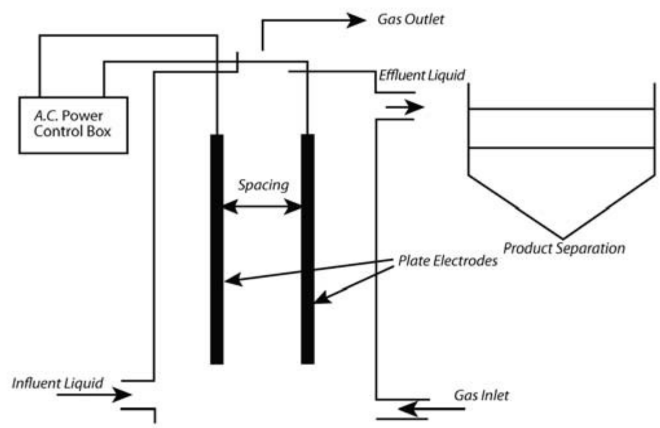
Electrocoagulation (EC) systems are effective for removal of emulsified oils, total petroleum hydrocarbons (TPH), suspended solids, and heavy metals from exceptionally polluted industrial wastewater and stormwater runoff. EC technology is an alternative to the use of chemical coagulants such as alum, metal salts, or polymers and polyelectrolyte addition(s). The EC process removes pollutants from aqueous media by introducing highly charged metal hydroxide species that neutralize suspended solids and oil droplets and facilitate agglomeration or coagulation. EC treatment is typically followed by sedimentation or filtration processes to remove flocculated material.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Actual treatment will depend on a number of variables including current density, conductivity, and pollutant load of influent, as well as the type of electrodes.

Schematic



Source: EPA

Key Design Elements

- Facilities required upstream to capture runoff and provide flood flow routing and bypass
- Mode of operation (batch or continuous)
- Power supply
- Design flow
- Electrical conductivity of influent water
- Sludge storage and disposal
- Need for pretreatment
- Cleaning/replacement needs for electrodes
- Maintenance access

Advantages

- Sludge formed by EC tends to be readily settleable and easy to de-water because it is composed mainly of metallic oxides/hydroxides
- Gas bubbles produced during electrolysis can carry the pollutant to the top of the solution where it can be more easily concentrated, collected, and removed
- Electrolytic processes in the EC cell are controlled electrically with no moving parts
- EC may be feasible where electricity is not available if solar panels are used (Note: A 50 gpm EC system requires 480 volt power supply)

Constraints

- Sacrificial electrodes are dissolved into wastewater streams as a result of oxidation, and need to be regularly replaced
- Use of electricity may be expensive
- Impermeable oxide film may be formed on the cathode leading to loss of efficiency of the EC unit
- High conductivity of the water suspension is required
- Treated waters may have high pH, which may require remediation
- Potential toxicity concerns due to overdosing
- Requires higher level of operator observation than other BMPs

Electrocoagulation

Maintenance Issues

Requirements:

None identified

Special Training:

Requires training to maintain and operate equipment

Project Development Issues

Right-of-Way Requirements:

Space required for upstream capture and downstream sedimentation

Siting Constraints:

May require power nearby and, possibly, a sewer connection

Construction:

Significant capital costs and start-up/test requirements

Design, Construction, Maintenance, and Cost Sources

Beagles, A. 2004. Electrocoagulation - Science and Applications. http://www.eco-web.com/edi/index.htm (accessed October 19, 2009).

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- E-Cell
- Kaselco EC
- FLUXCELL™
- Powell Water Systems EC

Alternative Designs

None identified

Permanent Pool

Description

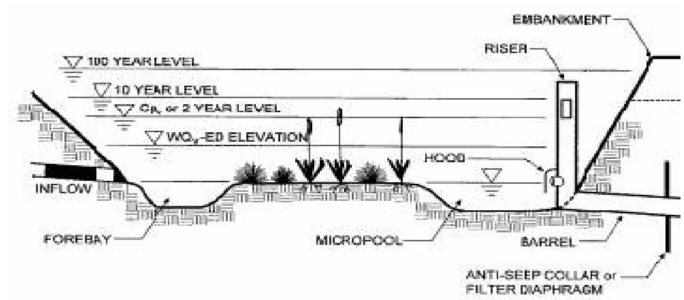
Detention systems provide treatment by detaining runoff to allow settling or sedimentation of particles under gravity. The effectiveness of these systems depends on the time allowed for sedimentation, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. In addition, systems with permanent pools support plant species that provide constituent removal by biological processes. The primary function of a permanent pool is energy dissipation and assuring a longer residence time for first flush of water. Examples of treatment systems with permanent pools include wet basins/ponds and constructed wetlands.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional wet basin performance. Blank cells indicate data not available or poor treatment performance. Small permanent pool systems operating at relatively high loading rates may not provide treatment as indicated.

Schematic



Source: EPA

Key Design Elements

- Capture volume and depth
- Drawdown time
- Permanent pool to capture volume ratio
- Sedimentation forebay
- Vegetation
- Debris screen to protect effluent control
- Maintenance access
- High flow routing
- Liner requirements

Advantages

- Recreational and aesthetic benefits
- Enhances wildlife habitat
- High removal efficiencies for many constituents
- Particularly advantageous to first flush of storms

Constraints

- Relatively high construction costs in comparison to other BMPs
- Wetland must have a source flow
- Species may restrict maintenance
- There are potential problems associated with mosquitoes
- The device may become a regulated wetland if not consistently maintained on an established schedule
- Wet basins are larger than extended detention basins because of the additional volume of the permanent pool

Permanent Pool

Maintenance Issues

Requirements:

- Active management of the hydrology and vegetation during the first few years is necessary for plant establishment
- Mosquito fish planting or other vector control methods are needed
- Vegetation thinning or removal may be necessary for vector control, wildlife may limit activities to a particular season
- Sensitive species inspections
- Sediment removal (hand removal has been found to be more cost-effective than mechanical removal)
- Removing standing water for the dry season may be required if not augmented by dry weather flow

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Space requirements are high for wet basins. The volume of the permanent pool should be at least three times the water quality volume

Siting Constraints:

- Soil should have a low infiltration rate or basin should be lined with a clay or geotextile liner so that water level is maintained in the basin
- Wet basins should be sited where a permanent pool of water can be maintained during the wet season
- Requires a minimum ten-foot separation between seasonal high groundwater and basin invert if a liner is not used

Construction:

- Plant establishment period is recommended
- Excavated soil surface should be suitable to support plant life
- If a pond liner is used, it must be carefully installed and maintained to avoid punctures

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

King County. 2005. Surface Water Design Manual, King County Surface Water Management Division, Washington. http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/SWDM-2009.pdf (accessed October 7, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Schueler, T. R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Washington, DC: Metropolitan Washington Council of Governments.

U.S. EPA. 1999. Wet Detention Pond Fact Sheet. EPA 832-F-99-048.

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- Airmaster Aerator
- AquaMaster®
- Kasco® Marine
- StormTreat™
- Aqua Control
- MWS Linear HYBRID
- SolarBee

Alternative Designs

- Vegetated wet channel
- Wet basin/pond
- Constructed wetland

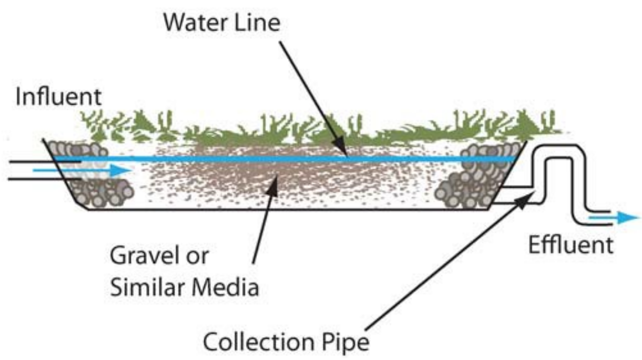
Permanent Pool

Vegetated Rock Filter

Description

Detention systems provide treatment by detaining runoff to allow settling of particles under gravity. The effectiveness of these systems depends on the time allowed for settling, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. In addition, systems with permanent pools support plant species that provide constituent removal by biological processes. The Vegetated Rock Filter (also called Subsurface Wetland) consists of a sealed, shallow basin or channel filled with substrate media and emergent aquatic plants. The substrate, typically gravel, rock, or other material, provides support for plant and algae. Treatment is primarily accomplished via settling, biological uptake by plants, and microbial breakdown. An alternative to a basin configuration is a linear trench configuration which is more suitable for roadside application.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional wet basin performance. Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- High flow routing
- Media type and depth
- Liner requirements
- Forebay or other pretreatment method
- Permanent pool to capture volume ratio
- Maintenance access

Advantages

- Enhances aesthetics and wildlife habitat
- High removal efficiencies for many constituents
- Particularly advantageous to first flush of storms
- Minimal vector concerns because permanent water level is below the surface

Constraints

- Relatively high construction costs compared to other BMPs
- Must have a continuous source flow to maintain plant community
- Wildlife may restrict maintenance
- May become a regulated wetland if not consistently maintained on an established schedule
- Larger than an extended detention basin because of the additional volume of the permanent pool
- Requires long-term maintenance to remove metals and persistent organics that accumulate in sediments
- Anaerobic conditions may increase biological availability of some metals (e.g. methyl mercury)

Permanent Pool

Vegetated Rock Filter

Maintenance Issues

Requirements:

- Active management of the hydrology and vegetation during the first few years is necessary for plant establishment
- Vegetation thinning or removal may be necessary, but wildlife may limit such activities to a particular season
- Sensitive species inspections
- Inspect the gravel bed annually for sediment build-up. Remove sediment periodically
- Check inlet and outlet devices for clogging during the rainy season

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Space requirements are high because of the volume of the permanent pool

Siting Constraints:

- Located on sites with less than two percent slope
- Soil should have a low infiltration rate or basin should be lined with a clay or geotextile liner so that water level is maintained in the basin
- Site where a permanent pool of water can be maintained
- Requires a minimum ten-foot separation between seasonal high groundwater and basin invert if a liner is not used

Construction:

- Plant establishment period is recommended
- Media surface should be suitable to support plant life
- If a pond liner is used, it must be carefully installed and maintained to avoid punctures

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

King County. 2005. Surface Water Design Manual, King County Surface Water Management Division, Washington. http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/SWDM-2009.pdf (accessed October 7, 2009).

NCHRP. 2006. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

San Francisco Stormwater Design Guidelines Draft. 2009. http://sfwater.org/Files/FactSheets/DRAFT_AppenA.pdf (accessed November 18, 2009).

Schueler, T. R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Washington, DC: Metropolitan Washington Council of Governments.

US EPA. 1999. Wet Detention Pond Fact Sheet. EPA 832-F-99-048.

Available Vendor Products

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Alternative Designs

BMP Fact Sheet

Detention/Sedimentation

Plate and Tube Settlers

Description

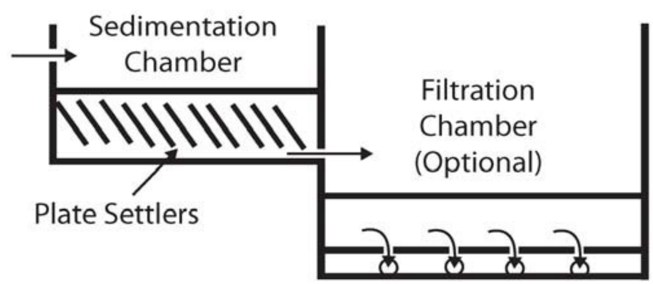
Plate and tube settlers typically consist of parallel plates or inclined tubes that permit solids to reach the plate or tube after only short distances of settling. This reduction in the distance particles must travel increases the rate of sedimentation. The effectiveness of these systems depends on the time allowed for sedimentation (controlled by the effective overflow rate), the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. Sedimentation in the first chamber of an Austin sand filter or in a concrete detention basin can be improved by installing a plate or tube settler.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional dry detention basin performance. Blank cells indicate data not available or poor treatment performance. Small plate and tube settlers operating at very high overflow rates may not provide treatment as indicated.

Schematic



Source: Caltrans

Key Design Elements

- Effective overflow rate
- Size and mounting of plates or tubes
- Sludge collection and removal facilities
- Pretreatment for litter
- Maintenance access
- High flow routing

Advantages

- Enhances particle removal of detention/sedimentation BMPs
- May reduce footprint of a detention/sedimentation BMP or Austin sand filter when used as pretreatment
- May decrease maintenance frequency of downstream filters

Constraints

- Maintenance is more difficult than in an open basin. May require confined space entry and hand cleaning of tubes or plates
- Water must be introduced so that it flows uniformly through the settlers
- Settled particulates can be resuspended if critical velocity is exceeded
- Requires litter removal before passing water through tubes or plates
- Other constraints as listed on the Detention Basin fact sheet (see Appendix C)

BMP Fact Sheet

Detention/Sedimentation

Plate and Tube Settlers

Maintenance Issues

Requirements:

- Cleaning and maintenance of the plate or tube settlers may require removal of the settler structure
- May require hand cleaning of tubes or plates
- Litter may get trapped in the settler structure

Special Training:

Training may be required for confined space entry

Project Development Issues

Right-of-Way Requirements:

Reduces right-of-way requirements for a detention basin or Austin sand filter when used as pretreatment

Siting Constraints:

Similar to siting constraints for a detention basin or Austin sand filter (see Appendix C)

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Terre Hill Concrete Products. www.terrestorm.com (accessed November 2, 2009).

Available Vendor Products

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- Hydro Quip IPS
- Terre Kleen™
- Lamella® Gravity Settler

Alternative Designs

None identified

BMP Fact Sheet

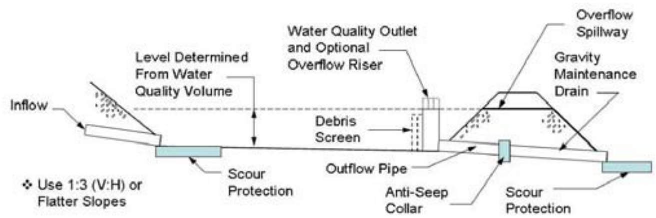
Detention/Sedimentation

Temporary Pool

Description

Detention systems provide treatment by detaining runoff to allow settling or sedimentation of particles under gravity. The effectiveness of these systems depends on the time allowed for sedimentation, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. Treatment systems with temporary pools, which are normally dry between events, include above ground dry detention ponds/basins and below grade storage.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional dry detention basin performance. Blank cells indicate data not available or poor treatment performance. Small systems with relatively short detention times may not provide treatment as indicated.

Key Design Elements

- Capture volume and depth
- Drain time
- Debris screen to protect effluent control
- Maintenance access
- High flow routing

Advantages

- Relatively easy to operate and maintain
- Potential for substantial infiltration
- Can be sited more easily than Austin sand filters

Constraints

- Limited pollutant removal for fine particles, nutrients, and dissolved constituents
- Can only be placed in areas with sufficient hydraulic head
- If outlet clogs, resulting standing water may create mosquito habitat
- May require confined space entry for below grade storage
- May require liner in areas with high seasonal groundwater

BMP Fact Sheet
Detention/Sedimentation
Temporary Pool

Maintenance Issues

Requirements:

- Regular inspections for standing water, side slope stability, debris and sediment accumulation, and vegetative cover
- If vegetative cover is not established to acceptable thresholds, re-seeding or erosion control measures may need to be implemented
- Sediment removal

Special Training:

Training for confined space entry for below ground facilities

Project Development Issues

Right-of-Way Requirements:

Space requirements are relatively high

Siting Constraints:

- Site where there is sufficient hydraulic head to facilitate complete drainage
- Requires separation between seasonal high groundwater and basin invert if liner not used

Construction:

Minimize compaction of underlying soils to maintain infiltration capacity

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

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- Con/Storm™
- Extention Basin™
- StormTrap™
- Watermann™
- Corrugated Pipe (various suppliers)
- Faircloth Skimmer®
- Thirsty Duck
- Weir Guard™

Alternative Designs

- Hold & Release Detention
- Detention Basin
- Skimmer

BMP Fact Sheet

Detention/Sedimentation

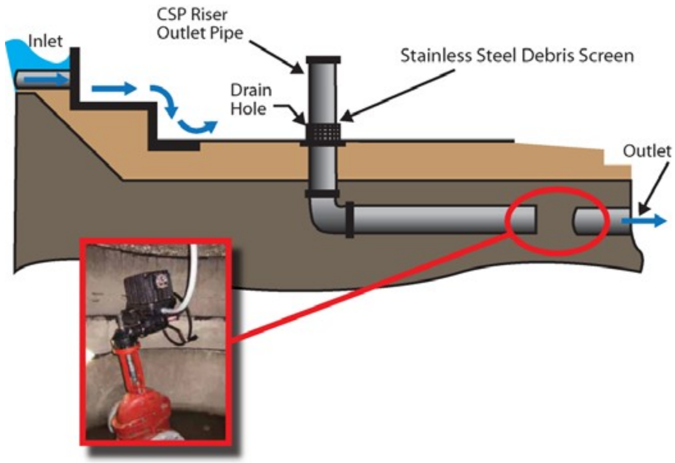
Temporary Pool

Hold and Release

Description

Detention systems provide treatment by detaining runoff to allow settling or sedimentation of particles under gravity. The effectiveness of these systems depends on the time allowed for sedimentation, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. Hold and release valves located on the outlet of the detention basin are used to provide a consistent detention time for a variety of storm sizes. Valves can be powered electrically or pneumatically. The timing of valve operations is adjusted by a logic controller and water depth sensors. Hold and release valves can also be used for infiltration basins in poorly infiltrating soils because they allow water that does not infiltrate to drain.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on field test results by Middleton and Barrett (2006) and removals observed for conventional dry detention basins. Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Valve type and size
- Power and controls system for operating outlet bladder or valve
- Maintenance access

Advantages

- Treatment for TSS and total metals is comparable to sand filtration, but with lower footprint and head requirements
- Increased infiltration potential compared to conventional detention basins

Constraints

- Reliability unknown
- Electric valves require power supply
- Pneumatic valves require high pressure gas source
- Orifice clogging may cause standing water, resulting in mosquito habitat
- Requires inspection and maintenance of hold and release valves, controller, and power supply

Maintenance Issues

Requirements:

- Valves and controller require inspection and periodic replacement. Determine inspection frequency during the first few years of operation
- Maintenance of battery sources and gas cylinders, if used

Special Training:

Training is required to inspect and maintain electric and pneumatic systems

Project Development Issues

Right-of-Way Requirements:

Similar to right-of-way requirements listed on the Detention Basin fact sheet (see Appendix C)

Siting Constraints:

- Equivalent to detention basin siting constraints
- Requires power supply

Construction:

Unknown

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2001. Detention Basin Optimization - Reconnaissance Study Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-029, pp. 3-7.

Caltrans. 2004. District 12 State Route 73 Pilot Program - Detention Basin Optimation and Retrofit. Basis of Design Report. CTSW-RT-04-090.09.1.

Middleton, J. R., J. F. Malina, and M. E. Barrett. 2006. Water Quality Performance of a Batch Type Stormwater Detention Basin. Center for Research in Water Resources On-Line Report 06-02. http://www.crwr.utexas.edu/reports/pdf/2006/rtp06-02.pdf (accessed November 6, 2009).

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Alternative Designs

Detention/Sedimentation

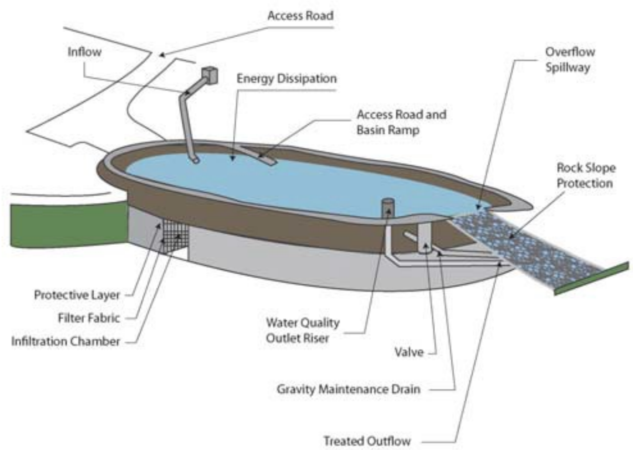
Temporary Pool

Infiltration Chambers

Description

Detention systems provide treatment by detaining runoff to allow settling of particles under gravity. The effectiveness of these systems depends on the time allowed for settling, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. Treatment systems with temporary pools, which are normally dry between events, include above ground dry detention ponds/basins and below grade temporary storage. Infiltration chambers is a concept developed by Caltrans to increase infiltration in conventional BMPs. The addition of infiltration chambers below the invert of earthen detention systems is expected to capture and infiltrate the first flush of stormwater runoff. These infiltration chambers can consist of gravel, high porosity storage media with a sand overlay, or native soil that has been amended to improve infiltration. In soils that infiltrate well, raising the riser orifice may provide the same treatment benefit as the installation of infiltration chambers.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional dry detention basin performance. Blank cells indicate data not available or poor treatment performance. Small systems with relatively short detention times may not provide treatment as indicated.

Key Design Elements

- Soil type and permeability
- Infiltration chamber volume capacity
- Infiltration chamber material (high porosity storage media, gravel, amended soil, etc.)
- High flow routing
- Capture volume and depth
- Drain time
- Debris screen to protect effluent control
- Maintenance access

Advantages

- Potential for substantial infiltration, even in poorly infiltrating soils
- Expected to improve treatment of fine particles, nutrients, and dissolved constituents relative to conventional detention

Constraints

- Not suitable in areas with high seasonal groundwater
- Increases construction and rehabilitation costs relative to conventional detention basins
- If outlet clogs, resulting standing water may create mosquito habitat

Maintenance Issues

Requirements:

- Regular inspections for standing water, side slope stability, debris and sediment accumulation, and vegetative cover
- May require construction equipment to rehabilitate clogged system
- If vegetative cover is not established to acceptable thresholds, re-seeding or erosion control measures may need to be implemented
- Sediment removal

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Space requirements are the same as for conventional detention systems

Siting Constraints:

- Site where there is sufficient hydraulic head to facilitate drainage through the outlet riser
- Requires separation between seasonal high groundwater and basin invert

Construction:

- Minimize compaction of underlying soils to maintain infiltration capacity
- Bypass water until drainage area is stabilized

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

Caltrans. 2008. Adding Infiltration Chambers to Approved Best Management Practices: Concept Development. Sacramento: Caltrans, Office of Storm Water Management, Division of Design. CTSWRT-TM-08-172-46.1.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User’s Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Available Vendor Products

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Alternative Designs

BMP Fact Sheet
Detention/Sedimentation
Temporary Pool — Skimmer

Description

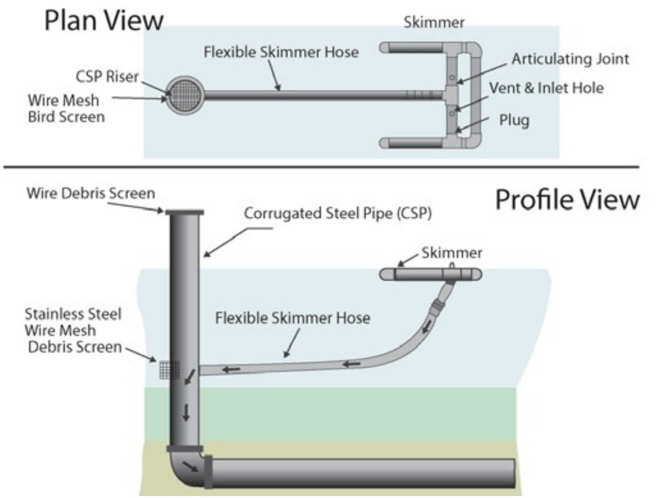
Detention systems provide treatment by detaining runoff to allow settling or sedimentation of particles under gravity. The effectiveness of these systems depends on the time allowed for sedimentation, the particle size, density, and settling velocity, and the extent to which contaminants are associated with the particulate fraction in the incoming water. Treatment systems with temporary pools, which are normally dry between events, include above ground dry detention ponds/basins and below grade storage. A skimmer drains water from just below the water's surface in a detention basin to improve sedimentation. Captured water is decanted to create a longer flow path compared to basins that drain from the invert.

Constituent Removal

Constituent Group	**Removal***
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on conventional dry detention basin performance. Blank cells indicate data not available or poor treatment performance.

Schematic



Source: Caltrans

Key Design Elements

- Means of removing water when skimmer is at its lowest position
- Orifice sizing of the skimmer
- Durability of materials used to construct skimmer
- Maintenance access

Advantages

- Potentially increased removal of suspended solids
- Can retain free oil and grease because clarified water is decanted from just below the water's surface

Constraints

- Limited pollutant removal for fine particles and dissolved constituents
- Secondary outlet may be required to drain water completely
- Prone to clogging by vegetation
- If clogged, resulting standing water can create mosquito habitat
- Frequent inspections may be required

Temporary Pool Skimmer

Maintenance Issues

Requirements:

- Valves and controller require inspection and periodic replacement. Determine inspection frequency during the first few years of operation
- Maintenance includes removal of vegetation attached to skimmer to prevent clogging

Special Training:
Unknown

Project Development Issues

Right-of-Way Requirements:
Similar to right-of-way requirements listed on the Detention Basin fact sheet (see Appendix C)

Siting Constraints:
Similar to siting constraints listed on the Detention Basin fact sheet (see Appendix C)

Construction:
None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2001. Detention Basin Optimization - Reconnaissance Study Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-029, pp. 3-7.

Caltrans. 2004. District 12 State Route 73 Pilot Program - Detention Basin Optimation and Retrofit. Basis of Design Report. CTSW-RT-04-090.09.1.

Jarrett, A. R. 2008. Controlling the Dewatering of Sedimentation Basins. Fact Sheet F253. Agricultural and Biological Engineering. College of Agricultural Sciences, Cooperative Extension. U.S. Department of Agriculture and Pennsylvania Counties Cooperating. University Park, PA.

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Alternative Designs

Chemical Treatment

Description

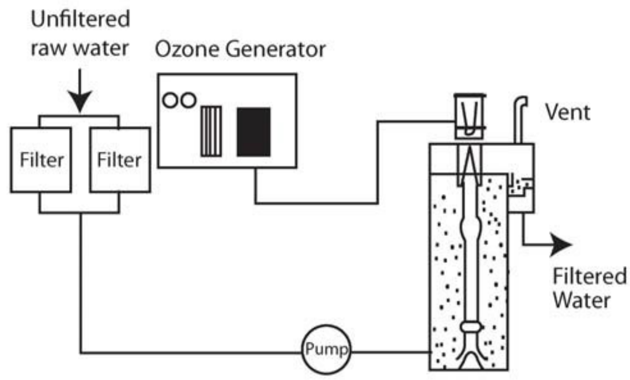
Chemical disinfection of stormwater can be achieved by the addition of a liquid (e.g., hypochlorous acid solution) or a gas (e.g., ozone). The basic treatment system consists of a chemical generation/storage system, a contact chamber, and a quenching chamber to remove residual chemical. For many years, chemical disinfection systems have been used successfully for inactivating pathogens and other microbial contaminants in drinking water and wastewater. For intermittent wet weather flow, a pretreatment device and an equalization/storage basin may be required.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance for drinking water and wastewater disinfection. Blank cells indicate data not available or poor treatment performance. Small disinfection systems operating at relatively high flow rates may not provide treatment as indicated.

Schematic



Source: UN Food and Agricultural Organization

Key Design Elements

- Chemical dose and contact time
- Chemical feed and storage facilities
- Mixing facilities
- Pretreatment to remove particles is required to achieve reliable disinfection
- Contact time must be provided in a contact basin or sedimentation basin downstream
- Quenching system may be required

Advantages

- Specific use guidelines available
- Proven effectiveness on microbial contaminants
- Mosquitoes are not an issue with chlorinated water
- Ozone is a strong disinfectant and has a limited number of by-products
- Low doses are required to complete disinfection
- Low residual ozone concentration in the treated effluent, minimizing impact on receiving waters
- Although ozone systems are complex, use of instrumentation makes the process automated and reliable

Constraints

- Declorination may be required to prevent harmful effects to receiving waters
- Pretreatment (e.g., removal of suspended solids, and oil and grease) required
- Requires special handling procedures and chemical storage tank on site
- Some organics may be converted to other (possibly more harmful) products
- Ozone must be produced on site because it cannot be stored
- Ozonation technology has a very high energy requirement
- Some ozonation by-products may be harmful to the receiving water
- Ozone escaping to the atmosphere may contribute to air pollution problems
- Ozone diffusers can be damaged easily by debris and sediments

Chemical Treatment

Maintenance Issues

Requirements:

- Mechanical equipment must be maintained
- Chemicals must be replenished
- Chemical concentration must be monitored
- Check generators daily when in operation
- Manual start-up of the ozone generator is preferable because it needs to be purged before each start-up

Special Training:

- Needed for special materials handling
- Needed for inspection and maintenance of the chemical dosing system, mixing chamber, and other design elements
- Needed for operation and maintenance of gas feed system, ozone generator, and contact chamber

Project Development Issues

Right-of-Way Requirements:

- Space requirements will depend on size of contact chamber needed to accommodate design flow
- Pretreatment space required for sedimentation, filtration, and equalization of design flow

Siting Constraints:

- Restricted to sites with available power

Construction:

- Avoid sediments in the contact chamber during construction
- May have start-up and testing requirements

Design, Construction, Maintenance, and Cost Sources

James M. Montgomery Consulting Engineers. 1985. Water Treatment Principles and Design. New York: Wiley.

PCI-Wedeco Environmental Technologies. One Fairfield Crescent, West Caldwell, NJ 07006.

U.S. EPA. 1999. Alternative Disinfectants and Oxidants Guidance Manual. Office of Water. EPA 815-R-99-014.

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- Biocide Fabric
- Klorigen™
- ClorTec®
- Osec®

Alternative Designs

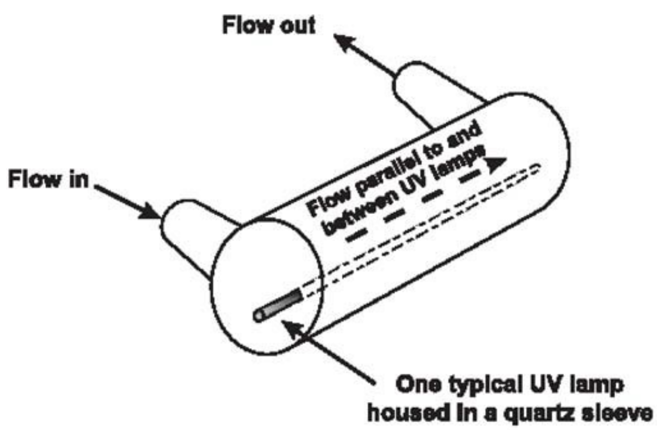
None identified

Ultraviolet

Description

Ultraviolet (UV) light disinfects water by altering the genetic material (i.e., DNA) in the cells of bacteria, viruses, and other microorganisms so that they can no longer reproduce or infect. In UV disinfection systems, the light is produced by germicidal lamps enclosed in a pressure vessel or submerged in a water channel. As the water flows past the UV lamps, the microorganisms are exposed to a lethal dose of UV energy. The UV dose is the product of the light intensity and contact time. The UV disinfection treatment is downstream of pretreatment BMPs, such as a Multiple Chamber Treatment Train (MCTT) or a media filter.

Schematic



Source: EPA

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance for dry weather flow treatment (City of Santa Monica). Blank cells indicate data not available or poor treatment performance. Small disinfection systems operating at relatively high flow rates may not provide treatment as indicated.

Key Design Elements

- Light intensity and contact time
- Hydraulic system for moving water past lamps
- Facilities for cleaning lamps
- Pretreatment to remove particles is required to achieve reliable disinfection

Advantages

- Natural process that disinfects without chemicals and has low maintenance requirements
- Automated operations and controls
- Compact system with a small footprint compared to other disinfection technologies
- Suitable for retrofit to existing BMPs
- No impact on other processes following UV treatment
- No chemical residual, minimizing impact to receiving waters

Constraints

- Pretreatment requirement may be substantial
- Clumping microorganisms can impact disinfection by harboring pathogens in the aggregates
- Specific design parameters vary for individual waters (UV transmittance)
- Under certain conditions, some organisms are capable of repairing damaged DNA and reverting back to an active state to reproduce (photoreactivation). This can be minimized by shielding the process stream or limiting the exposure of disinfected water to sunlight immediately following disinfection
- Organic and inorganic fouling usually occurs on UV lamp sleeves. Inorganic fouling, which is related to high lamp temperature, is the most difficult to clean because inorganics, such as iron and manganese, bind to the quartz sleeve

Ultraviolet

Maintenance Issues

Requirements:

- Each lamp must be cleaned periodically-typically every two weeks for wastewater discharges, but probably less frequently for intermittent stormwater discharges
- Lamps have a short life span and may require frequent replacement
- Pumps must be maintained

Special Training:

Trained staff is required for mechanical equipment maintenance

Project Development Issues

Right-of-Way Requirements:

May be compact, but pretreatment space requirement may be large

Siting Constraints:

- Restricted to sites with power available nearby
- Requires a volume-capture BMP to provide flow control

Construction:

Significant start-up and testing requirements

Design, Construction, Maintenance, and Cost Sources

City of Santa Monica. 2009. Urban Runoff Water Quality Monitoring. http://www01.smgov.net/epd/scpr/EnvironmentalPubllicHealth/EPH8_UrbanRunoff.htm (accessed October 8, 2009).

Available Vendor Products

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- Aqua UltraViolet Viper Series
- WEDECO TAK
- Siemens Barrier® Series

Alternative Designs

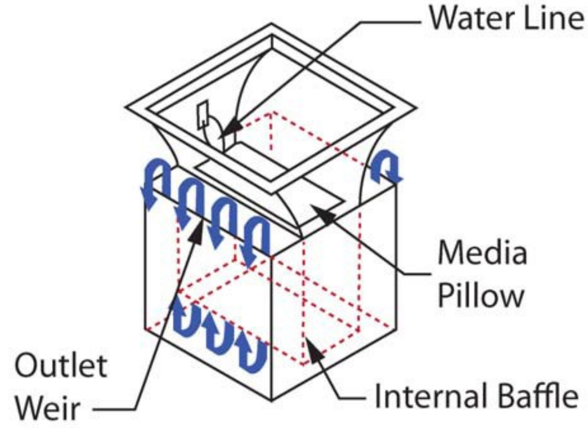
None identified

Baffle Box

Description

Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. Baffle type inserts utilize a series of baffles to force water to flow upwards before it is discharged, resulting in sedimentation of larger particles within the insert. Some inserts are designed to drop directly into existing drain inlets, while others may require attachment to drain inlet walls.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Some inserts may not provide treatment depending on size, configuration, and baffle specifications.

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass

Advantages

- Range of sizes can be retrofitted to storm drain requirements
- The device can be installed relatively easily in new and existing facilities without structural modification
- Suitable for areas with low volume traffic, such as Park and Ride lots

Constraints

- Standing water of some products may create mosquito habitat
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- High flows may flush accumulated material
- Capacity (size of basket) is constrained by the size of the drain inlet to be retrofitted
- May require frequent monitoring and maintenance because of limited capacity
- Maintenance activities may require traffic control if the device is installed along the traveled way


Baffle Box

Maintenance Issues

Requirements:

● Frequent inspection and maintenance may be required
● Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Installed within a stormwater inlet

Siting Constraints:

● Requires a grated drop inlet
● A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

A watertight installation of the product is important to capture low flows

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 2002. Storm Water O&M Fact Sheet, Catch Basin Cleaning. EPA 832-F-99-011.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of Arkansas. 2003. Environmental Technology Verification Report of the Low-Cost Stormwater BMP Study. Civil Engineering Research Foundation (CERF) and the University of Arkansas.

Available Vendor Products

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Hydro-Cartridge

Alternative Designs

None identified

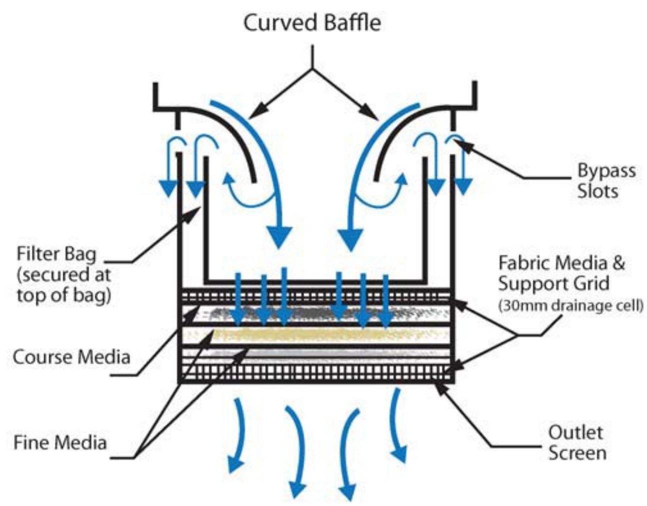
Basket/Box

Baffled Filtration Box

Description

Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. The baffled filtration box is a non-proprietary open-bottom filtration drain inlet insert that is designed to optimize sedimentation, filtration, and adsorption. A curved baffle directs flows into a filter bag made of a non-woven geotextile fabric. Surface filtration occurs as water flows through the geotextile. Sedimentation occurs as water flow exceeds the capacity of the fabric bag and spills over the sides. Water flowing through the fabric and overtopping the bag is further filtered by an arrangement of fabric and media at the bottom of the insert. Adsorption of different pollutants varies according to the media used. Overflow is allowed through bypass slots below the inlet.

Schematic



Source: Sacramento State, Office of Water Programs

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on laboratory testing by the Office of Water Programs at Sacramento State (unpublished preliminary results) and best professional judgment. Blank cells indicate data not available or poor treatment performance. Some inserts may not provide treatment depending on size, configuration, and media specifications.

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass to avoid flooding when the insert is full or clogged
- Geotextile type
- Media type, grain size, area, and depth

Advantages

- Range of sizes can be retrofitted to storm drain requirements
- Can be installed relatively easily in new and existing facilities without much structural modification
- Suitable for areas with low volume traffic, such as Park and Ride lots

Constraints

- Device can clog, resulting in standing water that may create mosquito habitat
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- Accumulated solids may be flushed out by high flows
- Capacity is constrained by the size of the drain inlet to be retrofitted
- May require frequent monitoring and maintenance because of limited capacity and potential clogging issues
- Maintenance activities may require traffic control if the device is installed along the traveled way

Basket/Box

Baffled Filtration Box

Maintenance Issues

Requirements:

- Frequent inspection and maintenance may be required, depending on solids loading and media grain size/area
- Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Install within a stormwater inlet

Siting Constraints:

- Requires a grated drop inlet
- A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

A watertight installation of the product is important to capture low flows

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Available Vendor Products

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Alternative Designs

BMP Fact Sheet

Drain Inlet Insert

Basket/Box

GSR Basket (Mechanically Removed)

Description

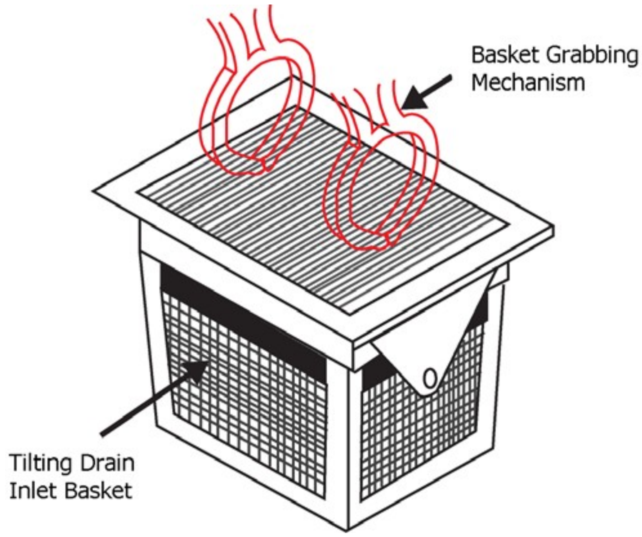
Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. The GSR Basket is a non-proprietary concept developed by Caltrans that is similar to other basket inserts that rest on the sidewalls of standard drain inlets. This insert has an integrated drop inlet grate, and a unique design that allows for automated removal of the entire basket by mechanisms similar to those used by garbage trucks. Flood flow bypass would occur by overflowing the basket.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgement. Blank cells indicate data not available or poor treatment performance.

Schematic



Source: Caltrans

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass to avoid flooding when the insert is full or clogged
- Screen type, area, and opening size
- Maintenance access

Advantages

- Maintenance can be simple and quick
- The device can be installed relatively easily in new and existing facilities without structural modification
- Suitable for areas with low traffic volumes, such as Park and Ride lots

Constraints

- Capacity (size of basket) is constrained by the size of the drain inlet to be retrofitted
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- High flows may flush accumulated material
- May require frequent monitoring and maintenance because of limited capacity
- Maintenance activities may require traffic control if the device is installed along the traveled way

Drain Inlet Insert

Basket/Box

GSR Basket (Mechanically Removed)

Maintenance Issues

Requirements:

- Frequent inspection and maintenance may be required if there is high solids loading (often caused by vegetation within the drainage area)
- Specially modified garbage trucks
- Vector control or abatement may be required

Special Training:

Operator training is necessary to operate mechanized removal equipment

Project Development Issues

Right-of-Way Requirements:

Install within a stormwater inlet

Siting Constraints:

- Requires a curb inlet
- A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

Replaces the inlet grate

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

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Alternative Designs

BMP Fact Sheet
Drain Inlet Insert
Fabric

Description

Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. Inserts typically consist of a filtering medium such as fabric, sand, or other media. Fabric type inserts utilize a fabric bag to capture gross solids and provide filtration. Some inserts are designed to drop directly into existing drain inlets, while others may require attachment to drain inlet walls.

Schematic

Source: Delaware Department of Transportation

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Some inserts may not provide treatment depending on size, configuration, and fabric specifications.

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass
- Fabric type, area, number of layers, and apparent opening size

Advantages

- Range of sizes can be retrofitted to storm drain requirements
- The device can be installed relatively easily in new and existing facilities without structural modification
- Suitable for areas with low volume traffic, such as Park and Ride lots

Constraints

- Device can clog resulting in standing water that may create mosquito habitat
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- Accumulated solids may be flushed out by high flows
- Capacity is constrained by the size of the drain inlet to be retrofitted
- May require frequent monitoring and maintenance because of limited capacity and potential clogging issues
- Maintenance activities may require traffic control if the device is installed along the traveled way

BMP Fact Sheet

Drain Inlet Insert

Fabric

Maintenance Issues

Requirements:

- Frequent inspection and maintenance may be required, depending on solids loading, fabric type, and fabric area
- Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Installed within a stormwater inlet

Siting Constraints:

- Requires a grated drop inlet
- A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

A watertight installation of the product is important to capture low flows

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 2002. Storm Water O&M Fact Sheet, Catch Basin Cleaning. EPA 832-F-99-011.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of Arkansas. 2003. Environmental Technology Verification Report of the Low-Cost Stormwater BMP Study. Civil Engineering Research Foundation (CERF) and the University of Arkansas.

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- Catch-All
- DrainPac™
- FloGard+PLUS®
- Sewer Eco-Collar
- Ultra-Drain Guard®
- Water Decontaminator WD-10X18A
- Drain Diaper™
- Ecosol™ RSF 100
- SeaLife Saver®
- StreamSaver™
- Flexstorm Inlet Filter

Alternative Designs

None identified

BMP Fact Sheet

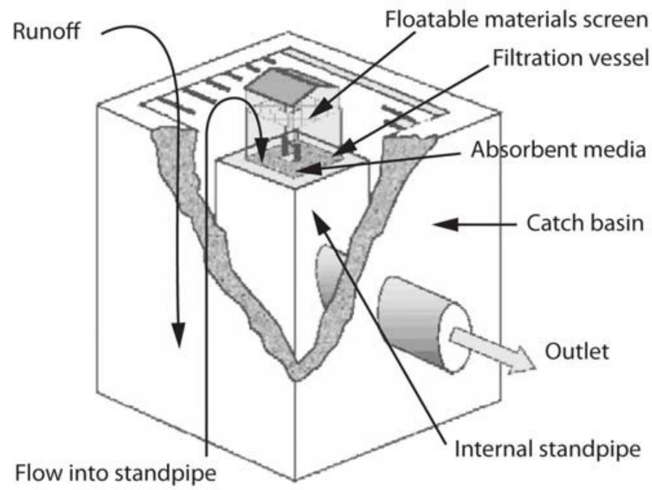
Drain Inlet Insert

Media

Description

Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. Inserts typically consist of a filtering medium such as fabric, sand, or other media. Media type inserts use granular inert or absorbent media in bags/pillows, canisters, or trays. Some inserts are designed to drop directly into existing drain inlets, while others may require attachment to drain inlet walls.

Schematic



Source: Connecticut Stormwater Quality Manual (2004).

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Some inserts may not provide treatment depending on size, configuration, and media specifications.

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass
- Media type, grain size, area, and depth

Advantages

- Range of sizes can be retrofitted to storm drain requirements
- The device can be installed relatively easily in new and existing facilities without structural modification
- Suitable for areas with low volume traffic, such as Park and Ride lots

Constraints

- Device can clog resulting in standing water that may create mosquito habitat
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- Accumulated solids may be flushed out by high flows
- Capacity is constrained by the size of the drain inlet to be retrofitted
- May require frequent monitoring and maintenance because of limited capacity and potential clogging issues
- Maintenance activities may require traffic control if the device is installed along the traveled way

Media

Maintenance Issues

Requirements:

- Frequent inspection and maintenance may be required, depending on solids loading and media grain size/area
- Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Installed within a stormwater inlet

Siting Constraints:

- Requires a grated drop inlet
- A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

A watertight installation of the product is important to capture low flows

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 2002. Storm Water Technology Fact Sheet, Sorbent Materials in Storm Water Applications. EPA 832-F-02-020.

US EPA. 2002. Storm Water O&M Fact Sheet, Catch Basin Cleaning. EPA 832-F-99-011.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of Arkansas. 2003. Environmental Technology Verification Report of the Low-Cost Stormwater BMP Study. Civil Engineering Research Foundation (CERF) and the University of Arkansas.

Available Vendor Products

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- Aqua Filtration Unit
- Clean Way
- EcoSense™
- Envirosafe™
- Inceptor®
- Piranha
- SIFT Filter™
- StormBasin®/StormPod®
- Triton Curb Inlet Filter™
- Triton TT3 Filter™ (Trench Drain)
- Aqua-Guardian™
- Diamond-Flow™
- Enviro-Drain®
- Hydro-Kleen™
- Manhole Filter
- Raynfiltr®
- Storm PURE™
- Triton Catch Basin Filter™
- Triton T-DAM Filter™ (Trench Drain)
- Ultra-Urban® Filter

Alternative Designs

Baffled Filtration Box

BMP Fact Sheet

Drain Inlet Insert

Screen

Description

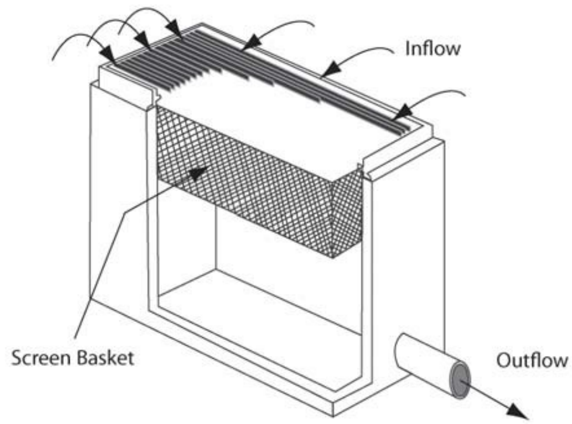
Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. Inserts typically consist of a filtering medium such as fabric, sand, or other media. Screen type inserts utilize one or more screens to filter out gross solids and coarse particulates. Some inserts are designed to drop directly into existing drain inlets, while others may require attachment to catch basin sidewalls.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Some inserts may not provide treatment depending on size, configuration, and screen specifications.

Schematic



Source: Caltrans

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass
- Screen type, area, and opening size

Advantages

- Range of sizes can be retrofitted to storm drain requirements
- Some configurations can be installed relatively easily in new and existing facilities without structural modification
- Suitable for areas with low volume traffic, such as Park and Ride lots

Constraints

- Capacity (size of basket) is constrained by the size of the drain inlet to be retrofitted
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- Maintenance activities may require traffic control if the device is installed along the traveled way
- High flows may flush accumulated material
- May require frequent monitoring and maintenance because of limited capacity

BMP Fact Sheet

Drain Inlet Insert

Screen

Maintenance Issues

Requirements:

- Frequent inspection and maintenance may be required if there is high solids loading (often caused by vegetation within the drainage area)
- Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Installed within a stormwater inlet

Siting Constraints:

- Requires a curb inlet
- A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

- May require attachment to sidewalls
- A watertight installation is important to capture low flows

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 2002. Storm Water O&M Fact Sheet, Catch Basin Cleaning. EPA 832-F-99-011.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of Arkansas. 2003. Environmental Technology Verification Report of the Low-Cost Stormwater BMP Study. Civil Engineering Research Foundation (CERF) and the University of Arkansas.

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- ClearWater BMP
- Grate Inlet Skimmer Box
- SuperFlo II Downspout
- Curb Inlet Basket
- HydroScreen

Alternative Designs

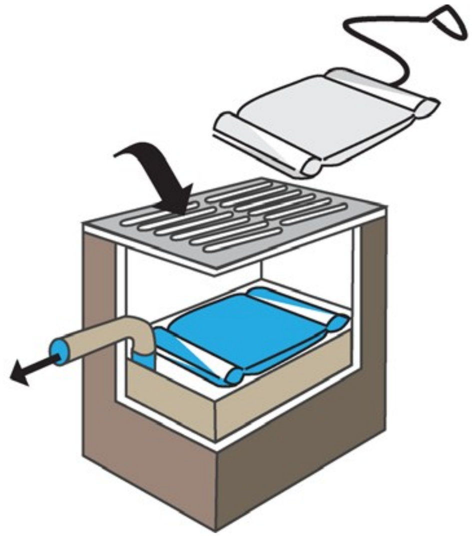
GSR Basket

Skimmer

Description

Drain inlets inserts, also known as catch basin or curb inlet inserts, are used to remove pollutants at the point of entry to the storm drain system. The effectiveness of drain inlet inserts depends on their design and on the frequency of maintenance to remove accumulated litter and sediment. Skimmer type inserts consist of a media pillow that floats directly on the water surface within a drain inlet and absorbs floating hydrocarbons. The hydrocarbons are transformed into manageable solid waste when captured by the media pillows.

Schematic



Source: EPA

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass
- Skimmer size and media type

Advantages

- May absorb hydrocarbons with minimal leaching, so skimmers can remain in place for long periods
- Can be installed relatively easily in new and existing facilities without structural modification
- Maintenance is quick and simple

Constraints

- Skimmers trap only hydrocarbons and do not contribute to sediment control
- A Caltrans study (2004) discourages the use of drain inlet inserts along highway drain inlets due to safety considerations
- Maintenance activities may require traffic control if the device is installed along the traveled way
- If a skimmer has absorbed to its maximum capacity, additional hydrocarbons will not be captured until the device is replaced

Skimmer

Maintenance Issues

Requirements:

- Must be inspected annually
- Maintenance consists of removing and replacing the skimmer
- Vector control or abatement may be required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Installed within a stormwater inlet

Siting Constraints:

A previous Caltrans study (2004) of drain inlet inserts suggests limiting deployment to maintenance stations due to safety considerations

Construction:

Simple installation

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 2002. Storm Water O&M Fact Sheet, Catch Basin Cleaning. EPA 832-F-99-011.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of Arkansas. 2003. Environmental Technology Verification Report of the Low-Cost Stormwater BMP Study. Civil Engineering Research Foundation (CERF) and the University of Arkansas.

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- AbTech Passive Skimmer
- Ultra-Passive Skimmer®
- StreamGuard Passive Skimmer

Alternative Designs

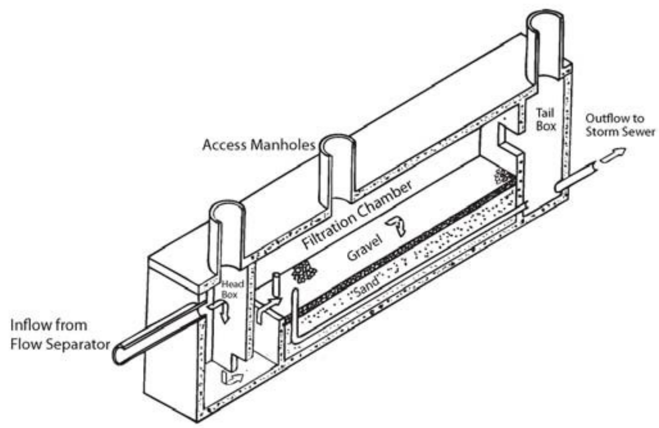
None identified

Bed

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In bed filters, stormwater flows through one or more layers of open-bed granular media before discharging through an underdrain system. The media can be inert, such as sand or gravel, or adsorptive, such as peat or a manufactured media. The effectiveness of the system depends on the loading rate on the filter, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. If the media is adsorptive, the water chemistry will also determine the effectiveness of the filter in removing dissolved constituents. Pretreatment may be necessary prior to filtration to prevent clogging and premature failure of the media.

Schematic



Source: EPA

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance of an Austin Sand Filter (see Appendix C). Blank cells indicate data not available or poor treatment performance. Small filtration devices operating at relatively high loading rates may not provide treatment as indicated.

Key Design Elements

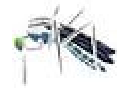
- Flood flow routing and bypass
- Water quality design flow
- Media type, grain size, and area
- Pollutant storage capacity
- Need for pretreatment
- Maintenance access

Advantages

- Typically smaller than basin type BMPs
- Can be installed below grade
- Media can be selected to target specific constituents of concern

Constraints

- Media may be proprietary
- A permanent pool of water in the treatment vault of some configurations can provide mosquito breeding opportunities
- No infiltration and volume reduction, when constructed within a concrete vault
- Confined space entry
- Entry needs to be kept accessible
- Footprint increased if pretreatment required




Bed

Maintenance Issues

Requirements:

- Routine maintenance may include periodic sediment and debris removal as well as spent media replacement. Layered media may complicate maintenance
- Vector control or abatement may be required

Special Training:

- Requires training for media maintenance/replacement
- May require confined space entry training

Project Development Issues

Right-of-Way Requirements:

Space requirements depend on sizing criteria, typically smaller than for basins

Siting Constraints:

Head requirements for gravity drain

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User’s Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

US EPA. 2002. Storm Water Technology Fact Sheet, Sorbent Materials in Storm Water Applications. EPA 832-F-02-020.

WSDOT. 2008. Highway Runoff Manual. Washington State Department of Transportation. Document Number M31-16.01.

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- Aqua-Filter™
- Aquip™

Alternative Designs

- Austin Filter
- DC Filter
- Media Filter Drain
- Delaware Filter
- Granular Activated Carbon Filter

Bed

Austin Filter with Alternative Media

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In bed filters, stormwater flows through one or more layers of open-bed granular media before discharging through an underdrain system. The effectiveness of the system depends on the loading rate on the filter, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. Conventional Austin Filters can be augmented with a layer of alternative media, such as an adsorptive manufactured media that removes fine particles and dissolved constituents. Alternative media tested by Caltrans includes activated alumina, iron-modified activated alumina, and limestone. A top layer of sand can reduce life-cycle costs because capturing particles on the sand layer prolongs the adsorptive life of the more expensive underlying media.

Constituent Removal

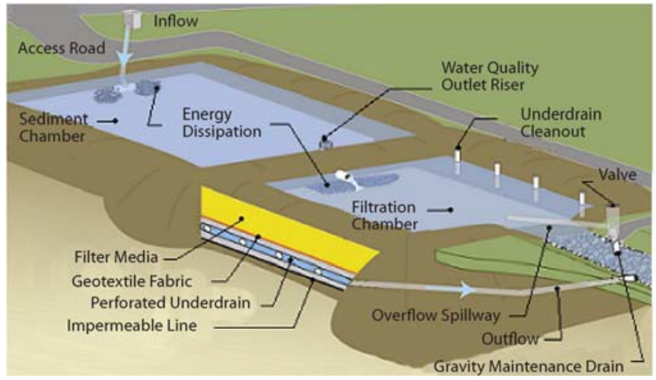
Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on the ongoing Highway 50 Activated Alumina Media Filter Pilot Study (Caltrans 2007) and best professional judgment. Blank cells indicate data not available or poor treatment performance.

Advantages

Effective constituent removal for suspended solids, fine particles, and total and dissolved phosphorus

Schematic



Source: Caltrans

Key Design Elements

- Flood flow routing and bypass
- Media grain size, area, and depth
- Outlet orifice plate to control media contact time
- Maintenance access

Constraints

- Media may be proprietary
- If media clogs, resulting standing water may create mosquito habitat
- No infiltration and volume reduction when constructed within a concrete vault
- Media may need to be washed to avoid substantial pH changes and metals leaching
- Effluent may require monitoring during first year for elevated pH and dissolved metals

Bed — Austin Filter with Alternative Media

Maintenance Issues

Requirements:

● Routine maintenance may include periodic sediment and debris removal as well as spent media replacement. Layered media may complicate maintenance

● Vector control or abatement may be required

Special Training:

Training is required for media handling, removal, and replacement

Project Development Issues

Right-of-Way Requirements:

Space requirements are similar to an Austin Sand Filter

Siting Constraints:

● Head requirement of about four feet

● Avoid locations with base flow because of clogging due to algae growth

Construction:

If exposed to construction site runoff, remove and replace media after drainage area has been completely stabilized

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2007. Caltrans Tahoe Basin Highway 50 Activated Alumina Media Filter Pilot Study - Final Monitoring Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-06-157.02.1.

US EPA. Sand Filter Fact Sheet. Retrieved from www.epa.gov/owm/mtb/sandfltr.pdf (accessed November 6, 2009).

Available Vendor Products

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Alternative Designs

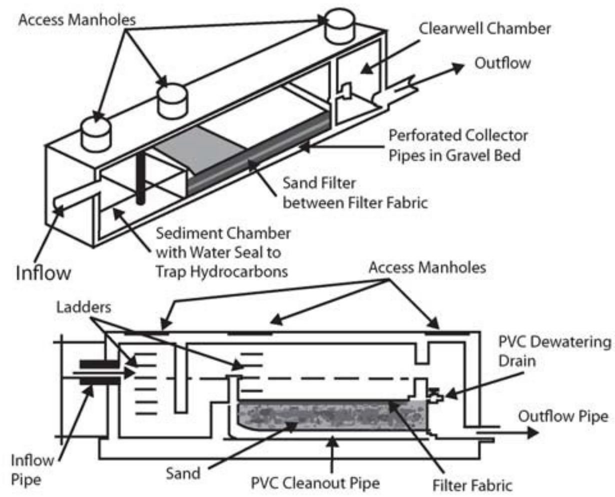
Bed

DC Sand Filter

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In bed filters, stormwater flows through one or more layers of open-bed granular media before discharging through an underdrain system. The effectiveness of the system depends on the loading rate on the filter, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. DC Sand Filters are typically designed to handle runoff from completely impervious drainage areas of 0.4 hectares (1 acre) or less. This filter design incorporates three chambers. Runoff flows through a sedimentation chamber before it enters a filter chamber where it passes through an open sand bed. Filtered water is collected in a gravel underdrain and flows into a clearwell chamber before discharging.

Schematic



Source: EPA

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on Delaware Sand Filter performance (see Appendix C), and data presented by Young et al. (1996). Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Flood flow routing and bypass
- Media area and depth
- Media grain size

Advantages

- DC Sand Filters are installed in urban settings with covers appropriate for the intended above ground land use such as sidewalks or landscaping
- Performance is similar to the Delaware Sand Filter and Austin Sand Filter, but DC Sand Filters have a narrower footprint and require less head than Austin Sand Filters. They are also designed to receive concentrated flows at one end, whereas Delaware Sand Filters are designed for sheet flows along one side

Constraints

- Designed to treat impervious areas of one acre or less
- If media clogs, resulting standing water may create mosquito habitat
- No infiltration and volume reduction when constructed within a concrete vault
- Confined space entry
- Entry needs to be kept accessible
- The sedimentation basin holds a permanent pool of water that has the potential to provide breeding opportunities for mosquitoes

Maintenance Issues

Requirements:

- Routine maintenance may include periodic sediment and debris removal as well as spent media replacement
- Vector control or abatement may be required

Special Training:

- Requires training for media maintenance/replacement
- Requires confined space entry training

Project Development Issues

Right-of-Way Requirements:

Space requirements are similar to Delaware Sand Filters

Siting Constraints:

- Do not site where runoff from bare soil or construction activities can enter filter
- Head requirements for gravity drain

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

Connecticut Stormwater Quality Manual. 2004. http://www.ct.gov/dep/lib/dep/water_regulating_and_discharges/stormwater/manual/Table_of_Contents.pdf (accessed November 11, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

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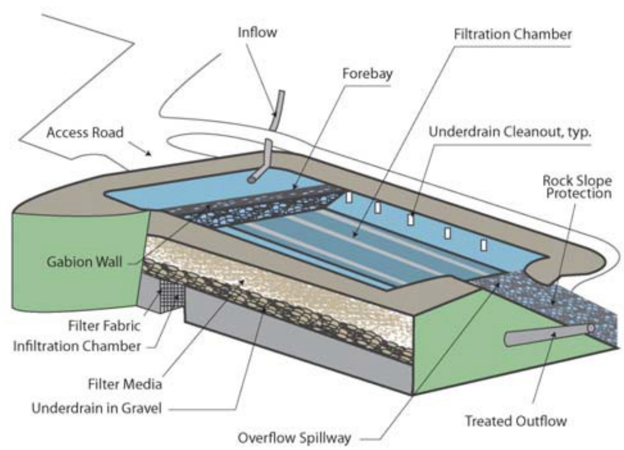
Alternative Designs

Bed Infiltration Chambers

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In bed filters, stormwater flows through one or more layers of open-bed granular media before discharging through an underdrain system. The effectiveness of the system depends on the loading rate on the filter, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. Infiltration chambers is a concept developed by Caltrans to increase infiltration in conventional BMPs. Addition of infiltration chambers below the invert of bed filters is expected to capture and infiltrate the first flush of stormwater runoff. These infiltration chambers can consist of gravel, high porosity storage media with a sand overlay, or native soil that has been amended to improve infiltration.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance of an Austin Sand Filter (see Appendix C). Blank cells indicate data not available or poor treatment performance. Small filtration devices operating at relatively high loading rates may not provide treatment as indicated.

Key Design Elements

- Soil type and permeability
- Infiltration chamber volume capacity
- Infiltration chamber material (high porosity storage media, gravel, amended soil, etc.)
- Flood flow routing and bypass
- Media grain size, area, and depth
- Outlet orifice plate to control media contact time
- Maintenance access

Advantages

- Potential for improved infiltration, even in poorly infiltrating soils
- Expected to improve treatment of fine particles, nutrients, and dissolved constituents relative to conventional sand filters

Constraints

- Not suitable in areas with high seasonal groundwater
- Increases construction and rehabilitation costs relative to conventional sand filters
- If media clogs, resulting standing water may create mosquito habitat

Bed Infiltration Chambers

Maintenance Issues

Requirements:

- Routine maintenance may include periodic sediment and debris removal as well as spent media replacement
- Vector control or abatement may be required
- May require construction equipment to rehabilitate clogged system
- Sediment removal

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Space requirements are the same as those for conventional filters

Siting Constraints:

- Site where there is sufficient hydraulic head to facilitate drainage through the sand bed
- Requires separation between seasonal high groundwater and basin invert
- Avoid locations with base flow because of possible clogging due to algae growth

Construction:

- If exposed to construction site runoff, remove and replace media after drainage area has been completely stabilized
- Minimize compaction of underlying soils to maintain infiltration capacity
- Bypass water until drainage area is stabilized

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2007. Caltrans Tahoe Basin Highway 50 Activated Alumina Media Filter Pilot Study - Final Monitoring Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-06-157.02.1.

Caltrans. 2008. Adding Infiltration Chambers to Approved Best Management Practices: Concept Development. Sacramento: Caltrans, Office of Storm Water Management, Division of Design. CTSWRT-TM-08-172-46.1.

US EPA. Storm Water Technology Fact Sheet, Sand Filter. EPA 832-F-99-007.

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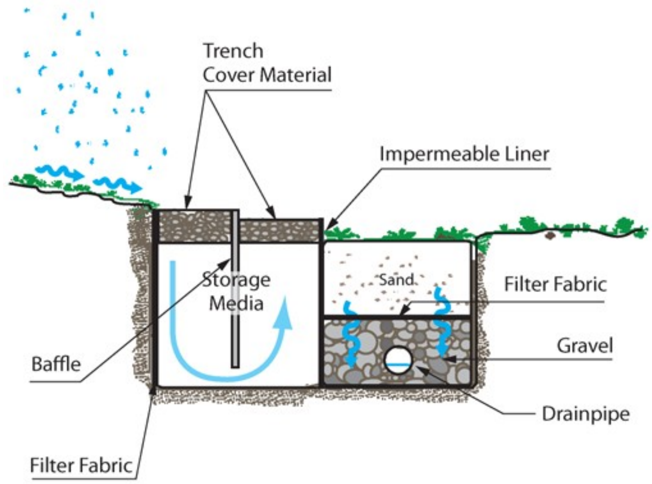
Alternative Designs

Linear Filter Trench

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. The Linear Filter Trench, a concept developed by Caltrans that is based on the Delaware Sand Filter, is intended for the narrow right-of-way that is typical of roadside areas. It consists of a sedimentation chamber with a permanent pool of water and a filter chamber with an underdrain. The Linear Filter Trench, however, would be constructed away from load-bearing areas so that trench construction can help reduce cost. A trench cover material on top of the sedimentation area prevents mosquito access to standing water. The use of a high-porosity storage media supports the overlay while maintaining the capture volume of the sedimentation chamber.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance of a Delaware Sand Filter (see Appendix C). Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Flood flow routing
- Water quality flow and detention time (if flow-based design)
- Storage volume and sand/gravel pore space (if volume-based design)
- Media type, grain size, and area
- Ponding depth above filter
- Traffic rating
- Maintenance access

Advantages

- Fits in a narrow right-of-way
- Lower construction costs than conventional below grade filters because of minimal use of concrete
- Can provide infiltration and volume reduction
- Can be constructed without pretreatment by a grass filter strip

Constraints

- The sedimentation chamber holds a permanent pool of water and has the potential to provide breeding opportunities for mosquitoes
- May require confined space entry
- Unknown maintenance frequency
- Maintenance activities may require traffic control

Maintenance Issues

Requirements:

- Disposal of accumulated trash and replacement of the upper few inches of sediment and sand when the filter clogs
- Vector control or abatement may be required

Special Training:

Requires training for media maintenance/replacement

Project Development Issues

Right-of-Way Requirements:

Designed to fit in a narrow right-of-way

Siting Constraints:

- Do not site where runoff from bare soil or construction activities will be allowed to impact the filter
- Minimum head requirement of two feet

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

Horner, R. R. and Horner, C. R. 1995. Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part III. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA.

US EPA. Sand Filter Fact Sheet. www.epa.gov/owm/mtb/sandfltr.pdf (accessed November 11, 2009).

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

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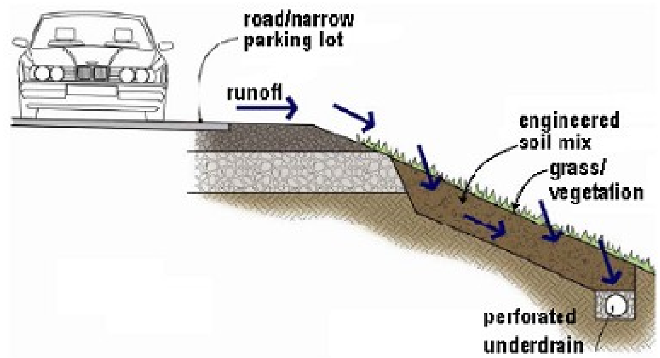
Alternative Designs

BMP Fact Sheet
Filtration
Bed
Media Filter Drain

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In bed filters, stormwater flows through one or more layers of open-bed granular media before discharging through an underdrain system. The effectiveness of the system depends on the loading rate on the filter, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. The Media Filter Drain is a bed filtration system that can be integrated into slopes adjacent to roadways. The concept, developed by the State of Washington's Department of Transportation, is typically constructed to accept sheet flow along its length. Water passes into a porous, alkalinity-generating media that is placed in a shallow excavation running parallel to the roadway. An underdrain carries filtered water downstream.

Schematic



Source: Pierce County, Washington State

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	✓
Microbiological	
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on monitoring by Washington State DOT (2008). Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Preferable lateral slopes less than 25% (4:1)
- Preferable longitudinal slope less than 5%
- Design water quality flow rate
- Bed mixture and dimensions
- Pretreatment needs by biofiltration strips
- Slope stability
- Underdrain
- Maintenance access

Advantages

- Fits in a narrow right-of-way
- No vector concerns, because water treatment is accomplished below surface

Constraints

- Requires sheet flow
- Not suitable for steep lateral and longitudinal slopes
- Vegetation may develop slowly, though filtering still occurs
- Media mix may require washing before installation
- Must avoid concentrated flows
- Maintenance activities may require traffic control

Media Filter Drain

Maintenance Issues

Requirements:

- Maintain uniform sheetflow distribution
- Periodic media maintenance

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Designed to fit in a narrow right-of-way

Siting Constraints:

Not advised in longitudinal slopes steeper than 5%, wetlands, wetland buffers, or unstable slopes

Construction:

Certain soil types may require perforated pipe in the underdrain trench to ensure proper flow through media bed

Design, Construction, Maintenance, and Cost Sources

Washington Department of Transportation (WA DOT). 2008. Highway Runoff Manual. M 31-16.01.

Available Vendor Products

The names of vendor products that appear here are for information only. The vendor products listed below are NOT APPROVED FOR USE by the California Department of Transportation. Their appearance here IS NOT AN ENDORSEMENT OF THE PRODUCTS BY CALTRANS OR THE STATE OF CALIFORNIA.

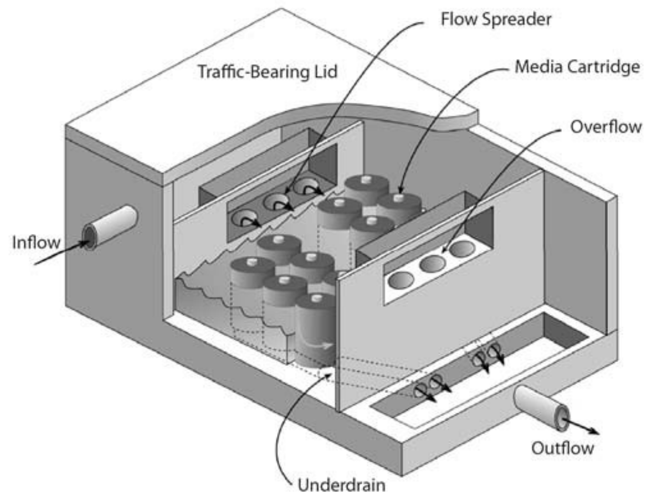
Alternative Designs

Cartridge/Canister

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In cartridge/canister systems, the filter media is placed inside cartridges or canisters that are typically enclosed in an underground vault. The media used can be inert, such as sand or gravel, or adsorptive, such as peat or a manufactured media. The effectiveness of these systems depends on the loading rate on the cartridges/canisters, the type, size and porosity of the media, and the type and size distribution of the particles in the incoming stormwater. If the media is adsorptive, the water chemistry will also determine the effectiveness of the filter in removing dissolved constituents. Pretreatment may be necessary prior to filtration to prevent clogging and premature failure of the media.

Schematic



Source: City of Medford, Oregon

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on performance of a StormFilter™ (Caltrans 2004), and best professional judgment. Blank cells indicate data not available or poor treatment performance. Cartridges/canisters operating at relatively high loading rates (about 2 gpm per square foot for each cartridge/canister) may not provide treatment as indicated.

Key Design Elements

- Flood flow routing and bypass
- Water quality design flow
- Flow restriction for maximum operational flow
- Media type, grain size, and area (determined by size, configuration, and number of cartridges/canisters)
- Pollutant storage capacity
- Need for pretreatment
- Maintenance access

Advantages

- Can be applied in confined urban areas and areas with limited space if placed in an underground vault
- Suitable for wide range of drainage areas
- Media can be selected to target specific constituents of concern

Constraints

- Can be expensive to construct
- Major maintenance may be costly due to the large number of filter canisters required
- Proprietary device
- Media may be proprietary
- Requires pretreatment
- A permanent pool of water in the treatment vault of some configurations can provide mosquito breeding opportunities
- Small storm events may not actuate the floats in some systems, and the water will reside in the unit until the next storm
- May require confined space entry
- Entry needs to be kept accessible

Cartridge/Canister

Maintenance Issues

Requirements:

- Periodic sediment removal and canister replacement required
- Vector control or abatement may be required
- May require hand cleaning following removal of media canisters

Special Training:

- Training in use of equipment needed to remove media canisters and clean out pretreatment vault
- Must be trained to repair or replace any cartridge filter or part, or plan to contract for maintenance
- Training needed for confined space entry

Project Development Issues

Right-of-Way Requirements:

Space requirements depend on sizing criteria, but typically smaller than basins

Siting Constraints:

- Do not allow runoff from bare soil or construction activities to enter filter
- Sufficient hydraulic head is needed to operate filter

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Division of Environmental Analysis, Sacramento. CTSW-RT-01-050

US EPA. 2002. Storm Water Technology Fact Sheet, Sorbent Materials in Storm Water Applications. EPA 832-F-02-020.

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

Available Vendor Products

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- BayFilter™
- Perk Filter™
- StormPlex™
- Up-Flo™
- Media Filtration System (MFS)
- Puristorm™
- VortFilter™

Alternative Designs

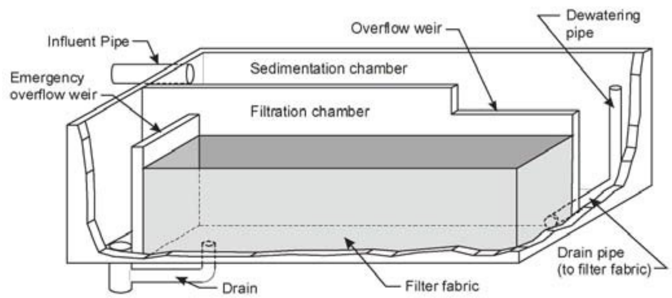
None identified

BMP Fact Sheet
Filtration
Fabric

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in the stormwater. In fabric filters, stormwater flows through fabric, typically in the form of a sequence of baffles. The effectiveness of the system depends on the loading rate on the fabric, the type, number of layers, and apparent opening size of the fabric, and the type and size distribution of the particles in the incoming stormwater. A fabric filtration system can be used as pretreatment for a subsurface detention or infiltration system.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Small filtration devices operating at relatively high loading rates may not provide treatment as indicated.

Key Design Elements

- Flood flow routing and bypass
- Fabric type, area, and apparent opening size
- Pollutant storage capacity
- Maintenance access

Advantages

- No negative aesthetic impact if installed below grade
- Can be used to provide pretreatment for other BMPs

Constraints

- May be difficult to achieve complete draining in a buried system
- Difficult to inspect and maintain because it is buried
- May require confined space entry
- Fabric panels may clog quickly
- A permanent pool of water in the treatment vault of some configurations can provide mosquito breeding opportunities

Filtration


Fabric

Maintenance Issues

Requirements:

- Replace fabric panels
- Because of site-specific loading, several wet season inspections may be required to determine maintenance frequency

Special Training:

Training needed for confined space entry

Project Development Issues

Right-of-Way Requirements:

Small footprint BMP

Siting Constraints:

May not be feasible in areas with high sediment and organic load because of premature clogging of fabric

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

None identified

Available Vendor Products

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- Stormfilter 400®
- Helix Filter
- Jellyfish™

Alternative Designs

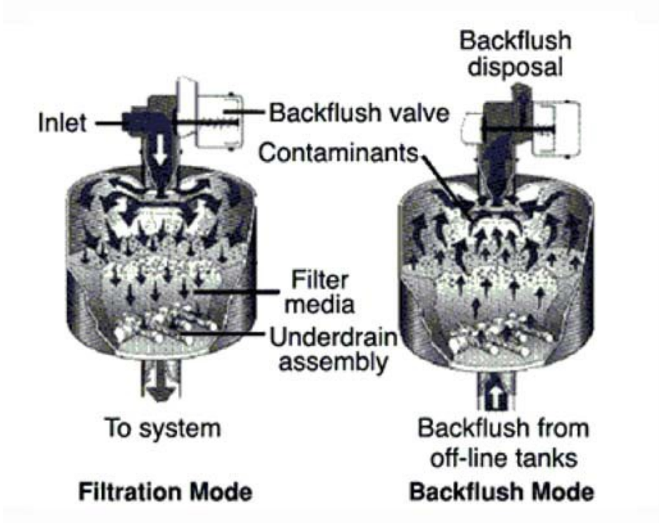
None identified

Pressure

Description

Filtration systems provide treatment by filtering out or straining particles and associated pollutants in stormwater. In pressurized filtration systems, an external pump is used to force water through a media, fabric, or micro-discs. The media can be inert, such as sand or gravel, or adsorptive, such as peat or a manufactured media. The effectiveness of the system depends on the loading rate on the media or fabric, the type, size and porosity of the media or fabric, and the type and size distribution of the particles in the incoming stormwater. If the media is adsorptive, the water chemistry will also determine the effectiveness of the filter to remove dissolved constituents. Pressure filtration is more common for construction site runoff than for post-construction.

Schematic



Source: Virginia Cooperative Extension

Constituent Removal

Constituent Group	**Removal***
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Facilities required upstream to capture runoff and provide pretreatment
- Power supply
- Flood flow routing and bypass
- Design flow
- Media type, grain size, and area
- Backwash cycle water storage and disposal
- Maintenance access

Advantages

- Using pressure rather than gravity to force water through a media bed allows a smaller footprint
- Backwashing cycle cleans sediment from the filter media as opposed to periodically excavating a portion of the media as required for slow-rate sand filters
- Pressure filter technology uses pumps, which allow more layout flexibility than gravity filtration systems

Constraints

- Connection to sewer or drying bed needed for backwashed wastewater
- Connection to a clean water tank is needed for backwashing
- Power supply required for pump
- More maintenance is needed for a pressure filter than for a gravity filter because of the use of mechanical equipment
- Requires a pretreatment system for litter and debris
- Requires a higher level of operator observation than that for other BMPs

Pressure

Maintenance Issues

Requirements:

- Mechanical equipment must be maintained
- Pretreatment may be necessary prior to filtration to prevent clogging and premature failure
- Pressure filters require backwashing, a process in which water is forced through the media bed in an opposite direction. The backwashed wastewater must be disposed if a sanitary sewer connection is not available

Special Training:

Crews need to be trained to operate and maintain equipment

Project Development Issues

Right-of-Way Requirements:

Total footprint may be high (including facilities required upstream to capture runoff and provide pretreatment)

Siting Constraints:

- Restricted to sites with available power nearby
- Space required for upstream pretreatment system
- Requires a sanitary sewer connection or dry beds

Construction:

Unknown

Design, Construction, Maintenance, and Cost Sources

US EPA. 2002. Storm Water Technology Fact Sheet, Sorbent Materials in Storm Water Applications. EPA 832-F-02-020.

Available Vendor Products

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- Arkal Filter
- Purmutit® CD Series
- DynaSand®

Alternative Designs

None identified

BMP Fact Sheet

Hydrodynamic Separator

Description

Hydrodynamic separators, also called vortex separators or swirl concentrators, are cylindrical structures in which water moves in a centrifugal fashion rather than in a straight line. Stormwater enters the separator tangentially and creates a swirling vortex flow pattern that allows larger particles to settle out by gravity around the outer edges of the main chamber. Differences between configurations include the nature and type of internal flow-modifying components and the location of inlets and outlets. Hydrodynamic separators are small footprint devices that can be used in small spaces. The effectiveness of these devices depends on the flow rate, the size and configuration of the device, and the sediment characteristics (i.e., type and size distribution of the particles) of the incoming stormwater.

Constituent Removal

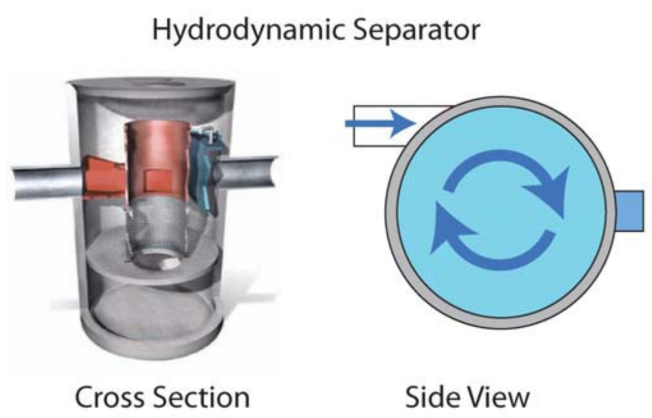
Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Treatment for separators operating at relatively high flow rates or with poor sediment retention ability may not be as indicated.

Advantages

- Relatively limited head is needed to operate device
- Can be used to provide pretreatment for other BMPs

Schematic



Source: University of New Hampshire Stormwater Center

Key Design Elements

- Flood flow routing and bypass
- Water quality design flow
- Detention time
- Maximum operational flow
- Sediment storage capacity and ability to prevent scouring
- Maintenance access

Constraints

- A permanent pool of water is often maintained in the unit, creating a breeding opportunity for mosquitoes
- Not effective for removing dissolved constituents or fine particles
- Can be a source of pollutants due to decomposition of previously captured material unless maintained regularly
- Maintenance activities may require traffic control if the device is installed along the traveled way
- Proprietary device

Maintenance Issues

Requirements:

- Usually requires vactor truck
- Vector control or abatement may be required

Special Training:
Unknown

Project Development Issues

Right-of-Way Requirements:
Small footprint

Siting Constraints:
Low head requirement

Construction:
None Identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Connecticut Department of Environmental Protection. 2002. Stormwater Treatment Devices, Section 319 Project # 99-07, Final Report.

NCHRP. 2006b. User’s Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

US EPA. 1999. Hydrodynamic Separators. Storm Water Technology Fact Sheet. EPA 832-F-99-017.

US EPA. 2004. The Use of Best Management Practices (BMPs) in Urban Watersheds. EPA/600/R-04/184.

Available Vendor Products

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- Aqua-Swirl™
- Continuous Deflective Separation™ (CDS)
- EcoStorm Plus™
- Hydrofilter
- Storm Trooper®
- Terre Kleen™
- V2B1™
- VortSentry™
- Downstream Defender™
- EcoStorm™
- FloGard Dual-Vortex™
- Hydroguard
- Stormceptor®
- Unistorm™
- Vortechs®

Alternative Designs

None identified

BMP Fact Sheet

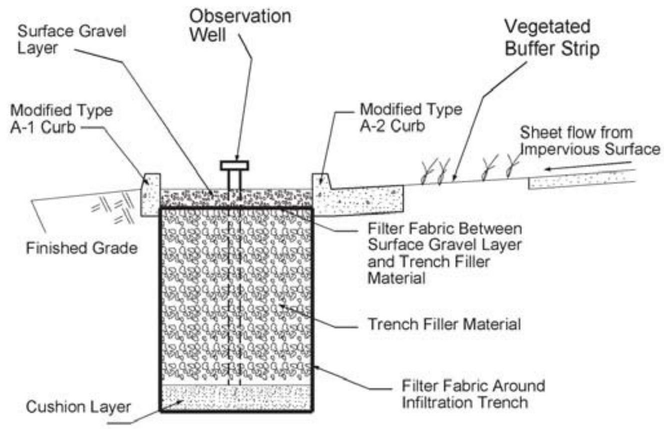
Infiltration

Below Grade

Description

Infiltration BMPs provide treatment by allowing the stormwater runoff to infiltrate surrounding soils. Pollutants are filtered out as the water percolates through the soils. Infiltration BMPs are assumed to provide 100% treatment of the design water quality volume because no water is discharged to surface waters. An overflow mechanism is recommended in case of clogging.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	✓

* Based on the assumption that most water is infiltrated and does not overflow, and litter is captured within the BMP. Removal ability reported in the literature is usually based on overflow discharge (Young et al. 1996).

Key Design Elements

- Water quality volume
- Permeability of soil
- Distance to groundwater
- Class V injection well determination may be required
- Overhead cover requirements and load-bearing capacity
- Maintenance access

Advantages

- When properly sized in suitable soils, infiltration BMPs eliminate surface discharge up to the design storm
- Below grade infiltration inhibits access for mosquitoes
- Underground BMPs have limited aesthetic impacts
- Caltrans modeling indicates that underlying soils are not likely to become hazardous within five or more years, and typical Caltrans concentrations will not likely impact groundwater quality (Caltrans 2016)

Constraints

- High rehabilitation cost when clogging occurs at the bottom of the trench
- Water percolation may impact structural integrity and stability
- Avoid high groundwater
- Avoid areas prone to spills of groundwater contaminants
- Potential EPA Class V injection well regulations
- Higher construction costs per capture volume than infiltration basins
- Although narrow, could be a large footprint BMP depending on design constraints

Infiltration

Below Grade

Maintenance Issues

Requirements:

- Rehabilitation is required when the system clogs. Rehabilitation requires construction equipment
- Young et al. (1996) report that below grade infiltration (trenches, specifically) may require reconstruction every 10 years

Special Training:

Training in confined space entry

Project Development Issues

Right-of-Way Requirements:

- Space requirements are less than infiltration basins because of vertical side walls
- Pretreatment is recommended

Siting Constraints:

Permeable soils and adequate separation to groundwater

Construction:

- Avoid clogging the underlying soils by compaction from vehicles, or by fine particles introduced during or after construction
- Bypass water until drainage area is stabilized

Design, Construction, Maintenance, and Cost Sources

ASCE/WEF. 1998. Urban Runoff Quality Management. ASCE No. 87, WEF No. 23.

Caltrans. 2007. Mathematical Modeling of Fate and Transport of Aqueous Species in Stormflow Entering Infiltration Basin. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-06-168-17.2.

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

US EPA. 2003. When are Storm Water Discharges Regulated as Class V Wells? http://www.epa.gov/npdes/pubs/sw_class_v_wells_fs.pdf (accessed January 22, 2010).

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. US Department of Transportation.

Available Vendor Products

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- Eljen In-Drain™
- Rainstore®
- StormTank™
- Cultec Contacter® and HVLV™ Recharger®
- EcoRain™
- SAGES™
- Terre Arch™
- VersiCell®
- Maxwell Plus or Maxwell IV
- Matrix™
- StormChamber™
- StormTech® Chambers
- D-Raintank®
- Rotondo Detention with Recharge
- Stormcell®
- Triton™ Chamber
- CUDO

Alternative Designs

- Infiltration Vault
- Infiltration Trench
- Linear Infiltration Filter Trench

BMP Fact Sheet

Infiltration

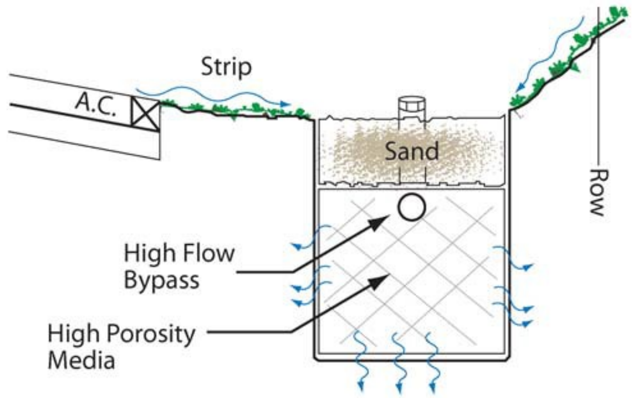
Below Grade

Linear Infiltration Filter Trench

Description

Infiltration BMPs provide treatment by allowing stormwater runoff to infiltrate surrounding soils. Pollutants are filtered out as the water travels through the soils. Infiltration BMPs are assumed to provide 100% treatment because the design water quality volume is not discharged to surface waters. An overflow mechanism is recommended in case of clogging. The Linear Infiltration Filter Trench is a non-proprietary design developed by Caltrans in which stormwater flows as sheet flow through a sand filter prior to infiltration. Treatment within the sand layer reduces clogging of the trench, inhibits mosquito access in areas where slow soil infiltration results in standing water, and may eliminate the need for pretreatment. The trench is backfilled with gravel or a high porosity media that is available from several suppliers.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	✓
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	✓

* Based on the assumption that most water is infiltrated and does not overflow, and that litter is captured within the BMP.

Key Design Elements

- Water quality volume
- Permeability of soil and sand
- Distance to groundwater
- Load-bearing capacity
- Maintenance access
- Ponding depth above the sand

Advantages

- Designed to fit a narrow right-of-way
- When properly sized in suitable soils, infiltration BMPs eliminate surface discharge up to the design storm
- Below grade infiltration inhibits access for mosquitoes
- Underground BMPs have limited aesthetic impact
- Caltrans modeling indicates that underlying soils are not likely to become hazardous within five or more years, and that typical Caltrans concentrations will not likely impact groundwater quality (Caltrans 2016)

Constraints

- High rehabilitation cost when clogging occurs at the bottom of the trench
- Water percolation may impact structural integrity and stability
- Avoid high groundwater
- Avoid areas prone to spills of groundwater contaminants
- Higher construction costs per capture volume than infiltration basins
- Although narrow, could be a large footprint BMP depending on design constraints

Below Grade — Linear Infiltration Filter Trench

Maintenance Issues

Requirements:

- May require construction equipment to rehabilitate clogged system
- Young et al. (1996) report that below grade infiltration (trenches, specifically) may require reconstruction every 10 years

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

- Space requirements are less than infiltration basins because of vertical side walls
- Pretreatment is recommended

Siting Constraints:

Permeable soils and adequate separation to groundwater

Construction:

- Avoid clogging the underlying soils by compaction from vehicles or by fine particles introduced during or after construction
- Bypass water until drainage area is stabilized

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2007a. Mathematical Modeling of Fate and Transport of Aqueous Species in Stormflow Entering Infiltration Basin. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-06-168-17.2.

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

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Alternative Designs

Porous Surface

Asphalt Overlay

Description

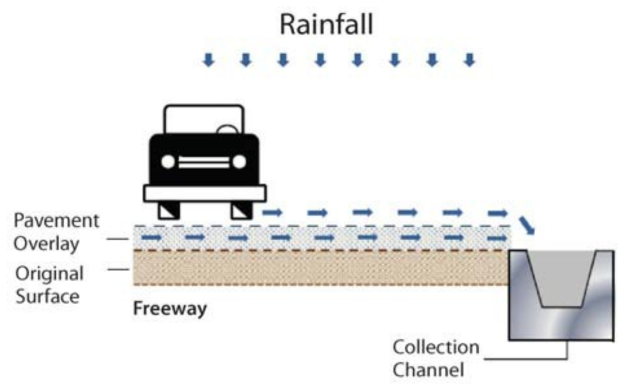
A porous asphalt overlay, also called a open graded or permeable friction course, is a layer of porous asphalt applied on top of conventional pavement. Stormwater drains through the porous asphalt layer to the conventional road surface below, and then travels along the boundary between the pavement types until it emerges as runoff at the edge of the pavement. The porous layer reduces traffic noise and improves safety by reducing splash and draining water away from the surface. Studies suggest that porous asphalt overlays may also provide water quality benefits by trapping particulates and by reducing the amount of pollutants washed from vehicles.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	✓
Pesticides	
Total Metals	✓
Dissolved Metals	
Microbiological	
Litter	
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on removals found by Stanard et al. (2008). Blank cells indicate data not available or poor treatment performance.

Schematic



Source: Caltrans

Key Design Elements

- Load requirements
- Gradation of asphalt mix
- Thickness of porous layer

Advantages

- Reduces or eliminates space needed for other BMPs
- Increases road safety and reduces traffic noise
- Suitable for highway application

Constraints

- Not feasible where traction sand is applied
- More costly than traditional asphalt concrete
- Durability affected by temperature and traffic load
- Water quality benefit expected to deteriorate with overlay age due to clogging of pores

Porous Surface

Asphalt Overlay

Maintenance Issues

Requirements:

- Inspect porous pavements annually
- Vacuum-style street sweepers are recommended, but not required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Requires no additional right-of-way

Siting Constraints:

May not be suitable in areas with highly erosive soils

Construction:

Construction requires special care and some changes to normal practices and scheduling

Design, Construction, Maintenance, and Cost Sources

National Asphalt Pavement Association (NAPA). 2008. http://www.hotmix.org (accessed October 19, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Stanard, C.E., M. E., Barrett, and R.J. Charbeneau. 2008. Stormwater Quality Benefits of a Permeable Friction Course. Center for Research in Water Resources. University of Texas. CEWR Online Report 08-03. http://www.utexas.edu/research/ctr/pdf_reports/0_5220_1.pdf (accessed January 22, 2010).

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None identified

Alternative Designs

None identified

BMP Fact Sheet

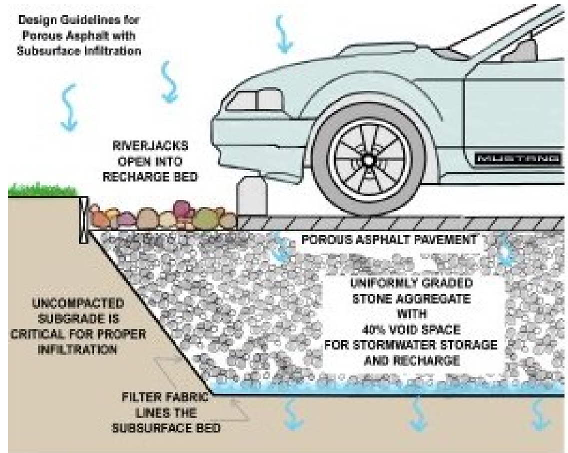
Porous Surface

Asphalt Pavement

Description

Porous asphalt pavement, with a life span of 20 years or more, provides stormwater storage and infiltration. Porous asphalt pavement is composed of a permeable asphalt surface placed over a granular "choke" course that is on top of a reservoir of large stone. The lower reservoir layer is designed for load requirements and water storage capacity. An overflow for the reservoir layer is recommended in case of insufficient infiltration. The pavement may also be designed to receive off-site runoff.

Schematic



Source: Cahill Associates

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	✓

* Removals are assumed to be due to 100% infiltration of the design water quality volume because no water is discharged to surface waters. Blank cells indicate data not available or poor treatment performance. Removals reported in literature are usually based on overflows from the reservoir course (UNH 2007).

Key Design Elements

- Water quality volume
- Permeability of soil
- Distance to groundwater
- Load requirements
- Gradation of asphalt mix

Advantages

- Eliminates surface discharge up to the design storm when properly sized in suitable soils
- Below grade infiltration inhibits access for mosquitoes
- Reduces or eliminates space needed for other BMPs
- Infiltration addresses all pollutants, except litter
- Caltrans modeling indicates that underlying soils will not likely become hazardous within five or more years, and typical Caltrans concentrations will not likely impact groundwater quality (Caltrans 2016)

Constraints

- Only suitable for low traffic areas, such as Park and Ride lots
- Low permeability in the subgrade will increase discharge through the over drain and decrease removal efficiency
- Not feasible where traction sand is applied
- More costly than traditional asphalt concrete
- Durability affected by temperature
- Potential contamination from spills
- Water quality benefit expected to deteriorate with pavement age due to clogging of pores in the porous asphalt

Porous Surface

Asphalt Pavement

Maintenance Issues

Requirements:

- Inspect porous pavements annually
- Vacuum-style street sweepers are recommended, but not required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Requires no additional right-of-way

Siting Constraints:

- Similar to siting constraints for infiltration BMPs
- Some considerations are depth to groundwater, subgrade permeability, and soil type

Construction:

- Construction requires special care and some changes to normal practices and scheduling
- Minimize sub grade compaction to maintain soil permeability
- Before installation, erosion control should be in place until vegetation is established. Porous surface installation is recommended as the last item of construction

Design, Construction, Maintenance, and Cost Sources

Cahill Associates. 2006. Porous Asphalt with Subsurface Infiltration/Storage Bed. http://www.thcahill.com/pasphalt.html (accessed October 19, 2009).

Caltrans. 2007a. Mathematical Modeling of Fate and Transport of Aqueous Species in Stormflow Entering Infiltration Basin. Sacramento: Caltrans-Division of Environmental Analysis. CTSW-RT-06-168-17.2.

National Asphalt Pavement Association (NAPA). 2008. http://www.hotmix.org (accessed October 19, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

University of New Hampshire (UNH). 2007. 2007 Annual Report. University of New Hampshire, Stormwater Center. http://ciceet.unh.edu/unh_stormwater_report_2007/index.php (accessed October 19, 2009).

Yoko, G. 2005. From the Ground Up (Article #331). http://www.sldtonline.com/content/view/213/70 (accessed October 19, 2009).

Available Vendor Products

The names of vendor products that appear here are for information only. The vendor products listed below are NOT APPROVED FOR USE by the California Department of Transportation. Their appearance here IS NOT AN ENDORSEMENT OF THE PRODUCTS BY CALTRANS OR THE STATE OF CALIFORNIA.

None identified

Alternative Designs

None identified

BMP Fact Sheet
Porous Surface
Concrete Pavement

Description

Concrete porous surfaces allow infiltration into either storage basins or, more typically, into underlying soils. This unique cement-based concrete product with a porous structure is comprised of Portland cement, coarse aggregate rock, and water. The porous texture allows water to drain through it and into the underlying soils or reservoir. Because water infiltrates, hazards associated with standing water are less likely. An overflow mechanism is recommended in case of clogging of the underlying soils or reservoir. Suppliers of traditional concrete can usually mix and deliver porous concrete.

Schematic

Source: Puget Sound Partnership

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	✓

* Removals are assumed to be due to 100% infiltration of the design water quality volume because no water is discharged to surface waters. Blank cells indicate data not available or poor treatment performance. Removals reported in literature are usually based on overflows from the reservoir course (UNH 2007).

Key Design Elements

- Water quality volume
- Permeability of soil
- Distance to groundwater
- Load requirements
- Gradation of concrete mix

Advantages

- Eliminates surface discharge up to the design storm when properly sized in suitable soils
- Below grade infiltration inhibits access for mosquitoes
- Reduces or eliminates space needed for other BMPs
- Infiltration addresses all pollutants, except litter
- Caltrans modeling indicates that underlying soils will not likely become hazardous within five or more years, and typical Caltrans concentrations will not likely impact groundwater quality (Caltrans 2016)

Constraints

- Only suitable for low traffic areas, such as Park and Ride lots
- Low permeability in the subgrade will increase discharge through the over drain and decrease removal efficiency
- Not feasible where traction sand is applied
- More costly than traditional asphalt concrete
- Potential contamination from spills
- Water quality benefit expected to deteriorate with pavement age due to clogging of pores in the porous concrete

Porous Surface

Concrete Pavement

Maintenance Issues

Requirements:

- Inspect porous pavements annually
- Vacuum-style street sweepers are recommended, but not required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Requires no additional right-of-way

Siting Constraints:

- Similar to siting constraints for infiltration BMPs
- Some considerations are depth to groundwater, subgrade permeability, and soil type

Construction:

- Construction requires special care and some changes to normal practices and scheduling
- Minimize sub grade compaction to maintain soil permeability
- Before installation, erosion control should be in place until vegetation is established. Porous surface installation is recommended as the last item of construction.

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2007a. Mathematical Modeling of Fate and Transport of Aqueous Species in Stormflow Entering Infiltration Basin. Sacramento: Caltrans. Division of Environmental Analysis. CTSW-RT-06-168-17.2.

Sustainable Land Development Today. 2005. From the Ground Up (Article #331). www.sldtonline/content/view/213 (accessed October 30, 2009).

National Ready Mixed Concrete Association. 2008. www.perviouspavement.org (accessed October 30, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

Portland Cement Association & National Ready Mixed Concrete Association. Pervious Concrete Pavements (brochure). www.cement.org and www.nrmca.org (accessed October 30, 2009).

Available Vendor Products

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None identified

Alternative Designs

None identified

BMP Fact Sheet

Porous Surface

Permeable Pavers/Cellular Confinement

Description

Permeable pavers allow infiltration into either storage basins or, more typically, into underlying soils. Permeable pavers are fairly durable with a life span of approximately 20 years, and possibly more with proper maintenance. Typically built on an open-graded, crushed stone base, permeable pavers interlock or have a minimal sand-filled gap between them. As with most permeable surfaces, the lower reservoir layer is designed for load requirements and water storage capacity. An overflow mechanism for the underlying soils or reservoir is recommended in case of clogging. The pavement may also be designed to receive off-site runoff.

Schematic

Source: National Resource Conservation Service

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	✓
Total Phosphorus	✓
Pesticides	✓
Total Metals	✓
Dissolved Metals	✓
Microbiological	✓
Litter	
Biochemical Oxygen Demand (BOD)	✓
Total Dissolved Solids (TDS)	✓

* Removals are assumed to be due to 100% infiltration of the design water quality volume because no water is discharged to surface waters. Blank cells indicate data not available or poor treatment performance.

Key Design Elements

- Water quality volume
- Permeability of soil
- Distance to groundwater
- Load requirements

Advantages

- Eliminates surface discharge up to the design storm when properly sized in suitable soils
- Below grade infiltration inhibits access for mosquitoes
- Reduces or eliminates space needed for other BMPs
- Infiltration addresses all pollutants, except litter
- Caltrans modeling indicates that underlying soils will not likely become hazardous within five or more years, and typical Caltrans concentrations will not likely impact groundwater quality (Caltrans 2016)

Constraints

- Only suitable for low traffic areas, such as Park and Ride lots
- Low permeability in the subgrade will increase discharge through the over drain and decrease removal efficiency
- Not feasible where traction sand is applied
- More costly than traditional asphalt concrete
- Potential contamination from spills

BMP Fact Sheet

Porous Surface

Permeable Pavers/Cellular Confinement

Maintenance Issues

Requirements:

- Inspect annually
- Vacuum-style street sweepers are recommended, but not required

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Requires no additional right-of-way

Siting Constraints:

- Similar to siting constraints for infiltration BMPs
- Some considerations are depth to groundwater, subgrade permeability, and soil type

Construction:

- Construction requires special care and some changes to normal practices and scheduling
- Minimize sub-grade compaction maintain soil permeability
- Before installation, erosion control should be in place until vegetation is established. Porous surface installation is recommended as the last item of construction.

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2007a. Mathematical Modeling of Fate and Transport of Aqueous Species in Stormflow Entering Infiltration Basin. Sacramento: Caltrans-Division of Environmental Analysis. CTSW-RT-06-168-17.2.

Interlocking Concrete Pavement Institute. 2005. http://www.icpi.org (accessed October 29, 2009).

NCHRP. 2006a. Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual). National Cooperative Highway Research Program, Project 25-20(01).

NCHRP. 2006b. User's Guide for BMP/LID Selection (Guidelines Manual). National Cooperative Highway Research Program, Project 25-20(01).

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A large variety of products are available (too many to list)

Alternative Designs

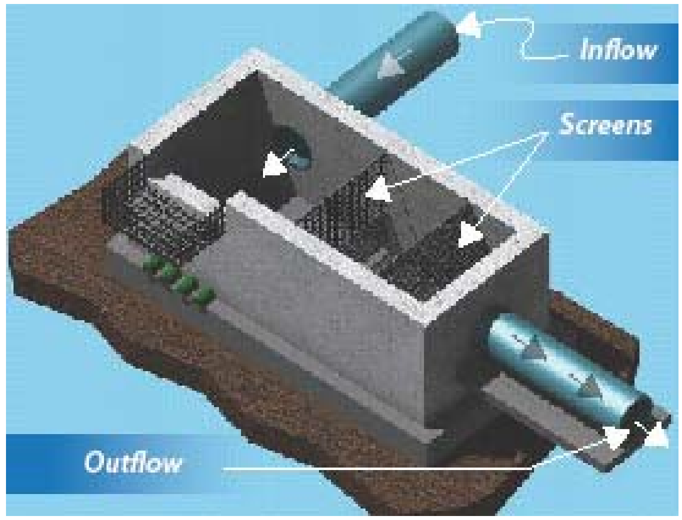
None identified

BMP Fact Sheet
Screening
Gross Solids Removal

Description

Gross solids, which consist of litter, debris, and vegetation, can be removed by passing the stormwater runoff through metal or fabric screens. Screens provide treatment by preventing solids larger than the screen opening from passing through. The effectiveness of screening systems depends on the flow rate, the type and opening size of the screen, and the type and size distribution of the gross solids in the incoming stormwater.

Schematic



Source: Caltrans

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance. Removal by small screening devices with insufficient storage capacity may not be as indicated.

Key Design Elements

- Flood flow routing and bypass
- Gross solids storage capacity
- Maintenance access
- Screen type and opening size

Advantages

- Can be retrofitted onto stormwater outfalls, pipe culverts, and channels of any shape
- Simple maintenance

Constraints

- Frequent maintenance or inspection may be required
- Requires access road for maintenance
- Maintenance activities may require traffic control if the device is installed along the traveled way

Screening

Gross Solids Removal

Maintenance Issues

Requirements:

- Requires access road for maintenance
- Frequent inspections may be required to check on the nets or screens
- Requires mechanical (Vactor) cleaning, and may require hand cleaning for some trapped solids

Special Training:

Unknown

Project Development Issues

Right-of-Way Requirements:

Increases space requirements if used for pretreatment

Siting Constraints:

Little or no site development needed to implement

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design. CTSW-RT-16-314.11.1

Available Vendor Products

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- Bandalong Litter Trap
- Gross Pollutant Trap (GPT)
- Net Cassette™
- Netting TrashTrap™
- Nutrient Separating Baffle Box
- StormScreen™
- StormTEE®
- Trashmaster™
- Bay Separator

Alternative Designs

- GSRD - Inclined Screen
- GSRD - Linear Radial

BMP Fact Sheet
Water Quality Inlet
Oil/Water Separator

Description

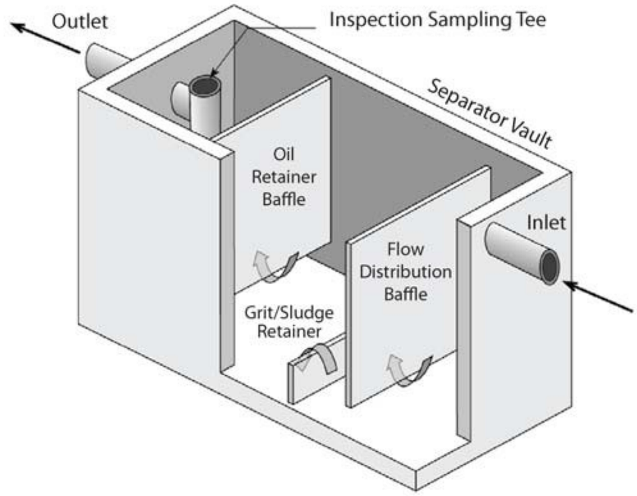
Water quality inlets, also called oil/grit separators or oil/water separators, consist of a series of chambers that promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater. Most water quality inlets also contain screens to help retain larger or floating debris, and may include a coalescing unit that helps to promote oil/water separation. Water quality inlets typically capture only the first portion of runoff for treatment, and are generally used for pretreatment of runoff before discharging to other BMPs.

Constituent Removal

Constituent Group	Removal*
Total Suspended Solids (TSS)	✓
Total Nitrogen	
Total Phosphorus	
Pesticides	
Total Metals	
Dissolved Metals	
Microbiological	
Litter	✓
Biochemical Oxygen Demand (BOD)	
Total Dissolved Solids (TDS)	

* Based on best professional judgment. Blank cells indicate data not available or poor treatment performance.

Schematic



Source: City of Medford, Oregon

Key Design Elements

- Hydraulic capacity and pollutant storage capacity
- Provision for overflow or bypass
- Detention time
- Vector control if permanent pool present
- Maintenance access

Advantages

- Relatively small footprint
- Simple maintenance

Constraints

- Limited pollutant removal, especially for fine particles and dissolved constituents
- Vector concern if permanent pool present
- Can be a source of pollutants due to decomposition of previously captured material unless maintained regularly
- May require confined space entry

BMP Fact Sheet

Water Quality Inlet

Oil/Water Separator

Maintenance Issues

Requirements:

- Because of site-specific loading, several wet season inspections may be required to determine appropriate maintenance frequency
- Vactor equipment is recommended for cleaning, but is not required
- Vector control or abatement may be required

Special Training:

Training may be required for confined space entry

Project Development Issues

Right-of-Way Requirements:

Relatively small footprint

Siting Constraints:

- Minimal head requirement
- Effective oil removal by similar technologies usually requires influent concentrations above 50 mg/L (Caltrans 2004)

Construction:

None identified

Design, Construction, Maintenance, and Cost Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

US EPA. 1999. Storm Water Technology Fact Sheet, Water Quality Inlets. EPA 832-F-99-029.

Available Vendor Products

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- ADS® Water Quality Unit
- BioSTORM™
- CrystalStream™
- First Flush - 1640FF
- Hanson Oil and Grit Separator Unit
- Kleerwater™
- SNOUT®
- VortClarex™
- BaySaver® BaySeparator
- Clara™
- EcoSep®
- Hancor®-Storm Water Quality Unit
- HD Q-Pac®
- PSI Separator
- StormVault™

Alternative Designs

None identified

APPENDIX C: CALTRANS-APPROVED BMP FACT SHEETS

Appendix C presents fact sheets for BMPs approved for installation on Caltrans facilities. Implementation of these BMPs should follow the guidelines in the Storm Water Management Plan and the Storm Water Project Planning and Design Guide (PPDG).

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BMP Fact Sheet

Biofiltration

Strip

Description

Biofiltration strips are relatively flat, vegetated areas that accept stormwater runoff as sheet flow. Removal mechanisms include sedimentation, filtration, and infiltration. Strips can be used as pretreatment to infiltration trenches and basins, and sand filters. They can also be used in treatment trains with other BMPs.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	◒	●
Total Nitrogen	◒	◒
Total Phosphorus	○	◒
Pesticides	○	○
Total Metals	●	●
Dissolved Metals	◒	●
Microbiological	◒	◒
Litter	NA	
Biochemical Oxygen Demand (BOD)	○	○
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removal Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

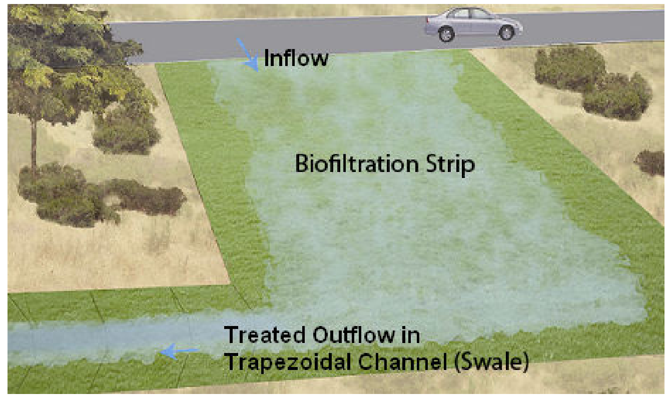
Notes:

Three biofiltration strips were sited, constructed, and monitored as part of the Caltrans BMP Retrofit Pilot Program (2004). Total nitrogen load removal is mostly dependent on infiltration losses. Phosphorus concentrations increased but infiltration compensated so that there was no net export of phosphorus load. This may be due to the vegetation selection of salt grass, which can uptake phosphorus and excrete it on its leaves. Phosphorus removal efficiency may be higher with alternative vegetation. BOD ratings are based on metadata compiled by Young et al. (1996). Pesticide ratings are based on the "Evaluation of Factors Controlling Herbicide Runoff to Surface Water" report (Caltrans 2005). Load removal analysis has been performed for a variety of roadside conditions (Caltrans 2008). Microbiological ratings are based on Rifai (2006) and Clary (2008).

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Maximize flow paths to maximize treatment
- Specify vegetation that occurs naturally to minimize establishment and maintenance costs
- Size the strips as long (in direction of flow) and flat as the site will reasonably allow, up to sheet flow boundaries (maximum length of biofiltration strips is approximately 100 ft)
- Minimum of 70% vegetation coverage
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
■□ / □□ (upper-left quadrant filled)	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Biofiltration

Strip

Maintenance Issues

Requirements:

● Regular inspections for side slope stability, debris and sediment accumulation, vegetative cover, and presence of burrowing animals
● If acceptable cover is not achieved, re-seeding or some type of erosion control will be needed

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Large footprint, but can be placed on fill slopes and occupy the clear recovery zone

Siting Constraints:

● Requires sheet flow, so site in areas where sheet flow predominates
● Climate and soil conducive to sustainable plant growth

Construction:

Minimize soil compaction

Advantages

● High removal efficiencies for total suspended solids and total metals
● Generally inexpensive relative to other BMPs
● Potential for substantial infiltration

Constraints

● Soil may need to be conditioned to allow vegetation to establish
● Climate may preclude vegetation establishment

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Performance Demonstrations Literature Sources

Barrett, M. E. 2008. Comparison of BMP Performance Using the International BMP Database. Journal of Irrigation and Drainage Engineering, 134(5), 556-561.

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Caltrans. 2005. Evaluation of Factors Controlling Herbicide Runoff to Surface Water. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-084-73.04.

Caltrans. 2008. Roadside Vegetated Treatment Sites (RVTS) Study Final Summary Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-08-208-03-1.

Clary, J., J. E. Jones, E. R. Urbonas, M. M. Quigley, E. Strecker, and T. Wagner. 2008. Can Stormwater BMPs Remove Bacteria? New Findings from the International Stormwater BMP Database. Stormwater Magazine, 9(3). http://www.stormh2o.com/may-2008/bacterm/may-2008/bacterial-research-bmps.aspx

Read, J., T. Wevill, T. Fletcher, and A. Deletic. 2008. Variation Among Plant Species in Pollutant Removal from Stormwater in Biofiltration Systems. Water Research, 42, 893-902.

Rifai, H. 2006. Study on the Effectiveness of BMPs to Control Bacteria Loads. Austin, TX: Texas Commission on Environmental Quality.

Certifications, Verifications, or Designations

None identified

Biofiltration

Swale

Description

Biofiltration swales are vegetated conveyance channels that concentrate flow. Removal mechanisms include filtration, infiltration, and sedimentation. Swales can be integrated into treatment trains with other type of BMPs.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	◒	●
Total Nitrogen	◒	◒
Total Phosphorus	○	◒
Pesticides	○	○
Total Metals	◒	●
Dissolved Metals	◒	●
Microbiological	○	◒
Litter	NA	
Biochemical Oxygen Demand (BOD)	○	○
Total Dissolved Solids (TDS)	○	○

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

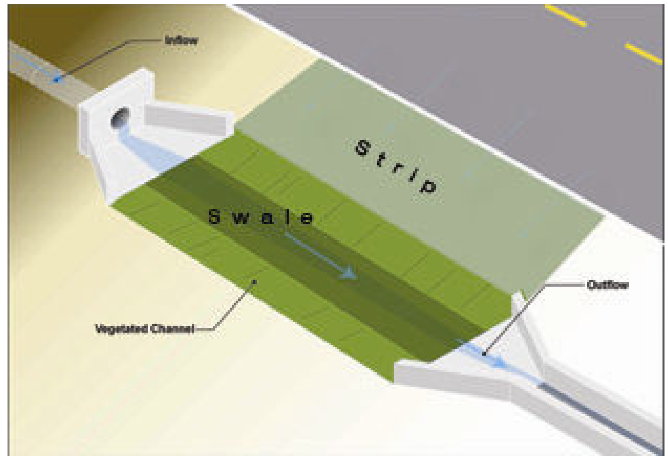
Notes:

Six biofiltration swales were sited, constructed, and monitored as part of the Caltrans BMP Retrofit Pilot Program (Caltrans 2004). Total nitrogen load removal is highly dependent on infiltration losses. Phosphorus concentrations increased but infiltration compensated so that there was no net export of phosphorus load. This may be due to the vegetation selection of salt grass, which can uptake phosphorus and excrete it on its leaves. Phosphorus removal efficiency may be higher with alternative vegetation, though analysis of the international BMP database by Barrett (2008) suggests a low removal rate. BOD ratings are based on metadata compiled by Young et al. (1996). Pesticide ratings are based on the findings in the "Evaluation of Factors Controlling Herbicide Runoff to Surface Water" report (Caltrans 2005).

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Length slope and width as quantified by the hydraulic residence time
- Specify vegetation that occurs naturally to minimize establishment and maintenance costs
- Minimum vegetation cover
- Energy dissipaters
- Side slopes constructed of narrow berms are not recommended because they are prone to damage by gophers or other burrowing animals
- Scour velocity
- Check dams may enhance infiltration
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◳	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Based on retrofit costs. Cost for new construction may be substantially lower.

Biofiltration

Swale

Maintenance Issues

Requirements:

● Regular inspections for side slope stability, debris and sediment accumulation, vegetation height, vegetative cover, and presence of burrowing animals
● If acceptable cover is not achieved, re-seeding or some type of erosion control will be needed

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Sufficient space required to achieve the target hydraulic residence time

Siting Constraints:

● Place in areas of natural lows or cut sections to minimize damage caused by gophers or other burrowing animals
● Climate and soil conducive to sustainable plant growth

Construction:

None identified

Advantages

● Incorporates well into the environment
● Effective removal efficiencies for total suspended solids and total metals
● Potential for substantial infiltration

Constraints

● Soil may need to be conditioned to allow vegetation to establish
● Climate may preclude vegetation establishment

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Performance Demonstrations Literature Sources

Barrett, M. E. 2008. Comparison of BMP Performance Using the International BMP Database. Journal of Irrigation and Drainage Engineering, 134(5), 556-561.

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Caltrans. 2005. Evaluation of Factors Controlling Herbicide Runoff to Surface Water. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-084-73.04.

Read, J., T. Wevill, T. Fletcher, and A. Deletic. 2008. Variation Among Plant Species in Pollutant Removal from Stormwater in Biofiltration Systems. Water Research, 42, 893-902.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Detention Basin

Description

A detention basin is an impoundment that collects stormwater via storm drain inlets. The basin captures and detains the design runoff volume (typically for 48 hours). Discharges from the basin typically occur through a perforated riser. The basin removes floatable debris and coarse suspended solids. Pollutant removal is achieved primarily through settling of sediments and particulate forms of pollutants.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	◒	●
Total Nitrogen	○	◒
Total Phosphorus	◒	◒
Pesticides	NA	
Total Metals	◒	●
Dissolved Metals	○	◒
Microbiological	○	○
Litter	●	◒
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removal Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

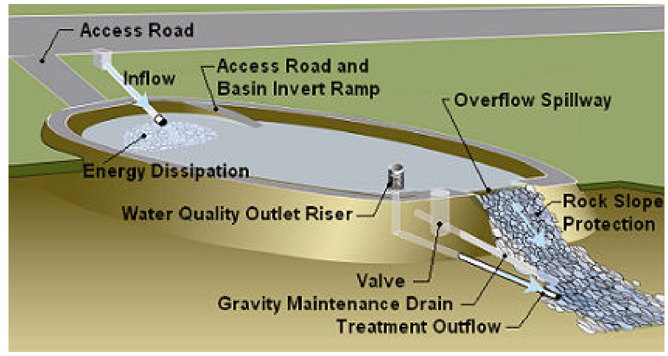
Notes:

Removal efficiency and levels of confidence ratings are based on results from unlined detention basins. The Caltrans Retrofit Pilot Program (2004) constructed five detention basins for study. The litter removal rating is based on best professional judgment.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Capture volume
- Drain time
- Debris screen to protect orifice
- Maintenance access
- Side slopes
- High flow routing
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Cost assessment is not applicable because cost effectiveness is relative to detention basins. Cost comparisons to other BMPs are based on a 20-year life cycle cost of \$673/m³ (1999 dollars) (Caltrans 2004).

Detention Basin

Maintenance Issues

Requirements:

- Regular inspections for standing water, side slope stability, debris and sediment accumulation, and vegetative cover
- If vegetative cover of the basin invert or side slopes is not established to acceptable thresholds, re-seeding or erosion control measures may need to be implemented
- Sediment removal

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Space requirements are relatively high

Siting Constraints:

- Site where there is sufficient hydraulic head to facilitate complete drainage
- Do not site in areas where groundwater contamination is a concern, unless lined (and anchored to combat floatation)

Construction:

None identified

Advantages

- Relatively easy to operate and maintain
- Potential for substantial infiltration
- Can be sited more easily than Austin filters

Constraints

- Limited pollutant removal for nutrients and dissolved constituents
- Can only be placed in areas with sufficient hydraulic head

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Glick, R., G. C. Chang, and M. E. Barrett. 1998. Monitoring and Evaluation of Stormwater Quality Control Basins, in Watershed Management: Moving from Theory to Implementation, Denver, CO, May 3-6, 1998, pp. 369-376.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Certifications, Verifications, or Designations

None identified

Dry Weather Flow Diversion

Description

A dry weather flow diversion device can divert dry weather flows from the storm drain system to the sanitary sewer system, and convey it to a publicly-owned treatment works (POTW). During wet weather, this diversion is suspended because stormwater flows can be greater than the flow the POTW is designed to manage.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	●	●
Total Phosphorus	●	●
Pesticides	●	●
Total Metals	●	●
Dissolved Metals	●	●
Microbiological	●	●
Litter	●	●
Biochemical Oxygen Demand (BOD)	●	●
Total Dissolved Solids (TDS)	●	●

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

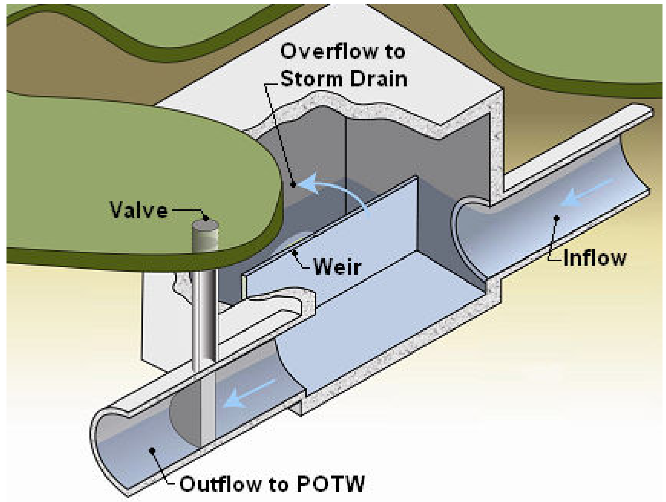
Notes:

Removal efficiency ratings are based on the diversion of dry weather flow events. The device does not treat stormwater flows when closed during wet weather.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◰	○

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Dry Weather Flow Diversion

Maintenance Issues

Requirements:

Depends on the complexity of the diversion

Special Training:

May require special training for inspection and maintenance of pumped diversions

Project Development Issues

Right-of-Way Requirements:

Small footprint

Siting Constraints:

Must be able to convey diverted flow to a POTW sewer

Construction:

Coordination required with local POTW

Advantages

Advanced treatment of the diverted flow

Constraints

- Must have agreement with POTW
- Cost is highly variable depending on site conditions

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

None identified

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Filtration

Bed

Austin Sand Filter

Description

The Austin Sand Filter includes a sedimentation basin and a filtration basin. The sedimentation basin captures and detains the design water quality runoff volume (typically for 24 hrs.) prior to discharge to the filtration basin. The sedimentation basin removes floatable debris and coarse suspended solids, and prevents premature clogging of the filter media surface. The sedimentation chamber effluent discharges to the filtration basin typically through a perforated riser. In the filtration basin, the water first passes through a sand layer, then through a geotextile layer, and finally into a gravel underdrain. Pollutant removal is achieved primarily by physical filtration of pollutants through the filtration media, and the settling of solids in the sedimentation basin. An Austin Sand Filter can also be designed so that the sedimentation and filtration sections are combined into one basin. In this design, gabions are used to disperse water and encourage sedimentation prior to the sand bed.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	○	●
Total Phosphorus	◒	●
Pesticides	NA	
Total Metals	◒	●
Dissolved Metals	◒	◒
Microbiological	◒	○
Litter	●	◒
Biochemical Oxygen Demand (BOD)	◒	◒
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

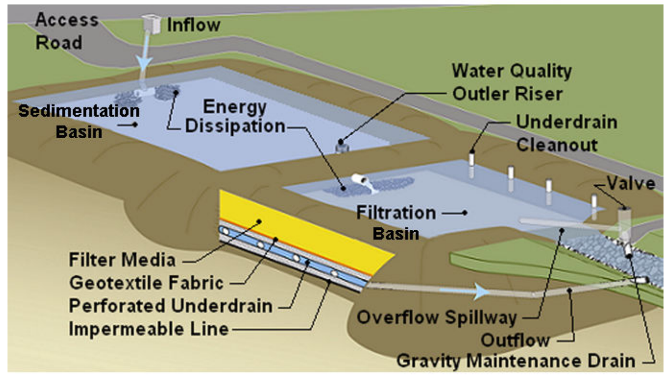
Notes:

Except where noted, removal efficiency and levels of confidence ratings are based on the Caltrans Retrofit Pilot Program Final Report (2004). Five Austin Sand Filters were constructed and monitored. While nitrate concentrations increased by 35%, total nitrogen decreased by 32%. The phosphorus removal efficiency rating is based on the average of results from Caltrans and Glick et al. (1998). BOD ratings are based on metadata compiled by Young et al. (1996). Litter removal ratings are based on best professional judgment.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Capture volume
- Orifice plate on effluent pipe to enhance sand media contact time
- Media area and depth
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◳	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Cost effectiveness determination pending further evaluation.

Filtration Bed

Austin Sand Filter

Maintenance Issues

Requirements:

- Media scraping
- Sediment removal
- Media replacement

Special Training:

Training required for media removal and replacement

Project Development Issues

Right-of-Way Requirements:

Space requirements are marginally higher than those for a detention basin

Siting Constraints:

- Head requirement of about 4 feet
- Avoid locations with base flow because of clogging due to algae growth

Construction:

If used for construction site runoff, remove and replace sand after drainage area has been completely stabilized

Advantages

- High constituent removal for suspended solids, total metals, and bacteria
- Provides consistent pollutant removal when properly maintained
- Treats runoff from drainage areas up to 20 hectares

Constraints

- Limited pollutant removal for nutrients
- More expensive to construct than a detention basin

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

US EPA. Storm Water Technology Fact Sheet, Sand Filters. EPA 832-F-99-007.

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Caltrans. 2007. Caltrans Statewide [Austin] Sand Filter Study Final 2006 Stormwater Monitoring Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-06-128.01.1.

Erickson, A. J., J. S. Gulliver, and P. T. Weiss. 2007. Enhanced Sand Filtration for Storm Water Phosphorus Removal. Journal of Environmental Engineering, 10.1061, (ASCE) 0733-9372 133:5(485).

Glick, R., G. C. Chang, and M. E. Barrett. 1998. Monitoring and Evaluation of Stormwater Quality Control Basins, in Watershed Management: Moving from Theory to Implementation, Denver, CO, May 3-6, 1998, pp. 369-376.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Filtration

Bed

Delaware Sand Filter

Description

Delaware Sand Filters are often located at the curbside edge of a paved area or parking lot, and consist of two parallel concrete chambers: a sedimentation chamber and a sand filter chamber. The sedimentation chamber holds a permanent pool of water. The sedimentation chamber removes coarse suspended solids and prevents premature clogging of the filter media surface. The sedimentation effluent discharges over a weir into the sand filter chamber where water is filtered first through a 12- to 18-inch sand filter, then through a geotextile layer, and finally into an under-drain. These on-line devices process all runoff leaving the site up to the point where the overflow limit is reached. The typical shape of the device is narrower (but longer) than some other treatment BMPs, which can be advantageous in some situations.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	○	◒
Total Phosphorus	◒	●
Pesticides	NA	
Total Metals	●	●
Dissolved Metals	◒	●
Microbiological	◒	◒
Litter	●	◒
Biochemical Oxygen Demand (BOD)	○	○
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

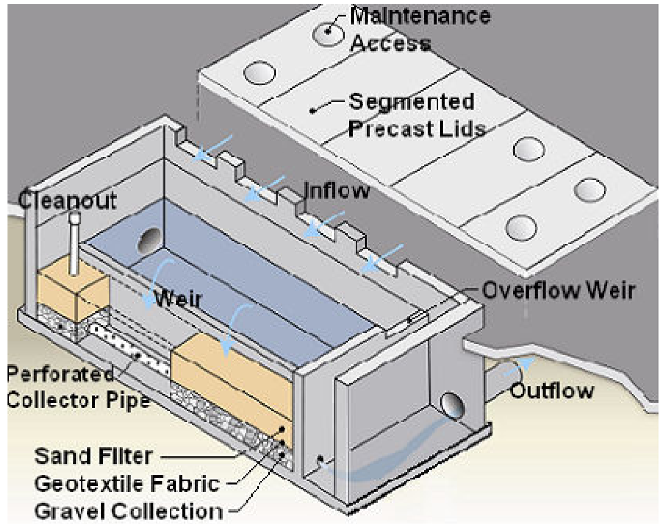
Notes:

This device was sited as part of the Caltrans BMP Retrofit Pilot Program (2004). Although not thought to be effective for removing dissolved constituents, some removal was observed. The litter removal rating is based on best professional judgment. Caltrans (2004) reported that nitrate concentrations increased by 78%, and a high removal efficiency for dissolved zinc. BOD ratings are based on metadata compiled by Young et al. (1996).

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- The Delaware unit that was evaluated was designed and installed according to the guidelines described by Young et al. (1996), which requires the sedimentation volume to equal 5 mm of runoff (0.2 inches). Consequently, if it is desired to treat a larger water quality volume, the unit must act as a flow-through device
- Size the filter based on unit values for the sedimentation chamber volume and filter bed area per acre of tributary area treated
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◳	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

BMP Fact Sheet

Filtration

Bed

Delaware Sand Filter

Maintenance Issues

Requirements:

● Maintenance for smaller, underground filters is usually best done manually
● Disposal of accumulated trash and replacement of the upper few inches of sand when the filter clogs
● Vector control or abatement

Special Training:

Training required for media removal

Project Development Issues

Right-of-Way Requirements:

Space requirements are relatively high

Siting Constraints:

● Do not site where runoff from bare soil or construction activities will be allowed to enter the filter
● Minimum head requirement of 3 feet
● Avoid locations with base flow

Construction:

None identified

Advantages

● Can be installed underground in urban settings with covers appropriate for the intended above ground land use, such as sidewalk or landscaping
● Similar in performance to the Austin Filter design with the principal advantage being narrower footprint that requires less head
● Waste media from the filters does not appear to be toxic and is likely to be environmentally safe for landfill disposal

Constraints

● The sedimentation basin holds a permanent pool of water and has the potential to provide breeding opportunities for mosquitoes
● Relatively expensive to construct compared to other approved BMPs (Caltrans 2004)
● Limited pollutant removal capability for nutrients

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

US EPA. Storm Water Technology Fact Sheet, Sand Filters. EPA 832-F-99-007.

Performance Demonstrations Literature Sources

Bell, W., L. Stokes, L. J. Gavan,and T. N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs. Department of Transportation and Environmental Services. Alexandria, VA. p. 140.

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Horner, R. R., and C. R. Horner. 1995. Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part III. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA.

Shaver, E., and R. Baldwin. 1991. Sand Filter Design for Water Quality Treatment. Delaware Department of Natural Resources and Environmental Control. Dover, DE. 14 pp.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Infiltration

Basin

Description

Infiltration basins are depressions used to detain stormwater runoff until it percolates into the groundwater table. Pollutant removal occurs through the infiltration of runoff and the adsorption of pollutants into the soil and vegetation. Infiltration basins are designed to infiltrate within 72 hours to prevent vector problems due to standing water. There needs to be sufficient space between the basin invert and the seasonally high groundwater elevation to allow infiltration to occur.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	●	●
Total Phosphorus	●	●
Pesticides	●	●
Total Metals	●	●
Dissolved Metals	●	●
Microbiological	●	●
Litter	●	●
Biochemical Oxygen Demand (BOD)	●	●
Total Dissolved Solids (TDS)	●	●

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

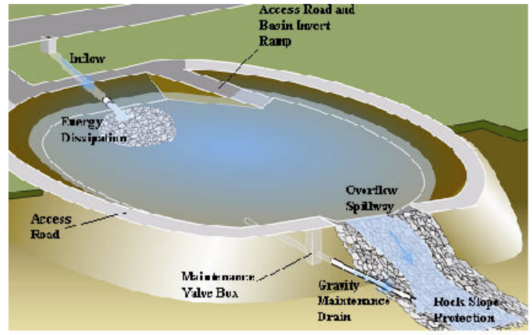
Notes:

The removal rating for infiltration is assumed to be 100% for the design water quality volume because no water is discharged to surface waters. Removal efficiencies reported in the literature are usually based on overflow discharge (Young et al. 1996). Litter is assumed to be captured within the basin.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Capture volume
- Basin invert area
- Maintenance access
- High flow routing
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
▚ (upper left quadrant filled)	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Based on Caltrans data (2004)

Infiltration

Basin

Maintenance Issues

Requirements:

● Conduct regular inspections for standing water, debris and sediment accumulation, and slope stability
● Avoid rubber tired vehicles in basin to reduce compaction
● Tracked equipment recommended for major maintenance

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Space requirements are relatively high for infiltration basins

Siting Constraints:

● Infiltration basins can only be placed in areas where soil is hydrologic soil group type A, B, or C soils and that meet permeability requirements
● Soil cannot have more than 30% clay or more than 40% clay and silt combined
● Minimum infiltration rate of 0.5 in/hr is preferred
● Distance between the groundwater elevation and the basin invert should be at least 4 feet, but 10 feet is preferable

Construction:

● Stabilize area draining into the facility. If possible, place a diversion berm to prevent sediment from entering the facility
● Build the basin without driving heavy equipment over the infiltration surface. Any equipment should have "low pressure" treads or tires
● After final grading, deeply till the infiltration surface
● Use appropriate erosion control seed mix

Advantages

Due to the infiltration of the entire water quality volume, the constituent removal is considered to be 100%

Constraints

● Site only in areas with the appropriate soil type/content and distance from the groundwater elevation to facilitate infiltration
● Restrict use if the runoff does not meet the requirement of a RWQCB-issued Basin Plan, or if the potential site is above a known pollutant plume

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Gaus, J. 1993. Soils of Infiltration Basins in the Puget Sound Region: Trace Metals and Concentrations. Masters Thesis. Univ. of Washington.

Hilding, K. 1993. A Study of Infiltration Basins in the Puget Sound Region. Masters Thesis. Dept. of Biological and Agricultural Engineering. Univ. of California, Davis.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Infiltration Trench

Description

An infiltration trench is typically a long and narrow excavation that is lined with filter fabric and backfilled with stone aggregate or gravel to form an underground basin. Runoff is diverted to the trench and infiltrates into the soil. Pollutants are filtered out of the runoff as it infiltrates the surrounding soils. Infiltration trenches must be sited in areas where soils meet the minimum infiltration rate. Regulators may caution against installation of this device in highly industrial areas or areas where highly soluble constituents may be discharged to the trench.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	●	●
Total Phosphorus	●	●
Pesticides	●	●
Total Metals	●	●
Dissolved Metals	●	●
Microbiological	●	●
Litter	●	●
Biochemical Oxygen Demand (BOD)	●	●
Total Dissolved Solids (TDS)	●	●

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

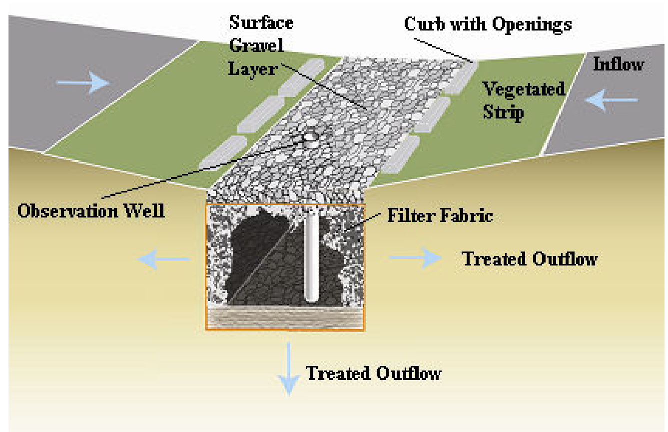
Notes:

Two infiltration trenches were evaluated as part of the Caltrans BMP Retrofit Pilot Program (2004). The removal rating for infiltration is assumed to be 100% for the design water quality volume because no water is discharged to surface waters. Removal efficiencies reported in the literature are usually based on overflow discharge (Young et al. 1996). Litter is assumed to be captured within the basin.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Trench depth and invert area
- Capture volume
- Backfill material
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
▝	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

BMP Fact Sheet

Infiltration

Trench

Maintenance Issues

Requirements:

● Remove trash and debris from the site on a regular basis
● Sediment accumulation should be inspected and, if visible on top of the trench, the top layer of trench, silt, filter fabric, and stone should be removed
● Replace fabric; stone can be reinstalled after it is washed

Special Training:
None identified

Project Development Issues

Right-of-Way Requirements:
Space requirements are relatively high, but it can fit in a narrow right-of-way

Siting Constraints:
● Do not site within about 100 feet of building or bridge foundations. Infiltration trenches sited within about 100 feet would require detailed site structural and geotechnical investigation. Infiltration trenches are suitable for drainage areas up to 4 hectares. Trenches work best at sites with an up-gradient drainage area slope of less then 5%
● Trenches should be sited where infiltration rates are at least one-half in/hr and there is at least about 10 feet separation between trench invert and the groundwater
● Trenches are not recommended in industrial land use areas or in locations were soluble constituents may impact ground water quality

Construction:
● During excavation for trench construction, light equipment should be used to avoid compaction of the soil
● Stabilize the entire area draining to the facility before construction begins. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction

Advantages

● Due to the infiltration of the entire water quality volume, the constituent removal is considered to be 100%
● Infiltration trenches can be narrow and are not highly visible

Constraints

● Infiltration trenches must have soils with adequate permeability and suitable groundwater separation
● Major maintenance (removal and replacement of the rock matrix) is relatively costly
● Pretreatment is recommended to reduce the amount of influent sediment
● Construction costs per capture volume are higher than infiltration basins
● Can clog prematurely if not properly maintained

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

US EPA. Storm Water Technology Fact Sheet, Infiltration Trench. EPA 832-F-99-019.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Litter and Debris Removal

GSRD–Inclined Screen

Description

The Gross Solids Removal Device (GSRD) Inclined Screen (IS) is a non-proprietary device whose primary function is to remove gross solids (litter and vegetative material) from stormwater runoff. Currently, there is one IS configuration approved as a full capture treatment device. This GSRD IS has a parabolic wedge-wire screen with spacing up to 5 mm (Caltrans 2007). The device is configured with an influent trough to allow some solids to settle (see schematic).

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	NA	
Total Nitrogen	NA	
Total Phosphorus	NA	
Pesticides	NA	
Total Metals	NA	
Dissolved Metals	NA	
Microbiological	NA	
Litter	●	●
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

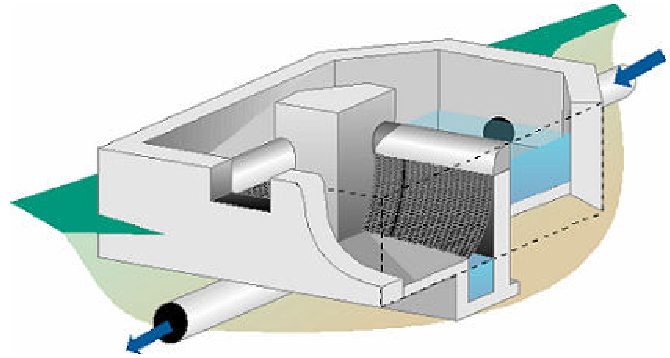
Notes:

Litter ratings are based on field studies (Caltrans 2003). Litter removal is the target constituent for the device. No long-term water quality monitoring studies have been conducted to evaluate treatment effectiveness of the GSRD IS on other water quality constituents.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Size the GSRD-IS to hold gross solids to be deposited during a 1-year period and pass the design flow (e.g., 25-year flow)
- Regulations may have a lower design storm than is associated with the drainage of the highway, and if upstream diversion is used the design event given in the regulation could be used
- Hydraulic head
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
▖	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

BMP Fact Sheet

Litter and Debris Removal

GSRD–Inclined Screen

Maintenance Issues

Requirements:

- Periodic inspections required to ensure that the device is functional
- Sediment/debris removal

Special Training:
None identified

Project Development Issues

Right-of-Way Requirements:
Small footprint

Siting Constraints:
Must provide sufficient hydraulic head to operate by gravity (about 3 feet)

Construction:
None identified

Advantages

- Small footprint
- Based on pilot studies, the devices remove nearly all the gross solids from stormwater runoff with minimal maintenance requirements

Constraints

Hydraulic head requirement

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

Caltrans. 2003a. Phase I Gross Solids Removal Devices Pilot Study: 2000-2002. Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-072.31.22.

Caltrans. 2003b. Phase II Gross Solids Removal Devices Pilot Study: 2001-2003. Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-097.31.22.

Caltrans. 2003c. Phase III Gross Solids Removal Devices Pilot Study: 2002-2003. Interim Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-099.31.24.

Certifications, Verifications, or Designations

LA RWQCB: Full Capture certification for trash

Litter and Debris Removal

GSRD–Linear Radial

Description

The Gross Removal Device (GSRD) Linear Radial (LR) is a non-proprietary device whose primary function is to remove gross solids (litter and vegetative material) from stormwater runoff. Currently, there is one GSRD LR configuration approved as a full capture treatment device. This GSRD LR utilizes a modular well casing with 5 mm x 64 mm louvers to serve as the screen. The GSRD LR is placed on a 2-percent slope.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	NA	
Total Nitrogen	NA	
Total Phosphorus	NA	
Pesticides	NA	
Total Metals	NA	
Dissolved Metals	NA	
Microbiological	NA	
Litter	●	●
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Litter ratings are based on field studies (Caltrans 2003). Litter is the target constituent for the device. No long-term water quality monitoring studies have been conducted to evaluate treatment effectiveness of the GSRDs LR on other water quality constituents.

Caltrans Evaluation Status

Approved

Schematic

Source: Caltrans

Key Design Elements

- Annual estimated gross solids loading rate size to hold gross solids to be deposited during a 1-year period and pass the design flow (e.g., 25-year flow)
- Regulations may have a lower design storm than is associated with the drainage of the highway, and if upstream diversion is used the design event given in the regulation could be used
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◱	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

BMP Fact Sheet

Litter and Debris Removal

GSRD–Linear Radial

Maintenance Issues

Requirements:

● Periodic inspections required to ensure that the device is functional

● Sediment/debris removal

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Small footprint

Siting Constraints:

● Must provide sufficient area to accommodate the length of linear radial GSRD required

● Low head requirement

Construction:

None identified

Advantages

● Small footprint

● Based on pilot studies, the device removes nearly all the gross solids from stormwater runoff with minimal maintenance requirements

Constraints

Length requirement

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

Caltrans. 2003. Phase I Gross Solids Removal Devices Pilot Study: 2000-2002. Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-072.31.22.

Certifications, Verifications, or Designations

LA RWQCB: Full Capture certification for trash

Multi-Chambered Treatment

Description

Multi-chambered treatment trains (MCTTs) use three treatment mechanisms. The first chamber is a catch basin used to remove large, grit-sized material. The second chamber is a settling chamber that removes settleable solids with tube separators, and oil and grease with sorbent pads. The third chamber is a sand/peat filter. The filtration chamber consists of a 450-mm filter media layer with a 50/50 mixture of sand and peat moss. This layer is separated from a gravel-packed underdrain by a layer of filter fabric. The filter area is determined from the recommended solids loading rate of a peat/sand mixture (5000 g TSS/m2/year). Gravity draining can be used to return the filtered runoff to the drainage system. These devices were originally designed to reduce toxicity in the runoff from critical stormwater source areas and to be implemented where toxicity in runoff is an identified problem.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	○	○
Total Phosphorus	○	○
Pesticides	NA	
Total Metals	◒	●
Dissolved Metals	○	◒
Microbiological	○	○
Litter	●	◒
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

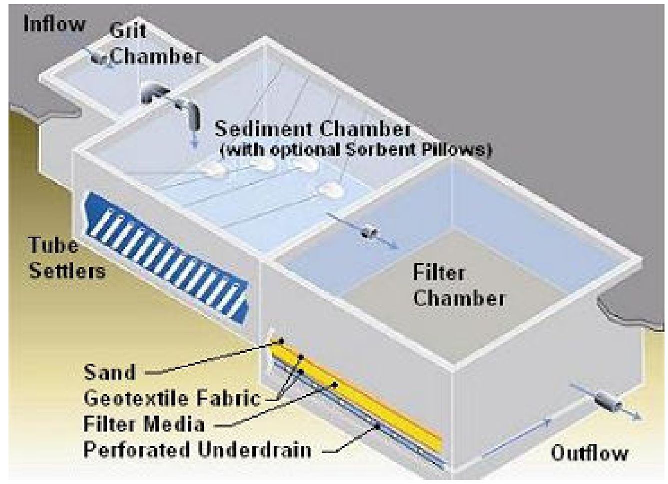
Notes:

Two MCTTs were sited, constructed, and monitored as part of the Caltrans BMP Retrofit Pilot Program (2004). The high TSS removal efficiency rating is based on Pitt et al. (1996). Caltrans data showed 75% TSS removal, but average influent was only 41 mg/L, nitrate concentrations increased by 62%, and dissolved zinc removal efficiency rating was high (Caltrans 2004). The litter removal efficiency rating is based on best professional judgment. Level of confidence based on the Caltrans study.

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Capture volume
- Mosquito proofing
- Settling chamber area
- Filter area
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◳	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Multi-Chambered Treatment


Maintenance Issues

Requirements:

● Periodic cleaning and replacement of media
● Inspection of mosquito proofing
● Vector control or abatement

Special Training:

Training required for media replacement

Project Development Issues

Right-of-Way Requirements:

Space requirements are relatively high

Siting Constraints:

● Site where there is a small, impervious contributing watershed
● Do not site MCTTs where runoff from bare soil or construction activities will be allowed to enter the filter
● MCTTs should be sited where enough vertical clearance (head) is provided, about 6.5 feet

Construction:

● Material availability for the filter, excavation for the device/unknown field conditions, and interface with existing activities at the site are the primary issues to be addressed in the construction of MCTTs
● The tube settler system is a special-order item with a significant lead-time

Advantages

● Constituent removal for suspended solids, metals, and bacteria similar to that for an Austin Sand Filter
● The MCTTs can provide consistent pollutant removal when properly maintained
● The target area for use of MCTTs are vehicle service facilities, parking areas, paved storage areas, and fueling stations with drainage areas up to 1 hectare

Constraints

● More expensive to construct than gravity-drained Austin Sand Filters, which provide comparable performance
● The presence of tube settlers in the sedimentation basin impedes maintenance activities
● A permanent pool of water is maintained in the MCTT, which increases vector concerns

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Pitt, R., B. Robertson, P. Barron, A. Ayyoubi, and S. Clark. 1999. Stormwater Treatment at Critical Areas Vol. 1: The Multi-Chambered Treatment Train. Birmingham: University of Alabama at Birmingham, Department of Civil and Environmental Engineering.

Certifications, Verifications, or Designations

None identified

BMP Fact Sheet

Traction Sand Trap

Double Barrel

Description

Double Barrel Traction Sand Traps are inverted pipe sections that capture traction sand that was previously applied to snowy or icy roads.

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	○	●
Total Nitrogen	○	○
Total Phosphorus	○	○
Pesticides	NA	
Total Metals	○	●
Dissolved Metals	○	○
Microbiological	NA	
Litter	NA	
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removal Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

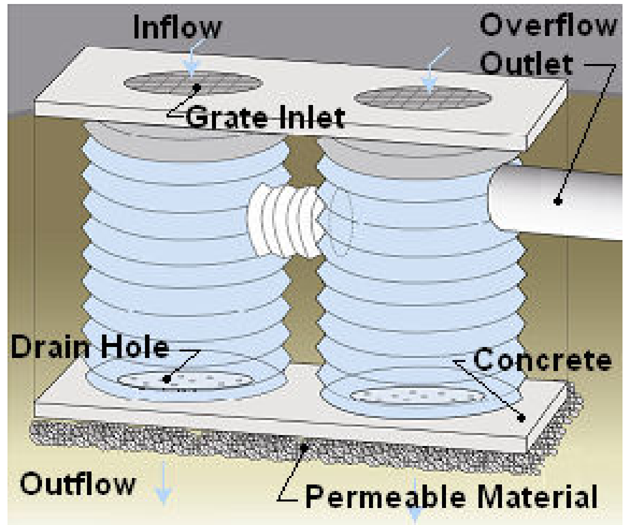
Notes:

Removal ratings and levels of confidence are based on the evaluations of two sand traps that were part of the Tahoe Sand Trap Effectiveness Study (2003).

Caltrans Evaluation Status

Approved

Schematic



Source: Caltrans

Key Design Elements

- Sand storage capacity
- Invert 3 to 6 ft above groundwater if drainage is allowed through base (CMP riser type)
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
▖ (lower-left quadrant: Benefit ↓ Cost ↓)	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

BMP Fact Sheet


Traction Sand Trap

Double Barrel

Maintenance Issues

Requirements:

- Annual vactoring out of the traction sand traps
- Vector control or abatement

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Small footprint

Siting Constraints:

Low head requirement

Construction:

None identified

Advantages

- Sand traps require very little land space
- Requires very little or no hydraulic head to operate

Constraints

Treatment for most constituents is marginal

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

Performance Demonstrations Literature Sources

Caltrans. 2003. Caltrans Tahoe Highway Runoff Characterization and Sand Trap Effectiveness Studies. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-03-054.36.02.

Certifications, Verifications, or Designations

None identified

Wet Basin/Pond

Description

A Wet Basin holds a permanent pool of water designed to detain and treat a runoff water quality volume. The basin supports plant species that provide constituent removal by biological processes. In addition, the vegetation may help reduce erosion of the side slopes and trap sediments. Sedimentation processes also occur in the basin. Wet basins are usually deep enough to prevent resuspension of particles, and should be sited where a permanent pool of water can be maintained from a dry weather flow source. In some references, this BMP is referred to as a "wet pond."

Constituent Removal

Constituent Group	Removal Efficiency	Level of Confidence
Total Suspended Solids (TSS)	●	●
Total Nitrogen	◒	◒
Total Phosphorus	○	○
Pesticides	NA	
Total Metals	●	●
Dissolved Metals	◒	●
Microbiological	●	○
Litter	●	◒
Biochemical Oxygen Demand (BOD)	NA	
Total Dissolved Solids (TDS)	NA	

Rating Key for Constituent Removel Efficiency and Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Removal ratings and levels of confidence were based on an evaluation of a wet basin as part of the Caltrans BMP Retrofit Pilot Program Study (2004). Average nitrate concentration from discharges after storm events was 132% greater than stormwater influent, however dry weather flow reductions caused a net annual removal of total nitrogen. The litter removal efficiency rating is based on best professional judgment.

Caltrans Evaluation Status

Approved

Schematic

Source: Caltrans

Key Design Elements

- Drawdown time
- Length width ratio
- Depth (deeper reduces maintenance of emerged vegetation)
- Permanent pool to capture volume ratio
- Basin side slopes
- Sedimentation forebay
- Vegetation selection
- Liner requirements
- Caltrans designers should follow the Project Planning and Design Guide (Caltrans 2007)

Cost Effectiveness Relative to Detention Basins

Cost Effectiveness	Level of Confidence
◳	●

Rating Key for Cost Effectiveness Relative to Detention Basins

Benefit ↑ Cost ↓	Benefit ↑ Cost ↑
Benefit ↓ Cost ↓	Benefit ↓ Cost ↑

Rating Key for Cost Effectiveness Level of Confidence

●	◒	○
High	Medium	Low

Notes:

Wet Basin/Pond

Maintenance Issues

Requirements:

- Sensitive species inspections
- Vegetation removal to maintain efficacy of mosquito fish
- Sediment removal (hand removal with machetes was found to be more cost-effective than mechanical removal)
- Vector control or abatement

Special Training:

None identified

Project Development Issues

Right-of-Way Requirements:

Space requirements are high for wet basins

Siting Constraints:

- A wet basin usually has an area of 1 to 3 percent of the contributing drainage area
- Soil should have a low infiltration rate or be lined with a clay or geotextile liner so that water level is maintained in the basin
- Wet basins should be sited where a permanent pool of water can be maintained from a dry weather flow source

Construction:

- Excavated soil surface should be suitable to support plant life
- If a pond liner is used, it must be carefully constructed to avoid punctures

Advantages

- High removal efficiencies for many constituents
- Recreational and aesthetic benefits

Constraints

- There are potential problems associated with mosquitoes and the device may become a regulated wetland if not consistently maintained per an established schedule
- A permanent pool of water must be maintained and therefore may have limitations on siting
- Wet basins are larger than extended detention basins

Design, Construction, Maintenance, and Cost Sources

Caltrans 2016. Caltrans Storm Water Quality Handbook: Project Planning and Design Guide. HQ Office of Stormwater Management Design CTSW-RT-16-314.11.1

King County. 2005. Surface Water Design Manual, King County Surface Water Management Division, Washington. Retrieved January 17, 2009, from Dnr.metrokc.gov/wlr/dss/2005SWDM/2005Manualwith Errata.pdf

US EPA. Storm Water Technology Fact Sheet, Wet Detention Ponds. EPA 832-F-99-048.

Performance Demonstrations Literature Sources

Caltrans. 2004. BMP Retrofit Pilot Program Final Report. Sacramento: Caltrans, Division of Environmental Analysis. CTSW-RT-01-050.

Schueler, T. R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC.

Urbonas, B. R., J. T. Doerfer, J. Sorenson, J. T. Wulliman, and T. Fairley. 1992. Urban Storm Drainage Criteria Manual, Volume 3 - Best Management Practices, Stormwater Quality, Urban Drainage and Flood Control District, Denver, CO.

Weber, S. L. 2007. Evaluation of Two Washington State Department of Transportation Stormwater Facilities Along State Route 18 Highway. Report prepared for MBA requirement from University of New Mexico.

Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. U.S. Department of Transportation.

Certifications, Verifications, or Designations

None identified