Design Considerations

- Soil for Infiltration
- Slope
- Aesthetics

Targeted Constituent	Removal
Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High
Flow Control	High

Description

An infiltration basin is a relatively large impoundment that is designed to infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually exfiltrates through the soil and eventually into the water table. This practice removes surface flow and associated pollutants through infiltration and can also help recharge groundwater, thus helping to maintain low flows in stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

California Experience

Infiltration basins have a long history of use in California, especially in the Central Valley. Basins located in Fresno were among those initially evaluated in the National Urban Runoff Program and were found to be effective at reducing the volume of runoff, while posing little long-term threat to groundwater quality (EPA, 1983; Schroeder, 1995). Proper siting of these devices is crucial as underscored by the experience of Caltrans in siting two basins in Southern California. The basin with marginal separation from groundwater and soil permeability failed immediately and could never be rehabilitated. The Water Augmentatoin Study (LASGRWC 2010) perfomred in the Los Angeles region showed no negative impact to ground water from infiltrating stormwater through infiltration practices treating stormwater from sites ranging from 0.5 acres to 7.4 acres.

Infiltration basins have been shown to be effective at reducing many of the pollutants regulated by the State and Regional Water Boards. Additionally, the Water Boards have determined that infiltration basins can qualify as a "Full Capture System (FCS)[1]" for trash. Accordingly, in addition to providing general specifications, this fact sheet includes trash-specific information to assist with upgrading either an existing BMP or the design of a planned BMP to meet the FCS definition. See the "**Full Trash Capture Compliance**" section and "***Trash FCS***" subsections in this fact sheet for more information.

Advantages

- Provides stormwater treatment and can be designed to meet hydromodification management requirements and the full capture system definition for trash control.
- 100% reduction in the load discharged to surface waters.
- Can achieve pre-development hydrology by infiltrating a significant portion of the average annual rainfall runoff.

Limitations

- Have a high failure rate if soil and subsurface conditions are not suitable.
- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C or D.

Performance

As water migrates through porous soil and rock, pollutant attenuation mechanisms include precipitation, sorption, physical filtration, and bacterial degradation (Table 1). Vegetation establishment may improve water quality performance and decrease residence time (i.e., increase water losses). If functioning properly, this approach is presumed to have high removal efficiencies for particulate pollutants and moderate removal of soluble pollutants. Actual pollutant removal in the subsurface would be expected to vary depending upon site-specific soil types. This technology eliminates discharge to surface waters except for the very largest storms; consequently, complete removal of all stormwater constituents can be assumed.

Table 1. Typical pollutant removal for constituents and removal processes

Pollutant	Typical Removal	Median Effluent Concentration[1]	Removal Processes	Treatment Depth	References
Sediment	High (90%)	9.9 mg/l	Settling, filtration and sedimentation in top 2 to 8 inches of media.	1.5 feet	Geosyntec Consultants and Wright Water Engineering 2012; Hatt et al. 2008; Hunt et al. 2012; Li and Davis 2008; Stander and Borst 2010; Maniquiz, 2010; Scholes, 2007

[1] Full Capture System (FCS): A treatment control, or series of treatment controls, including but not limited to, a multi-benefit projector a low impact development control that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour, storm in the subdrainage area, or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain.

Pollutant	Typical Removal	Median Effluent Concentration[1]	Removal Processes	Treatment Depth	References
Metals	High	TCd: 0.07 µg/L, TCr: 0.35 µg/L, TCu: 5.33 µg/L, *TFe: 1027 µg/L,* TPb: 0.19 µg/L, *TNi: 4.53 µg/L,* TZn: 12.0 µg/L	Settling with sediment and sorption to organic matter and clay in media.	2 feet	Geosyntec Consultants and Wright Water Engineering 2012; Hsieh and Davis 2005; Hunt et al. 2012; Maniquiz, 2010
Hydro-carbons	High (90-97%)	N/A	Volatilization, sorption, and degradation in mulch layer.	1 foot	Hong et al. 2006; Hunt et al. 2012; Barraud et al 1999; Dierkes and Geiger, 1999; Mikkelsen et al. 1997; Hong et al. 2006. Hsieh and Davis 2005; Pitt et al. 1999
Total phosphorus	High (-240% to 99%)	*0.240 mg/l*	Settling with sediment, sorption to organic matter and clay in media, and plant uptake. Poor removal efficiency can result from media containing high organic matter or with high background concentrations of phosphorus.	2 feet	Clark and Pitt 2009; Davis 2007; Geosyntec Consultants and Wright Water Engineering 2012; Hsieh and Davis 2005; Hunt et al. 2006; Hunt and Lord 2006; Li et al. 2010; Maniquiz 2010
Total nitrogen	High (TKN: -5% to 64%, Nitrate: 1% to 80%)	TN: 0.92 mg/l, TKN: 1.34 mg/l, $NO_{2,3}$-N: 0.37 mg/l	Sorption and settling (TKN), denitrification in IWS (nitrate), and plant uptake. Poor removal efficiency can result from media containing high organic matter.	3 feet	Barrett et al. 2013; Clark and Pitt 2009; Geosyntec Consultants and Wright Water Engineering 2012; Hunt et al. 2006; Hunt et al. 2012; Kim et al. 2003; Li et al. 2010; Passeport et al. 2009; Maniquiz, 2010; Winiarski et al. 2006

Pollutant	Typical Removal	Median Effluent Concentration[1]	Removal Processes	Treatment Depth	References
Bacteria	High	*Enterococcus*: 235 MPN/ 100 mL, *E.coli*: 101 MPN/100 mL	Sedimentation, filtration, sorption, desiccation, predation, and photolysis in mulch layer and media.	2 feet	Geosyntec Consultants and Wright Water Engineering 2012; Hathaway et al. 2009; Hathaway et al. 2011; Hunt and Lord 2006; Hunt et al. 2008; Hunt et al. 2012; Jones and Hunt 2010
Trash	High	*N/A*	Filtration	1.5 feet of media	Barrett et al. 2013

[1] Concentrations are based on bioretention performance data. Underlined effluent concentrations were (statistically) significantly lower than influent concentrations, as determined by statistical hypothesis testing on the available sampled data. Effluent concentrations displayed in *italics* were (statistically) significantly higher than influent concentrations.

Groundwater contamination concerns exists for infiltration basins (Lind and Karro, 1995; Datry et al., 2004; Pitt, 1999) but pollutant concentrations in the soil column have been shown to decrease rapidly with depth (within the first 6 to 18 inches) (Dechesne, M. et al., 2004; Dierkes and Geiger, 1999; Mikkelsen et al., 1997; Datry et al., 2004). However, pollutant concentrations can be of concern as deep as 10 feet, preferential flow pathways are suspected as the means of transport in some geologic settings (Winiarski et al. 2006). These observations warrant a 10 foot minimum between infiltration basin bottom and seasonal high water table.

Trash FCS

The Trash Amendments adopted by the State Water Board in April 2015 provide a performance standard for treatment of stormwater for trash in the form of the definition of FCS, which infiltration basin meets (see Section 5.6.1 for FCS details).

Suitability and Design

The use of infiltration basins may be limited by a number of factors, including type of native soils, climate, and location of groundwater table. Site characteristics, such as excessive slope of the drainage area, fine-grained soil types, and proximate location of the water table and bedrock, can also preclude the use of infiltration basins. The constraints of each site dictate the appropriate siting and footprint. Fundamental infiltration basin design components are as follows:

- Infiltration rate assessed on-site by a licensed geotechnical engineer or soil scientist.
- Unsuitable if known soil contamination is present, or if upstream drainage area uses or store chemicals or hazardous materials that could drain to the basin.
- 10 feet of separation between bottom of the basin and seasonal high water table.

- Drainage area that has been fully stabilized, plus use of a pretreatment BMP (e.g. grassed swales, gravity separator) at the entry point to ensure longevity.
- 10-ft setback from foundations, 100-ft from septic fields and water supply wells, and 50-ft from steep slopes.

Basin design is highly dependent on the constraints of the considered site. Costs will vary in accordance with the design. Table 2 details a number of core construction components and corresponding design considerations.

Table 2. Cost of design components and associated considerations

Component	Cost	Design Consideration
Excavation		Requires infiltration rate > 0.5 in/hr. When excavating ensure that subgrade compaction is minimized. Design for 6 to 18 inches average ponding depth. Basin should contain entire upstream WQV. After final grading, till the infiltration surface deeply
Without underdrains	\$2.75–\$5.00/ft^2	
With underdrains	\$3.90–\$6.15/ft^2	
Soil Media		1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and rooting depths) at minimum 5 in/hr infiltration. Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight. 65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock) by volume.
Recommended mix	\$2.90–\$4.30/ft^2	
With engineered media	\$3.60–\$5.40/ft^2	
Soil Media Barrier		When incorporating an underdrain, separate media from native soil with a geotextile layer, 2 to 4 inches of washed sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone.
Geotextile	\$0.45/ft^2	
Washed sand (2-inch layer)	\$0.20/ft^2	
No. 8 aggregate (min 2 inches thick)	\$0.28/ft^2	
No. 57 stone (1.5 + feet)	\$2.49/ft^2	
Hydraulic Restriction Layer		May use hydraulic restriction layer on vertical surfaces to restrict lateral flows to adjacent subgrades, foundations, or utilities.
Filter fabric	\$0.45/ft^2	
Clay	\$0.65/ft^2	
30-mil liner	\$0.35/ft^2	
Concrete barrier	\$12.00/ft^2	

Subsurface Option (Figure 1)		Constructing a subsurface facility includes excavating to depth, installing concrete unit, overdig, and backfill. Concrete unit height assumed here: 11' 4". *Requires pretreatment BMP to capture trash and debris.*
Excavation, Installation, and Backfill	\$9.20/ft²	
Concrete Unit	\$59.93/ft²	
Landscape	\$0.20–\$3.50/ft²	Armor surface with cobble or vegetation. If planted (optional), install native, deep rooting, and drought tolerant plants.

Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.

Basin invert area should be determined by the equation. Where:

$$A = \frac{WQV}{kt}$$

A = Basin invert area (m^2)

WQV = water quality volume (m^3)

k = 0.5 times the lowest field-measured hydraulic Conductivity (m/hr)

t = drawdown time (48 hr)

Design Variations

When traditional surface basins are infeasible because of land constraints, subsurface extended detention basin are ideal (Figure 1). Open space parks (e.g., baseball fields, etc.) are an example of where a subsurface infiltration basin is ideal because the park's purpose as a recreational area is not compromised. Additionally, recreational areas typical lack large structures, therefore the issue of overhead weight over the subsurface unit is not a concern.

Figure 1. Subsurface design of an infiltration basin, mid-construction.

Full Trash Capture Compliance

This section provides trash-specific information to assist with upgrading either an existing BMP or the design of a planned BMP to meet the FCS definition. In addition to developing and adopting the Trash Amendments, the State Water Board provides implementation information on its Trash Implementation web page: https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

The web page includes information on best management practices or Full Capture Systems, including lists of State-certified Multi-Benefit Trash Treatment Systems. So, when selecting BMPs for trash control, fact sheet users should refer to both this BMP fact sheet and the State Water Board's Trash Implementation web page.

Design Modifications to Prevent Trash Migration, Sustain Capacity, and Prevent Reduced Functionality

The infiltration basin must be configured to allow trash to enter the system and for trash to remain in the basin until it can be collected and removed. To meet the requirement, inlets must be designed to pass the peak flow produced by the one-year, one-hour design storm or the same flows as the capacity of the inlet storm drain and solids that would be retained by a 5 mm screen or mesh, must remain in the system.

Inlets

There are a multitude of inlet configurations that will allow trash to enter and be captured in an infiltration basin. An open inlet with a forebay is recommended.

Pretreatment

Pretreatment is beneficial to increase and consolidate trash capture while managing maintenance requirements. A forebay with mortared cobble is one example of incorporating pretreatment in the inlet (Figure 2). This configuration can slow flow and allow trash and gross solids to settle out while consolidating at the edge of the infiltration basin to make it easier for maintenance crews to collect and remove.

Figure 2. Example of a forebay as pretreatment for an infiltration basin.

Trash Containment

Once trash has been captured in an infiltration basin it must be contained so trash does not escape the infiltration basin. Containment may be provided by one or more of these features:

- an external design feature or up-gradient structure designed to bypass flows exceeding the region-specific one-year, one-hour storm event; or
- the BMP having sufficient capacity to trap particles from flows exceeding those generated by the one-year, one-hour storm event; or
- the BMP having sufficient capacity to treat either the design flows or volumes through media filtration or infiltration into native or amended soils; or
- use of a maximum 5 mm mesh screen on all outlets.

Figure 3. Example of an outlet with 5 mm screen.

Maintenance

A considerable cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin with a different technology after a relatively short period of time. To mitigate failure, ensure particulate loading of the stormwater is minimal, or is reduced with an adjacent pretreatment (i.e. vegetated buffer strip). Reducing the particulate loading enables the soils infiltrative capacity to stay high and functional.

Clogged infiltration basins reduced water quality performance but can also enable standing water to become a nuisance due to mosquito breeding. If the basin takes more than 48 hours to drain, then the rock fill should be removed and all dimensions of the basin should be increased by 2 inches to provide a fresh surface for infiltration. To mitigate failure, ensure particulate loading of the stormwater is minimal, or is reduced with an adjacent pretreatment (Figure 2). Reducing particulate loading enables the soil's infiltrative capacity to remain high and functional. Table 3 provides maintenance activity details, frequency, and costs.

Table 3. Typical maintenance activities and associated costs and frequency

Frequency	Cost	Activity
Routine Maintenance (required monthly to every 2 years)		Remove excess sediment, trash, and debris across the surface, inlet, and outlet. Check for and stabilize erosion. Pruning and mowing overgrown
Routine (small)	$7.62/ft^2	

Frequency	Cost	Activity
Routine (medium) Routine (large)	$1.91/ft^2 $1.91/ft^2	vegetation that interferes with access, or safety (if applicable).
End of Life Replacement (service life of 20 years) Replacement (small) Replacement (medium) Replacement (large)	 $10.52/ft^2 $10.17/ft^2 $10.11/ft^2	Excavate to the depth of soil media. Test soil for excessive soil contamination of common stormwater pollutants (e.g. metals, nutrients). Continue to remove underlying soil if pollutants exceed standard for contaminated soil. Replace with clean soil.
Note: Small System = 500 ft^2; Medium System = 2000 ft^2; Large System = 4000 ft^2 Underlined statement indicates that the activity may be required more frequently than shown in the table to meet the State Water Board maintenance criteria for Multi-Benefit Treatment Systems to be qualified as Full Capture Systems.		

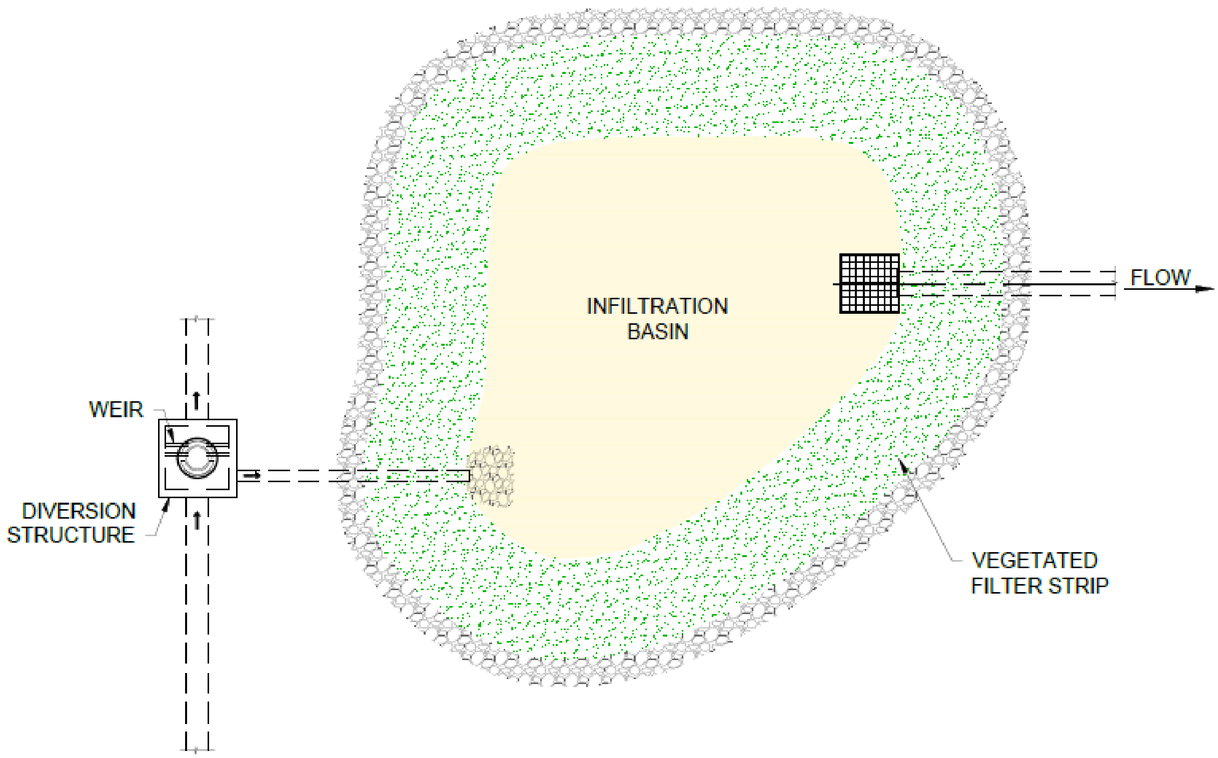
Trash FCS

Maintenance to Prevent Trash Migration, Sustain Capacity, and Prevent Reduced Functionality

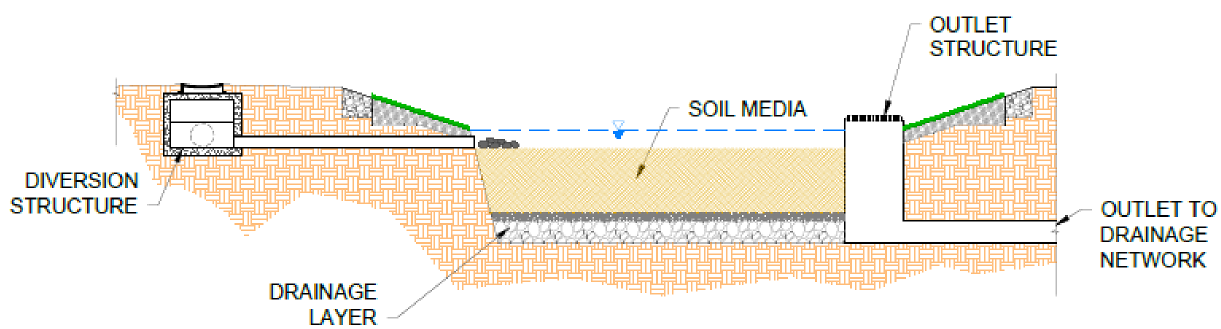
For Multi-Benefit Treatment Systems to be qualified as Full Capture Systems, the State Water Board requires regular maintenance to maintain adequate trash capture capacity and to ensure that trapped trash does not migrate offsite. Additionally, the State Water Board requires the BMP owner to establish a maintenance schedule based on site-specific factors, including the design trash capacity of the Infiltration Basin Multi-Benefit Trash Treatment System, storm frequency, and estimated or measured trash loading from the drainage area. To meet those criteria, it is likely that the frequency of trash and debris removal will have to be increased above the recommended monthly interval during the wet season to prevent trash from being blown from the BMP or being washed out of the infiltration basin in the subsequent rain events (see Table 3). Depending on the frequency and size of storms, and upstream pollutant characteristics, trash and debris removal can be as frequent as before and after every wet weather event. The optimum maintenance frequency is best determined by site observation over an average water year.

Trash maintenance not only plays a role in the functionality of the infiltration basin but also in the aesthetics and public perception of the infiltration basin (and of all BMPs). Part of maintaining positive perception among the public is the visibility of a well-maintained BMP. This positive perception can self-perpetuate further support for integrated stormwater management practices and therefore further investment in regular maintenance.

Schematic



A INFILTRATION BASIN - PLAN VIEW
- NOT TO SCALE



A INFILTRATION BASIN - SECTION
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