Addendum Sheet

Complying with the Edwards Aquifer Rules

Technical Guidance on Best Management Practices

RG-348 (Revised July 2005)

January 20, 2017

This addendum sheet lists additional information that is approved for inclusion in "Complying with the Edwards Aquifer Rules Technical Guidance on Best Management Practices" (Revised July 2005). The list indicates the location (chapter and section) where this additional information will be placed in a subsequent revision of the manual and provides the specific technical language that has been approved by the TCEQ Edwards Aquifer Protection Program.

RG-348 Location	**RG-348 Language**	**Justification**
1.4.19 Figure 1-44	**1.4.19 Sediment Control Rolls** Sediment Control Rolls (SCRs) trap detached sediments, reduce slope lengths, and decrease runoff velocity while allowing runoff to filter through the device. They are reusable, recyclable and constructed of overlapping layers of perforated polymeric sheets and one or more integrated filter. They are typically hollow tubular or rectangular assemblies that include a location flap and a method to interconnect. This measure has been tested by TxDOT and is approved for use on their projects. They function similar to silt fences, but because of their lower height are not appropriate for use where overtopping will occur except for extreme events. SCRs reduce runoff water velocity, filter out dislodged soil particles and significantly reduce the effects of slope steepness. SCRs are also used as water flow velocity dissipaters, filtering and trapping sediment. SCRs are designed to be reshaped after being run-over by construction equipment. A picture of a SCR installation is shown in Figure 1-44. This technology may be appealing for use in areas adjacent to foot traffic, since the lack of posts reduces the potential for injury.	TCEQ Approval of Innovative Technology

Figure 1-44 SCR Installed Along a Sidewalk

Limitations:

1) SCRs should not be used where there is a concentration of water in a channel or drainage way. If concentrated flow occurs after installation, corrective action must be taken such as placing a rock berm in the areas of concentrated flow.
2) If the uphill slope above the SCR exceeds 10%, the length of the slope should be less than 50 feet. For protection of large sloped areas, SCRs should be used in combination with other source control or erosion control measures – see common trouble points below.
3) Sediment Control Rolls have limited sediment capture zone (4 to 6”).
4) Do not use Sediment Control Rolls on slopes subject to creep, slumping, or landslide.

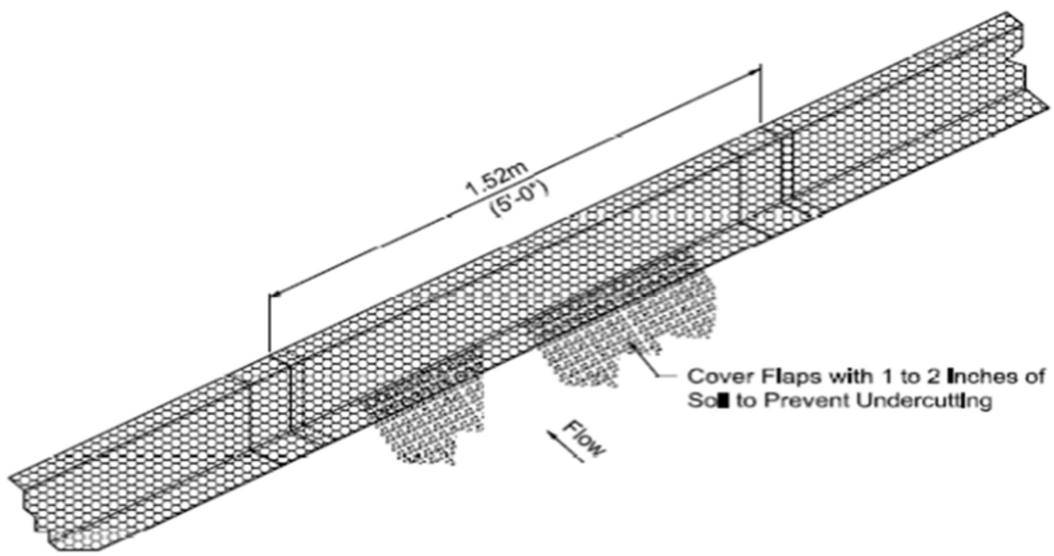
Materials:

1) SCRs are made from non-biodegradable materials at least 98% Recyclable HDPE (#2) by weight and can be recycled. The materials should be UV stabilized to stay functional or reusable for a minimum 4 years.
2) SCRs have a maximum height of 10 inches.
3) SCRs contain a filter with a minimum flow through rate of 15 gallons per sq. ft. per minute not to exceed 35 gallons per sq. ft. per minute and a percentage open area not less than 4%. Ultraviolet stability of the filter should exceed 90%.
4) Materials used in the manufacture of SCRs should be chemically resistant to acids and bases, hydrocarbons and other materials typically found at construction sites.

Guidelines for Installation:

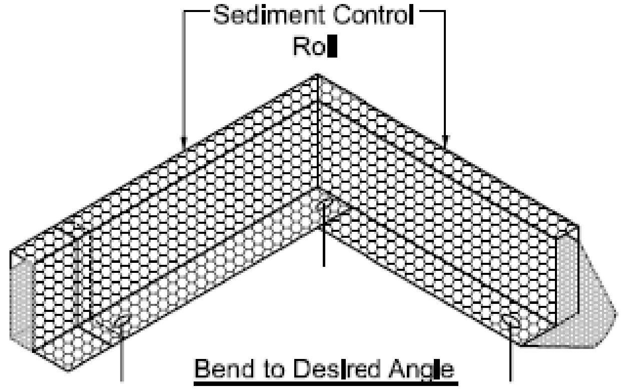
1) At a high traffic curbside, dig a trench 2” deep by 6” wide. Place SCRs in trench, on the soil surface, against curb with SCR flap directed upstream. Insure no gaps exist between the soil and the bottom of the SCR so that flowing water is forced through the filter. For other applications, it is not necessary to trench SCRs, however it is always important to key-in the flap by covering with one to two inches of soil.

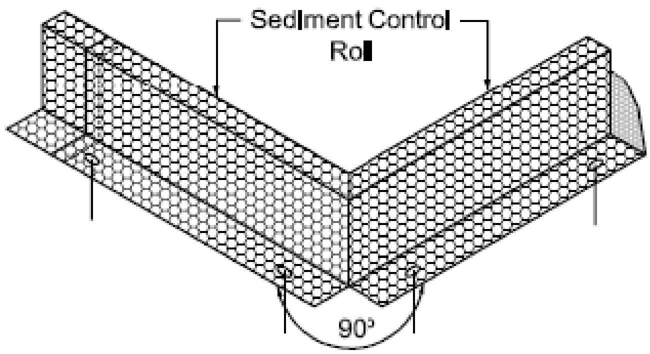
2) The end of one segment is inserted into the end of the adjoining segment and butted-up tightly. For easy assembly, tilt the male side to fit into connection joint. It is important to butt the two SCRs together firmly to prevent normal construction traffic from popping the joint open.



Straight Run on Flat Surface

3) SCRs can fold around obstacles. Slit the location flap with a pocket or utility knife. It is then possible to bend the SCR. First, squeeze the top of the SCR above slit then fold the SCR to the desired angle.





Angled Installation–90°

4) Anchor to the soil with 6 inch nails (for example 60d 6" bright common nails). Drive nails through the flap so that flap is in contact with the soil at a minimum of 2 nails every 5 foot length. To facilitate easy removal of single Sediment Control Roll lengths, do not install nail or pin in the overlap.

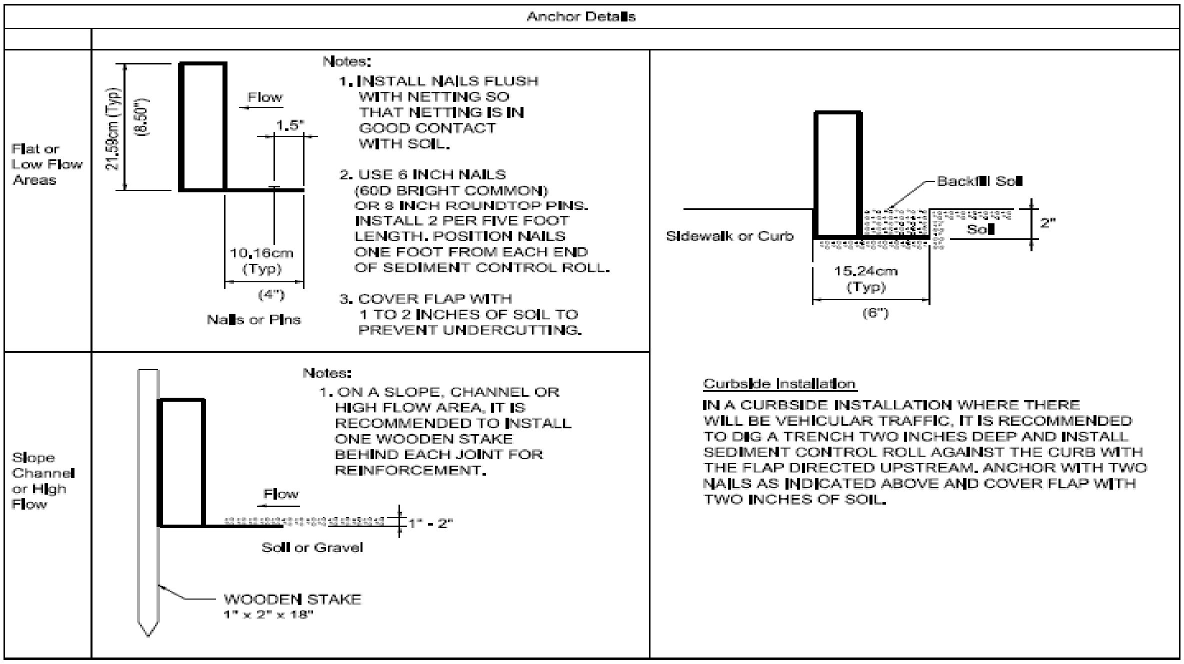
5) SCRs installed at curbside in high traffic areas should be trenched. In other applications, SCRs do NOT require trenching. The "location flap" serves to reduce undercutting. It is important to eliminate gaps under the SCRs. This can be done by back-filling or covering the location flap with soil. One to two inches of soil should be placed on top of the flap for anchoring and to minimize water undercutting.

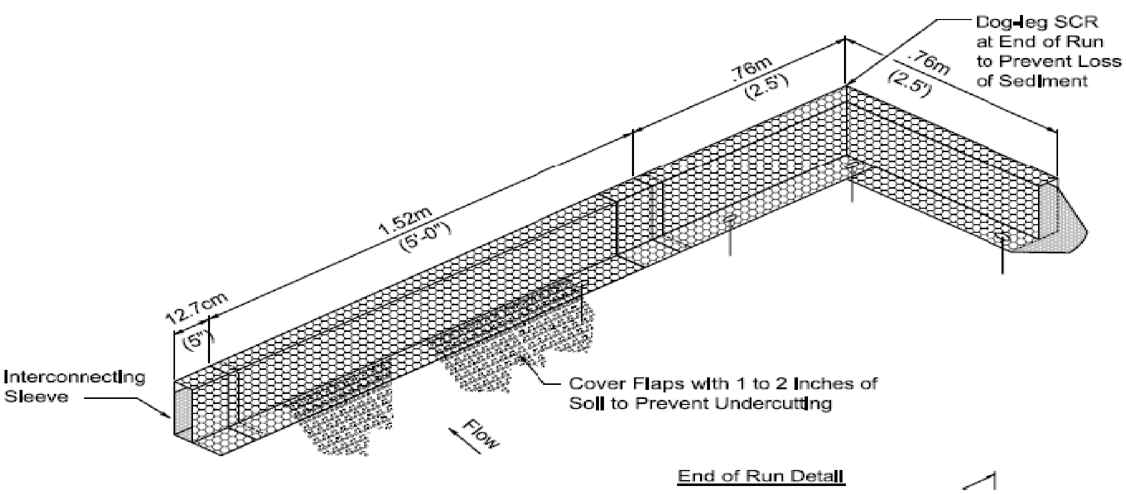
6) The last in-line SCR should be dog-legged up-slope to ensure sediment containment. It is also possible to bend part of an SCR upstream by slitting the flap where required. Cover flap as required. On a downhill run, periodically dogleg the SCR to prevent high velocity flow along, or inside the SCR.

7) High-flow areas tend to be less than 5% of the job site periphery. In high-flow areas and channels, it is recommended to reinforce Sediment Control Rolls by installing a wooden stake (1/2" X 1" X 18") behind the SCR every 5 feet.

8) When no longer required SCRs can be removed from the site and stored for reuse or relocated to another location on the project. To remove, position shovel behind

anchors. Work shovel under the SCR. Pry the anchors loose, and break-up the sediment. Once the anchors and sediment are loosened, the segment is easily removed. Assure that trapped sediment is uploaded upstream, away from the street. If not reusable due to damage, SCRs can be recycled as #2 (HDPE). Anchor materials, such as nails, can also be preserved for reuse.





Common trouble points:

1) SCR treating too large an area, or excessive channel flow (runoff overtops or collapses). In this case, SCRs can be highly effective when they are used in combination with other surface soil erosion/re-vegetation practices such as surface roughening, straw mulching, erosion control blankets, hydraulic mulching and application of bonded fiber matrix or other hydraulic soil stabilizers.
2) SCR not installed perpendicular to the flow line or not dog-legged so that runoff can escape around sides.

	3) The SCR flap not backfilled properly allowing undercutting. **Inspection and Maintenance Guidelines:** 1) Repair or replace split or torn SCRs with black 5" or 7" cable ties (zip-ties). 2) Inspect Sediment Control Rolls when rain is forecast. Inspect Sediment Control Rolls following rainfall events and a least daily during prolonged rainfall. Perform maintenance as needed or as required. 3) Sediment shall be moved when the sediment accumulation reaches 50% of the barrier height. Moved sediment shall be incorporated in the project at designated locations, upstream and/or out of any possible flow path.	
3.2.13 **Figure 3-10**	**Section 3.2.13 StormFilter®** **3.2.13 Stormwater Management StormFilter®** The Stormwater Management StormFilter® is a passive, siphon-actuated, media filled filter cartridge that traps and adsorbs particulates and pollutants. During a storm, runoff passes through the filtration media and starts filling the cartridge center tube. Air below the hood is purged through a one-way check valve as the water rises. When water reaches the top of the float, buoyant forces pull the float free and allow filtered water to drain. After the storm, the water level in the structure starts falling. A hanging water column remains under the cartridge hood until the water level reaches the scrubbing regulators. Air then rushes through the regulators releasing water and creating air bubbles that agitate the surface of the filter media, causing accumulated sediment to drop to the vault floor. This patented surface-cleaning mechanism helps restore the filter's permeability between storm events. The surface-cleaning system prevents surface blinding and extends the cartridge life cycle as well as maintenance intervals. The StormFilter is cost-effective, highly reliable, and easy to install. From small, pre-fabricated catch basins to large box culvert and panel vaults, StormFilter systems are normally installed underground, so they are often selected for use in space constrained locations. The compact design also reduces construction and installation costs by limiting excavation.	TCEQ Approval of Innovative Technology

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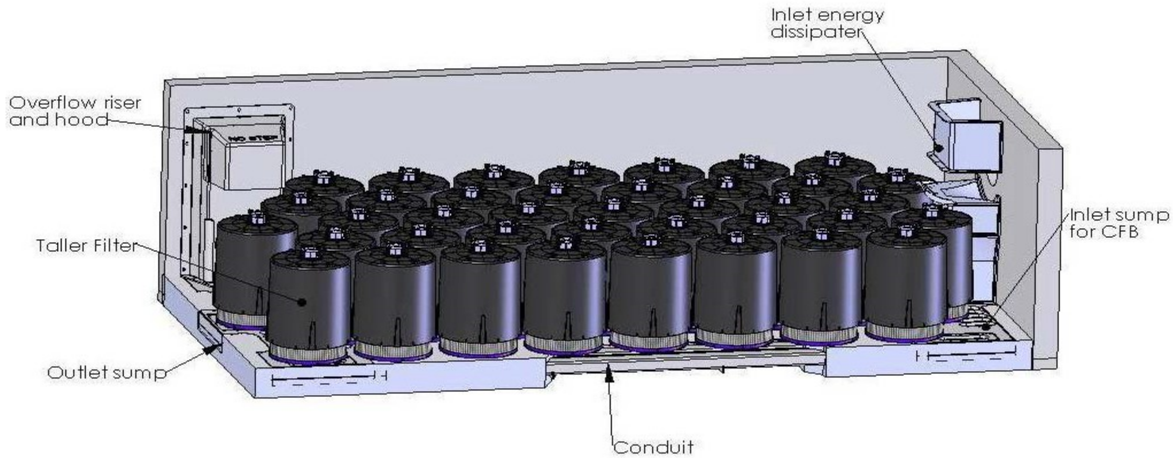
<tr><td></td><td>

Selection Criteria

Appropriate for space-limited areas
Appropriate for small to medium drainage basins
Requires a minimal amount of land since underground
Appropriate for retrofits as well as new development

Limitations

Requires drop across the system
Requires regular (targeted annually) maintenance

Cost Considerations
Cost of the StormFilter is generally less than that of a sand filter, particularly when installation costs are included.</td><td></td></tr>
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Table 3-8</td><td>Section 3.4.14 StormFilter®

The StormFilter® is a passive flow-through stormwater filtration system with filter media contained in cartridges. Field testing in multiple locations indicates a TSS removal efficiency of 83%. The StormFilter® can be used as a standalone device to treat stormwater, in a treatment train with a preceding extended detention basin, or with equalization (no credit for TSS removal) to reduce the number of cartridges required.

The Volume StormFilter® is typically composed of a storage component such as larger-diameter pipe to provide equalization followed by a filtration component composed of the rechargeable, media-filled StormFilter® cartridges. For some applications, both components may be provided in the same structure. When installed in a flow through configuration, the system must be able to treat the runoff resulting from the hyetograph below without bypass to achieve the required 80% removal efficiency. The size of the storage facility is determined by routing the design storm through the facility.

The minimum number of StormFilter® cartridges is a function of the design flow rate.</td><td>TCEQ Approval of Innovative Technology</td></tr>
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Each cartridge must be limited to a maximum specific flow rate of 1 gpm/ft2, and the total number of cartridges must be sufficient to treat the water quality volume (or flow depending on configuration) without bypass. Restrictor discs inside each StormFilter® cartridge will be used to control the discharge rate from the system. The size of the disc is calibrated to provide the design filtration rate at a specific live storage depth. Because of these discs (and the airlock cap with a one way valve), water can be impounded above the cartridges in the treatment bay. The storage facility needs to be large enough to capture and treat the design storm prior to bypass around the system. When used in a treatment train following extended detention, the number of cartridges must be sufficient to treat the maximum discharge rate of the water quality volume from the extended detention basin. Additional cartridges can be used to reduce the required maintenance frequency.

Design Criteria

Design Rainfall Depth – The design rainfall depth is dependent on the characteristics of the contributing drainage area. The method for calculation of the fraction of annual rainfall to be treated (F) and the design rainfall depth is specified in Section 3.3 of this manual (Edwards Aquifer Technical Guidance Manual, June 20, 2005).

Number of Filter Cartridges Required – The number of cartridges should be sufficient to treat the water quality volume (or flow depending on configuration) without bypass at a specific flow rate of 1 gpm/ft2. Additional cartridges can be provided to reduce maintenance frequency by using a mass-loading approach. The mass-loading design assumes that some typical mass of pollutant is washed off a site during the year. Some portion of the mass drops out in the storage component, while the balance passes through to the filtration component. The number of filter cartridges is then determined based upon the goal of removal of some balance of the mass, where each cartridge is expected to remove a certain mass per cartridge. The manufacturer can provide additional information to determine the optimum number of cartridges to balance cost with maintenance frequency.

Media Properties – The filter media should be ZPG™, a blend of zeolite, perlite and granular activated carbon.

Sizing of Filtration Chamber – The size of the filtration component is determined based on the number of cartridges required. The filtration component will typically consist of two chambers: the filtration chamber and the outlet chamber. The two chambers would be completely separated to ensure that overflows do not bypass through the unit. The restrictor discs at the base of each cartridge dictate the flow rate out of the unit. Peak outflow from the filtration component can be calculated by multiplying the number of cartridges by the cartridge filtration rate (7.5 gpm per cartridge).

Sizing of Storage Component – If a storage component is included to equalize the flow, it may be provided as pipe storage, vault storage, or other. The size of the storage component is determined by routing the design storm, with the volume increased by 20% to account for accumulation of sediment. In the flow through configuration, the design storm is defined in the table below, which must be treated without bypass to achieve the annual 80% TSS removal. The storage component and filtration component can be hydraulically connected, since the cartridge restrictor discs control the outflow from the system.

Table 3-8. Design Hyetograph to Achieve 80% TSS Removal with the StormFilter®

Time (min)	Incremental Rainfall Depth (in)
0	0.000
5	0.013
10	0.014
15	0.015
20	0.017
25	0.018
30	0.020
35	0.023
40	0.025
45	0.029
50	0.034
55	0.040
60	0.048
65	0.059
70	0.076
75	0.100
80	0.121
85	0.146
90	0.167
95	0.167
100	0.146
105	0.108
110	0.088
115	0.067
120	0.053
125	0.043
130	0.036
135	0.031

140	0.027
145	0.024
150	0.021
155	0.019
160	0.017
165	0.016
170	0.015
175	0.014
180	0.013

High-Flow Bypass – A high-flow bypass located upstream of the storage facility is recommended to divert flows in excess of the design storm around the storage and filtration components. An adjustable weir is recommended.

Sedimentation Facility – Typically, some facility is recommended to capture the mass of sediment that is expected to drop out in the storage component. This can be achieved either through 6-inches of dead storage in the storage component, or through a sedimentation (sumped) manhole between the storage component and the filtration component.

Design Assistance – The manufacturer will assist in design and provide details and supporting calculations (www.contechstormwater.com).

3.5.16 **Section 3.5.16 – StormFilter® Maintenance Guidelines**

The primary purpose of the Volume StormFilter® is to provide both storage and treatment of a design storm. The storage component of the system provides settling of particulates and capture of trash and debris, while the filtration component uses media-filled filter cartridges to remove pollutants, including finer particles, nutrients, total and dissolved metals, organics, and oil and grease.

The StormFilter® requires regular routine maintenance. Typical designs are intended for an annual maintenance cycle.

Recommended maintenance guidelines include:

- Inspections. Inspection of the storage component (and sedimentation manhole, if appropriate) should occur at a minimum of twice a year. It is recommended to wait 7 – 14 days after the last storm event, prior to making an inspection. This should allow for improved water clarity for observations in the storage facility. Sediment depth can be measured with a rod or other means. If sediment depth is greater than 1 foot, sediment removal in the storage facility is warranted.
- Cartridge Replacement. Cartridges should initially be replaced annually. If inspection of the removed cartridges indicates that their life expectancy exceeds one year, a

modified maintenance plan should be provided to TCEQ specifying the new replacement schedule. Cartridge replacement also may be required in the event of a chemical spill or due to excessive sediment loading from site erosion or extreme storms.

- Sediment Removal. Sediment removal should occur before the accumulated sediment occupies 20% of the settling chamber. Typically includes cartridge replacement and sediment removal from the vault.
- Debris and Litter Removal. Debris and litter must be removed when its presence threatens the proper operation of the system.

3.2.14

3.2.14 Storm*ceptor*®

TCEQ Approval of Innovative Technology

Storm*ceptor*® is a patented water quality treatment structure for storm drain systems. Storm*ceptor*® removes total suspended solids (TSS) and free oil (TPH) from storm water runoff through gravitational separation, and prevents small spills and non-point source pollution from entering downstream lakes and rivers. Storm*ceptor*® takes the place of a conventional manhole or inlet structure within a storm drain system. Rinker Materials manufactures the Storm*ceptor*® System with precast concrete components and a fiberglass disc insert. A diagram of a Storm*ceptor*® is presented in Figure 3-33.

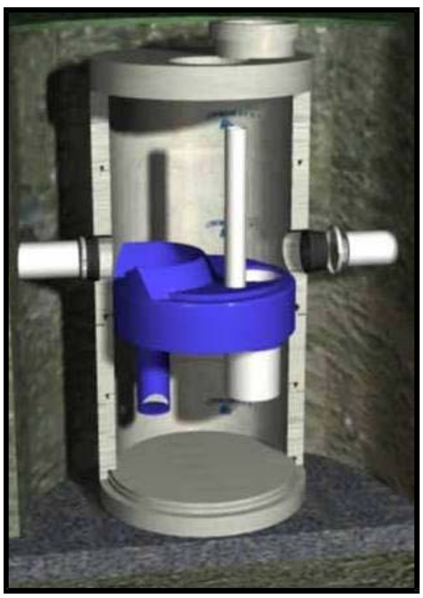
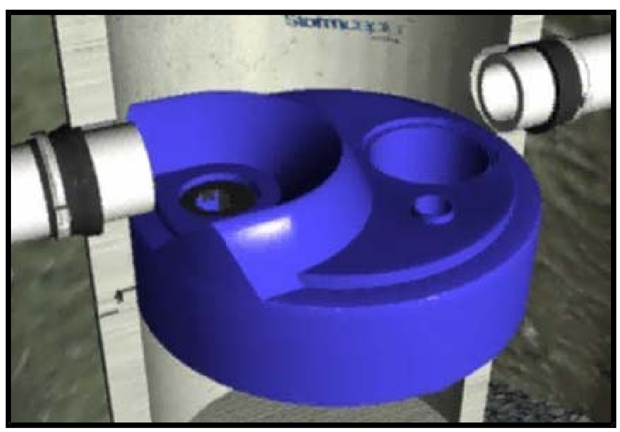


Figure 3-33 Storm*ceptor*® Diagram



The Storm*ceptor*® consists of a lower treatment/holding chamber, which is always full of water, and an upper conveyance chamber. Under standard operating conditions (frequent storm events), storm water flows in the upper conveyance chamber and is diverted down into the lower separation/holding chamber by the fiberglass weir. Flow entering the lower chamber is carefully controlled by an orifice plate, preventing excessive operational velocities, and maximizing capture and retention of suspended solids and hydrocarbons. This downward flow is directed tangentially around the circular walls of the lower chamber to maximize the flow path and detention time, reduce turbulent eddy currents, and prevent short-circuiting of flow path. Flow continues around the circumference of the unit, exits the lower chamber through the riser pipe, due to pressure head differential, and continues down the drainage system. Fine and coarse suspended solids settle to the floor of the chamber, under very low velocity (quiescent conditions), while the petroleum products rise and become trapped beneath the fiberglass insert. During infrequent high flow events, peak storm water flows will pass over the diverting weir and continue through the upper conveyance chamber into the downstream drainage system, while still providing positive treatment of storm water entering the lower chamber.

Selection Criteria

- Use only when space constraints make installation of a surface treatment system infeasible
- Achieves greater than 80% TSS removal when properly sized, so can be used as a standalone BMP, as well as in a treatment train
- Use where there is little elevation head available
- Appropriate for retrofits as well as new development

Limitations

- Below grade installation may inhibit maintenance access and require special equipment to remove accumulated sediment and other pollutants
- Requires annual removal of accumulated pollutants
- Cost for annual pumping and disposal of accumulated material in the facility is substantial
- Manhole cover must be removed to determine whether maintenance is required
- Use for relatively small catchment areas (less than 0.5 acres of 100% impervious land per single unit)
- Cannot be used as a drop structure
- Maximum treatable velocity within storm drain is 3.28 ft/s

Cost Considerations

The cost for a Stormceptor®, based on price/acre and the volume of runoff treated, may be significantly higher than many alternative technologies. Consequently, its primary use will be in space-constrained locations where surface systems such as sand filters may not be feasible.

Detailed Section

3.4.16 torm*ceptor*®

Storm*ceptor*® is a patented, below grade water quality treatment structure for storm drain systems. Storm*ceptor*® removes pollutants from storm water runoff through gravitational separation, and prevents small spills and non-point source pollution from entering downstream lakes and rivers. Storm*ceptor*® takes the place of a conventional manhole or inlet structure within a storm drain system.

Stormceptors should be located as far upstream in the drainage system as possible. The frequency of the magnitude of a flow rate is dependent on the upstream drainage area and the level of imperviousness of that drainage area. If the drainage area is too large, the required capture rate may exceed the capacity of a single unit; therefore, **the use of multiple units located on lateral storm lines rather than the main trunk line may be more beneficial both physically and economically.**

The most commonly installed unit is the In-Line Storm*ceptor*®. It is designed with single or multiple inlets and a single outlet, and is available in eight different unit sizes, ranging from 900 to 7,200 gallon separation chamber (see Figure 2 and Table 1). Each unit is constructed from precast reinforced concrete components and a patented fiberglass insert that separates the upper and lower chambers. In areas where oil or hydrocarbon/petroleum spills accumulate in substantial volume between cleaning, the fiberglass insert provides secondary containment to ensure trapped hydrocarbons are safely stored inside the treatment chamber. On single inlet inserts, the invert elevation drop across the unit is equal to 1”, while on the multiple inlet inserts the drop is 3”. Taking place of traditional inlet structures is the Inlet Storm*ceptor*® (STC 450i). The STC 450i can be used as an in-line unit, direct inlet device, or both simultaneously.

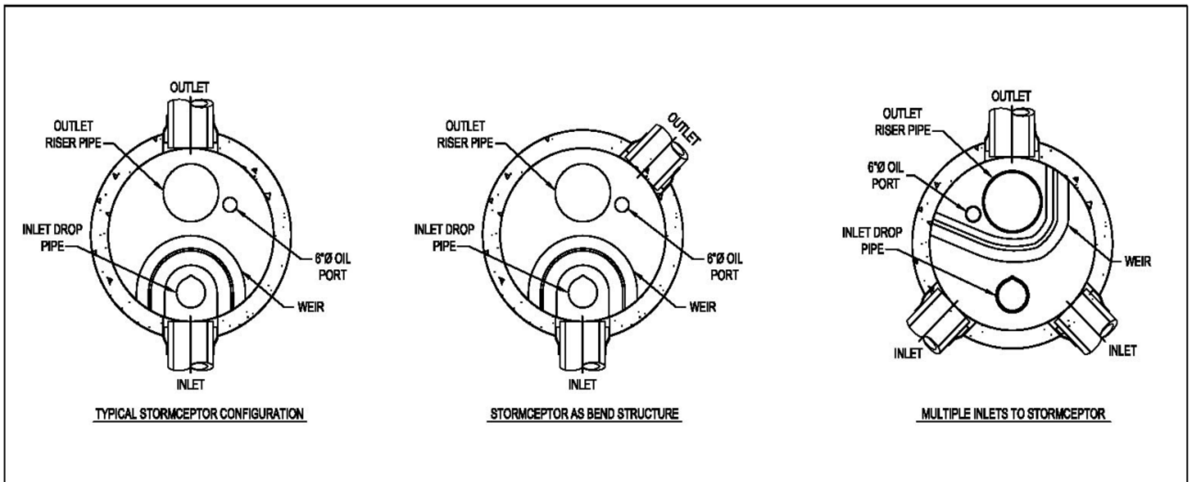


Figure 2 Storm*ceptor*® In-Line Configurations

Table 1 Stormceptor® Dimensions*			
Model	Treatment Chamber Diameter	Pipe Invert to Bottom of Base Slab	Water Surface Area
450i	4'	68"	12.57
900	6'	63"	28.27
1200	6'	79"	28.27
1800	6'	113"	28.27
2400	8'	108"	50.27
3600	8'	148"	50.27

4800	10'	140"	78.54
6000	10'	162"	78.54
7200	12'	148"	113.10
11000**	10'	140"	157.08
13000**	10'	162"	157.08
16000**	12'	148"	226.19

* Depths are approximate

** Two vertical structures

Sizing Guidelines

The Storm*ceptor*® System is designed based on the total annual rainfall (using historical rainfall data), total drainage area and the percent of impervious area. Small frequent storms account for a majority of annual rainfall and for a majority of the sediment loading.

Storm*ceptor*®sizing is based on computer simulation of suspended solids removal within the Storm*ceptor*®. This simulation is based on the USEPA SWMM Version 4.3. Solids build-up, wash-off and settling calculations were added to the hydrology code to estimate suspended solids capture by the Storm*ceptor*®.

The Wimberley Rainfall Station, collected from the National Oceanic and Atmospheric Association (NOAA), was used along with default site parameters and a predetermined particle size distribution to determine the Storm*ceptor*® model for multiple acreage sites. The results of the computer simulation were then used to develop the figure below. Table 2 is a plot of Effective Area vs. Storm*ceptor*® Model Number. The Effective Area is defined as the sum of the impervious area times 0.9 and the pervious area times 0.03.

$$EA = \left(IMP \times 0.9\right) + (PER \times 0.03)$$

Where: IMP = impervious area draining to facility

PER = pervious area draining to facility

Table 2 Storm*ceptor*® Sizing Chart

Effective Area (Ac.)	**Storm*ceptor*® Model**
E.A. < 0.015	**STC 450i**
0.015 < E.A. < 0.034	**STC 900 thru STC 1800**
0.034 < E.A. < 0.061	**STC 2400 thru STC 3600**
0.061 < E.A. < 0.095	**STC 4800 thru STC 6000**

0.095 < E.A. < 0.137	**STC 7200**
0.137 < E.A. < 0.19	**STC 11,000 thru STC 13,000**
0.19 < E.A. ≤ 0.273	**STC 16,000**

Notes:

1) Effective Area = C * A

2) Effective Area is the number of acres draining to each ***Single Stormceptor Unit***

3) Intermediate Stormceptor Models do not increase the treatable flow, but reduce maintenance cost and increase clean-out intervals

Please note that if your sizing parameters are more complex, or Stormceptor® is used within a treatment train, use Figure 3 (or Table 3) to determine the BMP Efficiency. The overflow rate is calculated using the following equation:

$$V_{OR} = \left(EA * I\right)/A$$

Where VOR = overflow rate (ft/s)

I = design storm intensity = 1.1 in/hr

A = water surface area of unit from Table 1 (ft2).

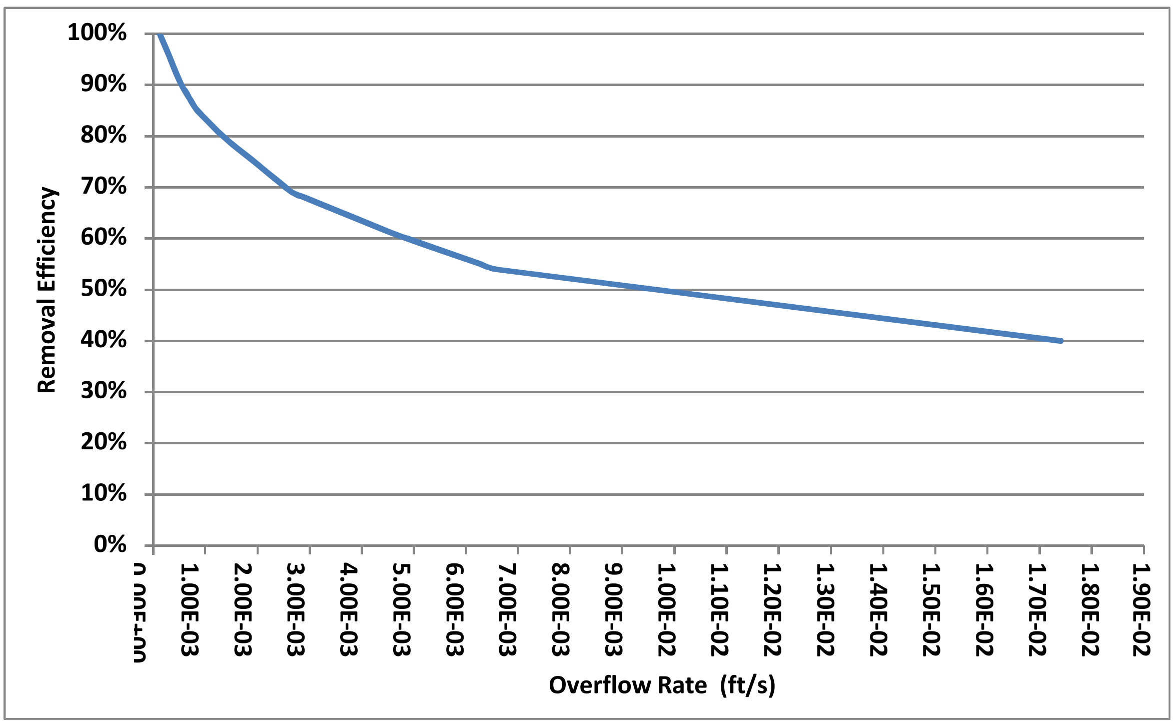


Figure 3 Relationship between Removal Efficiency and Overflow Rate

Table 3: Stormceptor BMP Efficiency vs. Overflow Rate

Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)
40%	1.74E-02	55%	6.28E-03	70%	2.54E-03	85%	8.38E-04
41%	1.66E-02	56%	6.00E-03	71%	2.42E-03	86%	7.78E-04
42%	1.58E-02	57%	5.72E-03	72%	2.30E-03	87%	7.18E-04
43%	1.51E-02	58%	5.44E-03	73%	2.18E-03	88%	6.58E-04
44%	1.43E-02	59%	5.16E-03	74%	2.06E-03	89%	5.98E-04
45%	1.35E-02	60%	4.87E-03	75%	1.93E-03	90%	5.36E-04
46%	1.27E-02	61%	4.59E-03	76%	1.81E-03	91%	4.95E-04
47%	1.20E-02	62%	4.35E-03	77%	1.69E-03	92%	4.54E-04
48%	1.12E-02	63%	4.11E-03	78%	1.57E-03	93%	4.13E-04
49%	1.04E-02	64%	3.87E-03	79%	1.45E-03	94%	3.72E-04
50%	9.65E-03	65%	3.63E-03	80%	1.33E-03	95%	3.31E-04
51%	8.88E-03	66%	3.39E-03	81%	1.23E-03	96%	2.90E-04
52%	8.11E-03	67%	3.14E-03	82%	1.13E-03	97%	2.49E-04
53%	7.34E-03	68%	2.90E-03	83%	1.04E-03	98%	2.08E-04
54%	6.56E-03	69%	2.66E-03	84%	9.38E-04	99%	1.67E-04

3.5.17

3.5.14 Storm*ceptor*® Maintenance Guidelines

Storm*ceptor*® recommends annual maintenance (1 time per year) of the Storm*ceptor*® Unit(s) in conjunction with quarterly monitoring (4 times per year). A Professional Engineer licensed by the State of Texas and knowledgeable in storm water quality treatment devices should perform inspection services. **All units with the optional trash screen must be inspected on a monthly basis at minimum. Owner must observe site conditions and determine whether or not pollutant loads require a more frequent inspection schedule.** Pollutant levels will be recorded monthly. Vacuum maintenance will be done on an annual basis at a minimum and when monitoring indicates any free oil or sediment exceeds maximum levels (see Table 2 in Storm*ceptor*® Monitoring section). Monitoring should be noted on the attached "Storm*ceptor*® Monitoring / Maintenance Plan Summary" sheet. All entries must be signed and dated by the property owner or designee. Storm*ceptor*® maintenance must be documented to include a copy of the applicable vacuum service manifest. Upon completion of the monitoring and the annual maintenance, the "Storm*ceptor*® Monitoring / Maintenance Plan Summary" sheet and all back-up documentation (to include manifest from vacuum service) should be maintained on-site.

Monitoring

Monitoring the Storm*ceptor*® unit requires a dipstick tube equipped with a ball valve (typically a Sludge Judge® or Core Pro®). A normal monitoring scenario requires removal of the manhole cover and lowering the dipstick tube through the oil port into the bottom treatment chamber (see Figure 5). Make sure the dipstick tube goes completely to the bottom. Lift the dipstick tube out of the unit and keep it in a vertical position and read the level of sediment and oils from the gauge on the dipstick. Record pollutant levels on your "Storm*ceptor*® Monitoring / Maintenance Plan Summary". Remove all trash and debris engaged with the trash screen. If the sediment in the dipstick tube exceeds the levels indicated on Table 2 or any free oil is present, maintenance of the Storm*ceptor*® is required. Please skip to "Storm*ceptor*® Maintenance". Upon completing the recording of pollutant levels, the dipstick tube is then drained back into the inlet side of the Storm*ceptor*®. This ensures that the pollutants in the dipstick tube do not leave the unit.

Table 2 – Storm*ceptor*® Maximum Pollutant Levels

Model	Down Pipe Orifice	Sediment Depth	Sediment Capacity (ft^3)
STC 450i	4"	8"	9
STC 900	6"	8"	19
STC 1200	6"	10"	25
STC 1800	6"	15"	37
STC 2400	8"	12"	49
STC 3600	8"	17"	75
STC 4800	10"	15"	101
STC 6000	10"	18"	123
STC 7200	12"	15"	149
STC 11000	10"	17"	224*
STC 13000	10"	20"	268*
STC 16000	12"	17"	319*

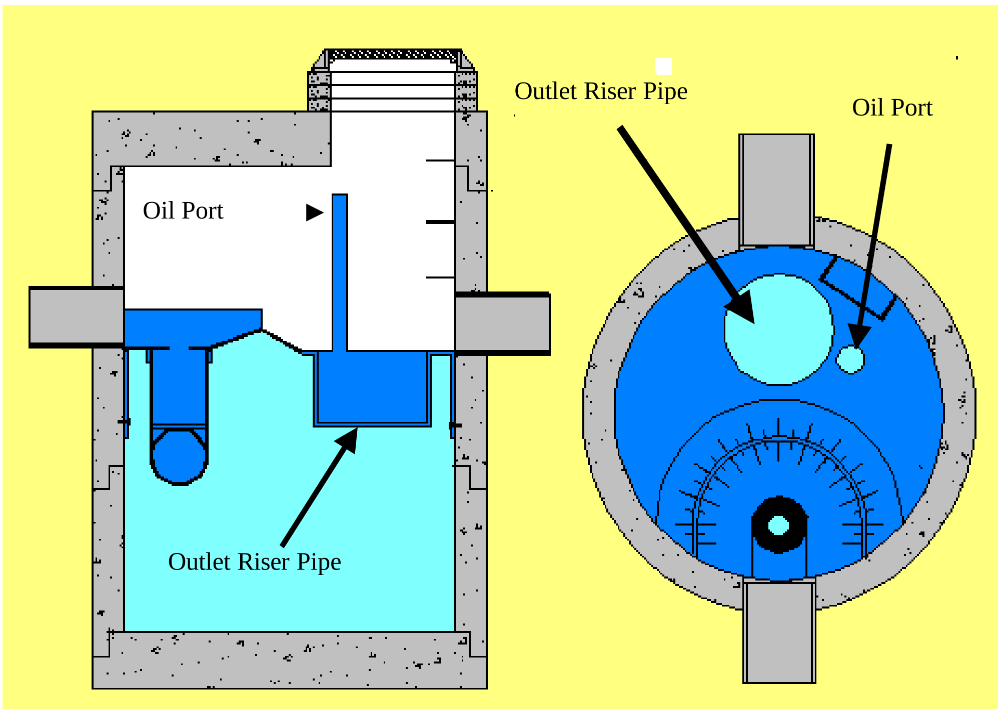
* Total both structures combined

Maintenance

Maintenance of the Storm*ceptor*® system is recommended at least once a year or when dictated by the pollutant levels referenced in Table 2. It is imperative that the Storm*ceptor*® be maintained regularly to ensure proper operation of the unit. Maintenance is accomplished when the owner contacts a representative of the vacuum service industry, a well-established sector of the service industry that cleans underground tanks, sewers, and catch basins. Cost to clean the Storm*ceptor*® will vary based on the size of the unit and transportation distances. If you need assistance for cleaning a Storm*ceptor*® unit, please contact your local Rinker Materials representative, or the Storm*ceptor*® Information Line at (800) 909-7763.

Typically, the Vacuum Service representative will maintain the Storm*ceptor*® by first removing the manhole. The vacuum service will first remove the oil through the oil port (refer to Figure 5). If the vacuum cannot remove the oils through the oil port (i.e. the vacuum service hose diameter is larger than the 6" oil port opening) water can be removed through the outlet pipe (refer to Figure 5) until such time that the oils can be removed. Typically, your vacuum service representative will recycle the oils at their facility. Sediments in the Storm*ceptor*® can be removed by inserting the vacuum service hose into the bottom treatment chamber via the outlet pipe (refer to Figure 1). In most areas the sediment, once dewatered at the vacuum service facility, can be disposed of in a sanitary landfill. Once the floatables and sediments have been removed from the Storm*ceptor*®, all remaining water in the unit must be removed. The unit is then required to be filled with clean water to the top of the riser / drop pipe. This completes the maintenance process. All waste should be disposed of in manner that complies with local, state, and federal laws and regulations pertaining to their specific situation and/or facility.

Once maintenance has been completed, document the information on the "Storm*ceptor*® Monitoring / Maintenance Plan Summary" sheet. Attach a copy of the manifest from the applicable vacuum service.



Monitoring / Maintenance Completion - Summary

Company Name: ____

Company Address: ____

City/State/Zip: ____

Phone: ____

Engineer: ____

Engineers Address: ____

City/State/Zip: ____

Phone: ____

Property Owner: ____

*Stormceptor Model ____

Monitoring / Maintenance Table

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Oil Depth (inches)												
Sediment Depth (inches)												
Completed By:												
Date												
Floatables (Optional)												

I hereby certify that the monitoring and maintenance of the Storm*ceptor*® unit was completed in accordance with the directions of the Storm*ceptor*® monitoring / maintenance plan.

____

(Signed by property owner or designee)

** Note – This form must be completed for both chambers of the STC 11000, STC 13000, and STC 16000.

Section 3.2.15

The Vortechs System

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The Vortechs system (Figure 1) is a patented hydrodynamic separator that effectively removes sediment, oil and grease, and floating and sinking debris. Its swirl concentrator and flow controls work together to minimize turbulence and provide stable storage of captured pollutants.

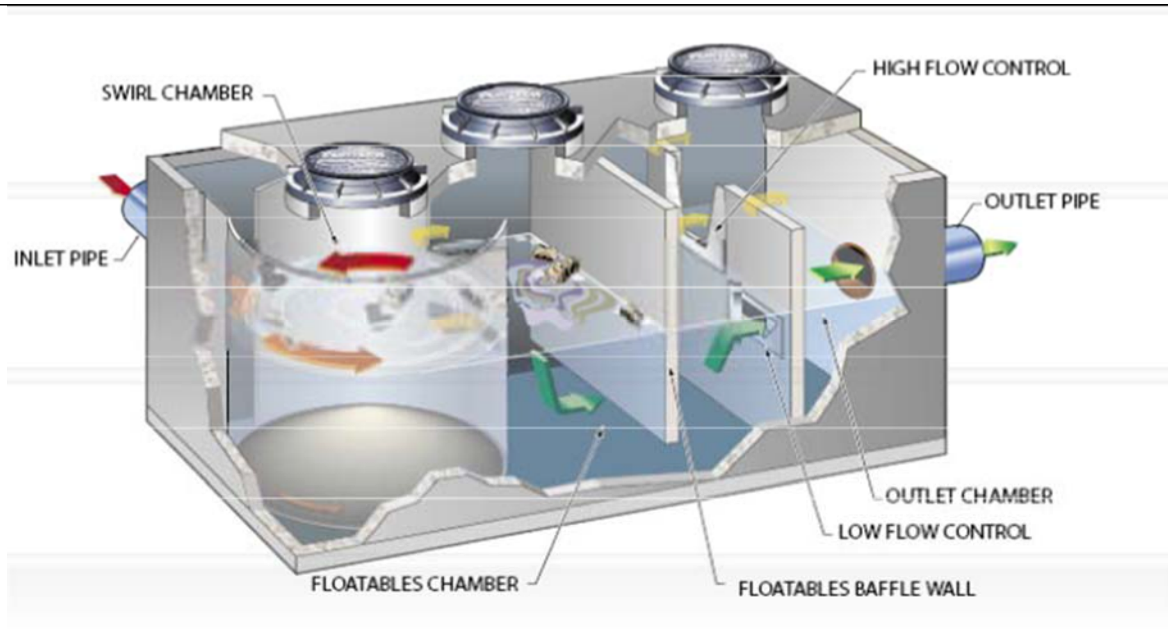


Figure 1. The Vortechs System.

Water enters the swirl chamber at a tangent, inducing a gentle swirling flow pattern and enhancing gravitational separation. Sinking pollutants stay in the swirl chamber while floating pollutants are stopped at the baffle wall. The system is designed so that the design storm is controlled exclusively by the low flow orifice. If the orifice size required to properly control the design storm is very small, a hydrobrake may be recommended to minimize the risk of orifice obstruction. This orifice effectively reduces inflow velocity and turbulence by inducing a slight backwater appropriate to the site.

During larger storms, the water level rises above the low flow control and begins to flow through the high flow control. The layer of floating pollutants is elevated above the influent pipe, preventing re-entrainment. Swirling action increases in relation to the storm intensity, which helps prevent re-suspension. When the storm drain is flowing at peak capacity, the water surface in the system approaches the top of the high flow control. The Vortechs system is sized so that previously captured pollutants are retained in the system even during these infrequent events.

As the storm subsides, treated runoff decants out of the Vortechs system at a controlled rate, restoring the water level to a dry-weather level equal to the invert of the inlet and outlet pipes. The low water level facilitates easier inspection and cleaning, and significantly reduces maintenance costs by reducing pump-out volume.

Selection Criteria

- Use only when space constraints make installation of a surface treatment system infeasible
- Appropriate for small to medium drainage basins
- Requires a minimal footprint of land

- Appropriate for retrofits as well as new development
- Appropriate for situations where a shallow profile is required

Limitations

- Requires annual removal of accumulated pollutants
- Cost for annual pumping and disposal of accumulated material in the facility is substantial
- Manhole cover must be removed to determine whether maintenance is required
- Below grade installation may inhibit maintenance access and require special equipment to remove accumulated sediment and other pollutants

Cost Considerations

The cost for a Vortechs system, based on price/acre and the volume of runoff treated, may be significantly higher than many alternative technologies. Consequently, its primary use will be in space-constrained locations where surface systems such as sand filters may not be feasible.

Section 3.4.16

Design Criteria

The Vortechs is available in several precast models. Table 1 summarizes the precast Vortechs models and dimensions:

Table 1: Vortechs Models

Vortechs Model	Swirl Chamber Diameter (ft)	Vault Width (ft)	Vault Length (ft)	Swirl Chamber Surface Area (ft^2)
Vx1000	3	3	9	7.1
Vx2000	4	4	10	12.6
Vx3000	5	5	11	19.6
Vx4000	6	6	12	28.3
Vx5000	7	7	13	38.5
Vx7000	8	8	14	50.3
Vx9000	9	9	15	63.6
Vx11000	10	10	16	78.5
Vx16000	12	12	18	113.1
Vx1319	13	13	19	132.7
Vx1421	14	14	21	153.9

The Vortechs can also be provided as a cast-in-place designed unit. These units are designed on a site-specific basis. Please contact CONTECH Stormwater Solutions for more information about this option.

The Vortechs system for the Edwards Aquifer is designed using the overflow rates provided in Table 2. These are calculated based on the surface area of the swirl chamber alone and a rainfall intensity of 1.1 inches/hour.

Table 2: Vortechs BMP Efficiency vs. Overflow Rate

Table 2: Vortechs BMP Efficiency and Overflow Rate (V_{OR})							
Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)
40%	0.0061	55%	0.0053	70%	0.0041	85%	0.0028
41%	0.0062	56%	0.0053	71%	0.0041	86%	0.0026
42%	0.0062	57%	0.0052	72%	0.0040	87%	0.0025
43%	0.0064	58%	0.0052	73%	0.0040	88%	0.0024
44%	0.0065	59%	0.0051	74%	0.0040	89%	0.0023
45%	0.0067	60%	0.0050	75%	0.0040	90%	0.0021
46%	0.0066	61%	0.0050	76%	0.0039	91%	0.0020
47%	0.0065	62%	0.0049	77%	0.0038	92%	0.0019
48%	0.0065	63%	0.0049	78%	0.0037	93%	0.0019
49%	0.0063	64%	0.0049	79%	0.0037	94%	0.0019
50%	0.0063	65%	0.0049	80%	0.0036	95%	0.0019
51%	0.0061	66%	0.0047	81%	0.0034	96%	0.0016
52%	0.0058	67%	0.0045	82%	0.0032	97%	0.0013
53%	0.0055	68%	0.0043	83%	0.0031	98%	0.0009
54%	0.0052	69%	0.0041	84%	0.0029	99%	0.0006

If additional values are required, please contact CONTECH Stormwater Solutions for more information.

Design Methodology

The Vortechs is designed based on the TSS removal and BMP sizing calculations in Section 3.3 of the manual. In a catchment area, the TSS load to be removed by the Vortechs is based upon the requirement of an 80% reduction of the increase in load resulting from development. The load required to be removed from the catchment area is calculated using Equation 3.3:

$$L_M = 27.2(A_N * P)$$

Where L_M = required TSS removal (lbs), A_N = increase in impervious cover for catchment area (ac) and P = precipitation (in).

The characteristics of the catchment area can be defined as the Effective Area (EA):

$$EA = (0.9 * A_I) + (0.03 * A_P)$$

Where EA = Effective Area, A_I = impervious area (ac) and A_P = pervious area (ac).

Using Table 3, a starting Vortechs model is selected for applications requiring 80% TSS removal. Note that this sizing methodology may require iterations on model size to determine the final unit size based on all design criteria. A larger model size may be required to offset uncaptured or untreated areas.

Table 3. Vortechs Sizing Chart for 80% removal.

Vortechs Model	Effective Area (EA)
Vx1000	EA ≤ 0.02
Vx2000	0.02 < EA ≤ 0.04
Vx3000	0.04 < EA ≤ 0.06
Vx4000	0.06 < EA ≤ 0.09
Vx5000	0.09 < EA ≤ 0.13
Vx7000	0.13 < EA ≤ 0.16
Vx9000	0.16 < EA ≤ 0.21
Vx11000	0.21 < EA ≤ 0.26
Vx16000	0.26 < EA ≤ 0.37
Vx1319	0.37 < EA ≤ 0.43
Vx1421	0.43 < EA ≤ 0.50

Using the starting model size, the overflow rate for the unit is calculated using Equation 3.5:

$$V_{OR} = (EA * I)/A$$

Where VOR = overflow rate (ft/s), I = design storm intensity = 1.1 in/hr, and A = surface area of unit from Table 1 (ft^2).

The BMP efficiency can then be determined from Table 2, using the overflow rate. If the overflow rate is between two percent efficiencies, use the smaller percent efficiency (round the overflow rate to the larger overflow rate).

Based on the BMP efficiency, the maximum load removal of the BMP (L_R) can be calculated, to confirm that the model exceeds the treatment requirement for the

	catchment area. Maximum load removal is calculated using Equation 3.8: $L_R = E * P * [(A_I * 34.6) + (A_P * 0.54)]$ Where L_R = maximum load removal of the BMP and E = BMP efficiency (in decimal form). In many cases, the maximum load removal will exceed the treatment requirement due to the distinct model sizes. In those cases, the potential for additional load removal can be applied as a credit towards uncaptured or untreated areas on the site. The TSS load credit (L_C) can be determined by calculating the difference between maximum load removal of the BMP (L_R) and the required load removal (L_M): $L_C = L_R - L_M$ The required TSS removal for the uncaptured or untreated area can be calculated using Equation 3.3 $L_{MU} = 27.2(A_{NU} * P)$ Where L_{MU} = required TSS removal from the uncaptured/untreated area (lbs) and A_{NU} = increase in impervious cover for the uncaptured/untreated area (ac). Is sufficient treatment available? If L_C is greater than or equal to L_{MU} then sufficient treatment is available. If not, then choose a larger size and repeat the calculations or redefine the catchment areas. The Vortechs unit shall be designed to treat the 1.1 in/hr storm, as well as passing the 4 in/hr storm through the unit. For flows in excess of the 4 in/hr storm that may be required to meet local design requirements, the need for external bypass should be evaluated. In general, the peak flow capacity of the Vortechs units is 100 gpm/ft^2. External bypass needs should be evaluated on a case-by-case basis. If the Vortechs is to be used as part of a treatment train, refer to Equation 3.6 for designing BMPs in series.	
Section 3.5.18	The Vortechs system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. Recommended intervals include quarterly inspections and annual maintenance. **<u>Inspections</u>**	

	Inspection is the key to effective maintenance and is easily performed. CONTECH Stormwater Solutions recommends ongoing quarterly inspections of the accumulated sediment. Pollutant deposition and transport may vary from year to year and quarterly inspections ensure that systems are cleaned out at the appropriate time. It is very useful to keep a record of each inspection, and an inspection and maintenance form is attached. All accumulated sediment, liquid contaminants, trash, litter, and debris must be removed from the system annually or when the sediment fills more than 25% of the space between the permanent water surface and the bottom of the swirl chamber, whichever occurs first. **Maintenance** Maintaining the Vortechs is easiest when there is no flow entering the system. For this reason, it is best to schedule the cleanout during dry weather. Cleanout of the Vortechs system with a vacuum truck is generally the most effective and convenient method of excavating pollutants from the system. Accumulated sediment is typically evacuated through the manhole over the swirl chamber. Simply remove the cover and insert the vacuum hose into the swirl chamber. As water is evacuated, the water level outside of the swirl chamber will drop to the same level as the crest of the lower aperture of the swirl chamber. It will not drop below this level due to the fact that the bottom and sides of the swirl chamber are sealed to the tank floor and walls. This "water lock" feature prevents water from migrating into the swirl chamber, exposing the bottom of the baffle wall. Floating pollutants will decant into the swirl chamber as the water level is drawn down. This allows most floating material to be withdrawn from the same access point above the swirl chamber. Water in the swirl chamber must be completely removed. In installations where the risk of large petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, an oil or gasoline spill should be cleaned out immediately. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use adsorbent pads since they are usually cheaper to dispose of than the oil water emulsion that may be created by vacuuming the oily layer. Trash can be netted out if you wish to separate it from the other pollutants. If maintenance is not performed as recommended, sediment may accumulate outside the swirl chamber. If this is the case, it may be necessary to pump out all chambers. It is a good idea to check for accumulation in all chambers during each maintenance event to prevent sediment buildup there. Manhole covers should be securely seated following cleaning activities, to ensure that surface runoff does not leak into the unit from above.	
Section 3.2.16	**The Permeable Friction Course** A permeable friction course (PFC) is a layer of porous asphalt up to 2 inches thick that is placed as an overlay on top of an existing conventional concrete or asphalt surface. Porous asphalt is an alternative to traditional hot mix asphalt and is produced by eliminating the fine aggregate from the asphalt mix. The overlay typically is referred to in the U.S. as Permeable Friction Courses (PFC) or Open Graded Friction Courses (OGFC). The void space in a PFC overlay generally is 18-22%. Rain that falls on the friction course drains through the porous layer to the original impervious road surface at which point the water drains along the boundary between the pavement types until the	TCEQ Approval of Innovative Technology

runoff emerges at the edge of the pavement. Historically, the main use of PFC in Texas has been to increase safety through improved visibility and better traction. An example of the reduction in spray behind vehicles is documented in Figure 1.

Figure 1 Difference in Spray from Conventional and PFC Pavements

When used as an overlay on high speed roadways with a rural cross-section (no curbs), recent research has documented TSS removal of 90% compared with conventional concrete or asphalt pavements. Consequently this material can be used to meet the TSS reduction requirements of the Edwards Rules. The open nature of the pavement reduces its strength over time, so the pavement will have to be replaced or rehabilitated periodically (approximately every 10 years) to maintain the water quality benefit, and prevent excessive raveling and pavement failure.

Selection Criteria

- Achieves 90 percent TSS removal, so can be used as a standalone BMP
- Incorporates stormwater treatment within the highway pavement
- Requires no additional purchase of right-of-way to provide stormwater treatment
- Appropriate for retrofits of existing roadways

Limitations

- May only be used on roadways with a minimum posted speed of 50 mph
- Use only on roadways without curbs and gutters
- May require specific R.O.W. restrictions and assurances of such restrictions
- Must be tested immediately following installation to demonstrate that desired permeability has been achieved.
- Should not be used in areas of heavy construction, since material tracked onto the roadway can fill the pores in the pavement and eliminate the water quality benefits
- Sand should not be applied to the pavement in cold whether to increase traction, since this will substantially reduce the permeability; however, deicing salts may be used.

	• Will require milling and replacement of the overlay at regular intervals, which entails significant expense.	
Section 3.4.17	**Design Criteria for Permeable Friction Course** A permeable friction course (PFC) is a porous asphalt overlay that removes 90% of the TSS in runoff in comparison with conventional concrete and asphalt pavements. The objectives of these design criteria are to ensure that the pavement has sufficient permeability and porosity to convey most runoff to the shoulder of the road within the pavement itself (not on the surface) and to provide storage for the accumulated TSS. To achieve a TSS removal of 90% the PFC must meet the following specifications: 1) *Material* – The PFC must meet the mixture and placement specifications in TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 342. (http://www.dot.state.tx.us/business/specifications.htm) 2) *Thickness* – The PFC must have a minimum thickness of 1.5 inches 3) *Roadway Characteristics* – The roadway should have a posted speed of at least 50 mph, and not more than 3 lanes in each direction, with typical cross slope of about 2%. The roadway must also have a rural cross-section (no curbs), so that the runoff can seep unimpeded on to the shoulder of the road. 4) *Water Quality Volume* – The water quality volume need not be calculated, since the design guidelines specified above ensure that the minimum annual pollutant reduction will be achieved. 5) *Initial Permeability Testing* – Initial permeability testing is performed after the overlay cools using the TxDOT Test Procedure Tex-246-F. Typical infiltration rate is normally less than 20 seconds for newly constructed PFC mixtures. The test should demonstrate that desired permeability of less than 60 seconds has been achieved.	
Section 3.4.19	**Maintenance Guidelines for Permeable Friction Course** ***Inspections*** In addition to the testing immediately following installation to demonstrate that the desired permeability has been achieved, routine inspections must be performed to determine that the PFC is achieving the necessary TSS removal. During the inspections a permeability test using the TxDOT Test Procedure Tex-246-F must be performed. Routine inspections should begin within 36 months after installation. Subsequent inspections should occur on a rolling 24 months period as long as the drainage time in the permeability test is less than 60 seconds. Once the drainage time exceeds 60 seconds, subsequent inspections should occur annually (rolling 12 month period). At least one such test must be performed for each mile of roadway in the project and the test locations should be located approximately equidistance from each other. A test location on the shoulder is preferred if available. At each location three tests at slightly different spots on the pavement should be tested and the geometric mean of the results reported. If more than 100 seconds are required for the water to drain, additional testing should be performed to determine the extent of clogging and the length of pavement to be	

	maintained. The new pavement must then be recertified by a Texas Licensed P.E. as achieving the desired drainage characteristics. ***Maintenance*** Maintenance of the pavement will consist of either actions to restore the permeability of the existing pavement or milling the old overlay, disposing of the used asphalt appropriately, and applying a new overlay in accordance with the guidelines specified in Section 3.4.16. Measures to restore the permeability might include sweeping or pressure washing the pavement, and material removed from the pavement must be collected and properly disposed of. Permeability tests must be performed at the time of rehabilitation or replacement to demonstrate that the pavement has the required permeability and then recertified by a Texas Licensed P.E. that the desired drainage characteristics have been achieved. If a material spill occurs on the PFC pavement, the spilled material must be removed to the extent possible including flushing of the pavement and capture of this material. The permeability of the pavement must be retested at the spill location to document that the material has not reduced the permeability below the 100 sec threshold. If the material contains solvents that affect the structural integrity of the pavement that section may need to be milled and replaced.	
Section 3.2.17	**Batch Detention Basins** A batch detention basin is an extended detention basin modified to operate as a batch reactor. A valve on the first detention basin outlet is used to capture the produced runoff for a fixed amount of time and then release it. As in an extended detention basin, the batch detention basin is primarily used to remove particulate pollutants and to reduce maximum runoff rates associated with development to their pre-development levels. Batch detention basins have superior water quality performance than traditional extended detention basins and achieve a total suspended solids (TSS) removal efficiency of 91%. (Middleton et al., 2006). These devices require less area and hydraulic head than sand filters, and provide similar TSS removal. The detention basins may be berm-encased areas, excavated basins, or buried tanks, although the latter are not preferred in most situations (below grade configurations will only be acceptable for sites of less than 5 acres). An example of a batch detention basin is pictured below in Figure **2**.	TCEQ Approval of Innovative Technology

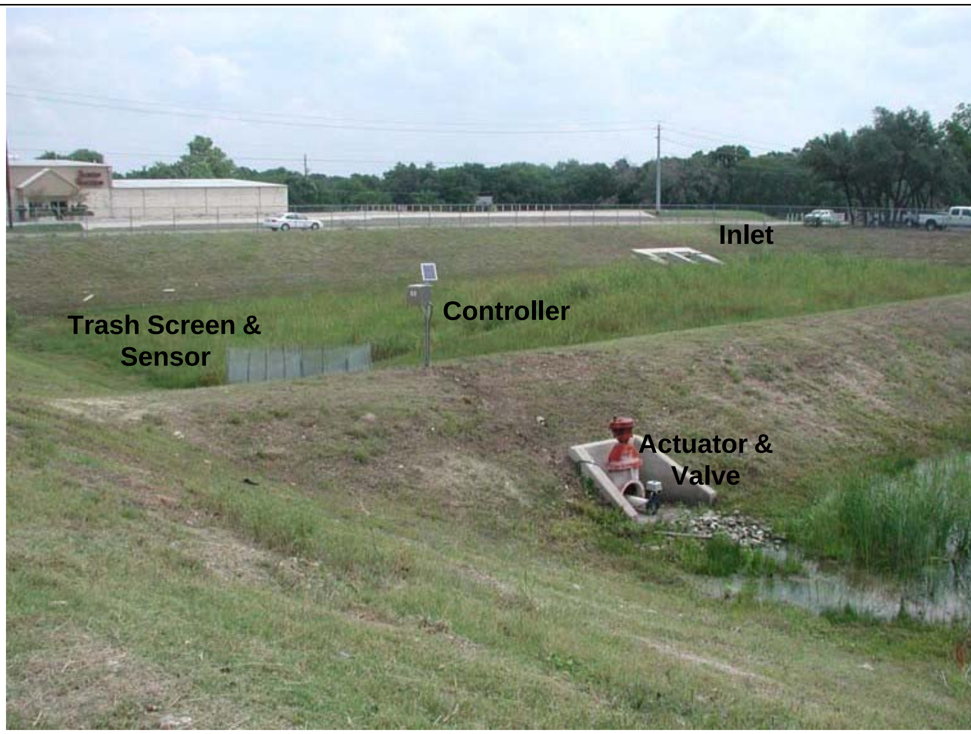


Figure 2 Batch Extended Detention Basin

A description of a batch detention basin is a series of depressed basins. The first basin temporarily stores a portion of stormwater runoff following a storm event. The collected discharge is controlled by a valve connected to the outlet structure of the first detention basin. The valve is closed between storm events. A controller opens the valve and releases the captured runoff into the second basin after a 12-hour detention time, and closes the valve after the first basin has drained. Substantial removal of TSS is achieved in the captured stormwater since the entire first flush volume is treated. Batch detention basins do not have a permanent water pool between storm events.

Selection Criteria

- Use when BMP methods are limited, because can achieve more than 80% TSS removal
- Use where water availability prevents use of wet basins
- Use where land availability is restricted (site is less than 5 acres for below grade installation) and there is little elevation head available
- Use where Hazardous Material Trap is required

Limitations

- As an active device, it may require more maintenance than a passive BMP.
- Placement of controller and actuator
- Drainage area less than 100 acres

	<u>Cost Considerations</u> This BMP is less expensive than sand filters, wet ponds, and created wetlands, but more expensive than grassy swales and vegetated buffer strips. Cost savings over sand filters results from smaller footprint and reduced construction costs. There are items to consider when designing a batch detention basin that can reduce the cost of construction. The largest single cost for the installation of a batch extended detention dry pond is the cost of excavation. Limiting the volume of excavation can therefore reduce costs substantially. This can be accomplished by utilizing natural depressions and topography as much as possible. In cases where a flood control basin already exists at the site, it may be possible to convert the existing BMP structure to provide batch detention by increasing the storage volume and modifying the outlet structure. If feasible, the conversion to a BMP structure can be made for a fraction of the cost of constructing a new pond. In addition to construction costs, maintenance costs must also be included when considering a batch detention basin. Routine maintenance costs can include money for such items as mowing, inspections, trash removal, erosion control, automatic controller repairs, and nuisance control. Non-routine maintenance costs to consider include structural basin repairs, sediment removal, and eventual replacement of the outlet structure. The frequency of sediment removal varies from basin to basin depending on the amount of sediment in the captured runoff. It is estimated, however, that batch detention basins should require sediment removal approximately every 5 to 10 years. The estimated life of outlet structures is approximately 25 years for corrugated metal and 50 to 75 years for reinforced concrete. The total annual cost for the above maintenance requirements, for both routine and non-routine maintenance has been estimated at three to five percent of the base construction cost.	
Section 3.4.18	**Design Criteria for Batch Detention Basins** Batch detention basins capture and temporarily detain the water quality volume from a storm event using an automated controller and valve. They are intended to serve primarily as settling basins for the solids fraction, and as a means of limiting downstream erosion by controlling peak flow rates during erosive events. Batch detention basins may be constructed either online or offline, however, offline structures are preferred. Batch detention basins are designed to prevent clogging of the outflow structure and re-suspension of captured sediment during a discharge. They also provide enhanced dissolved pollutant removal performance. The batch detention design typically incorporates a non-clogging outflow structure, such as an orifice protected by a trash rack, or a perforated riser pipe protected by riprap. Batch extended detention basins may be used in very small watersheds (no minimum size), since the discharge is regulated by a valve instead of an orifice. In addition, batch detention basins tend to accumulate debris deposits rapidly, making regular maintenance necessary to minimize aesthetic and performance problems. Batch detention basins can readily be combined with flood and erosion control detention basins by providing additional storage above the water quality volume as illustrated below in Figure 2.	

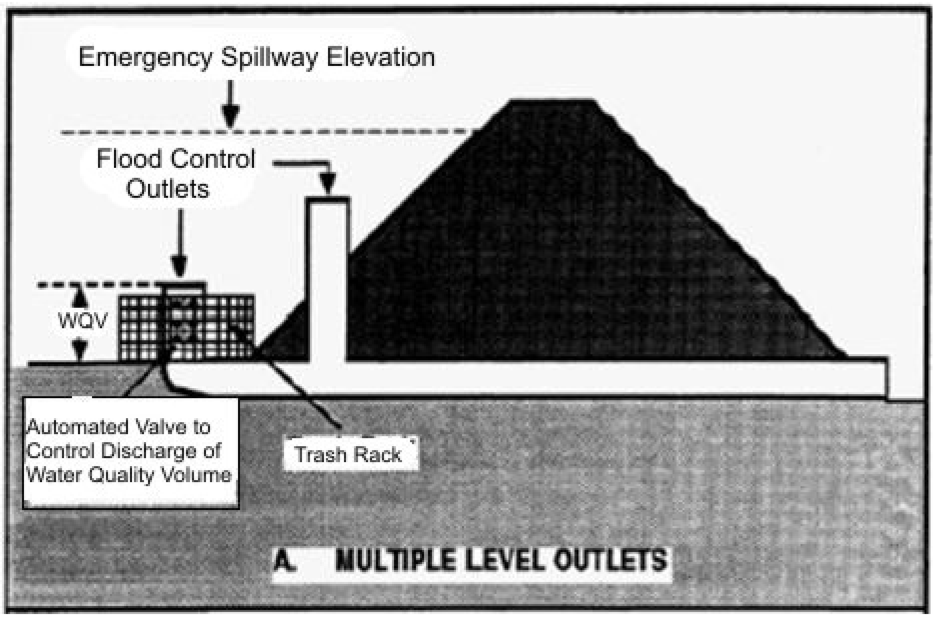


Figure 3 Example of Configuration Combining Flood and Water Quality

Design Criteria

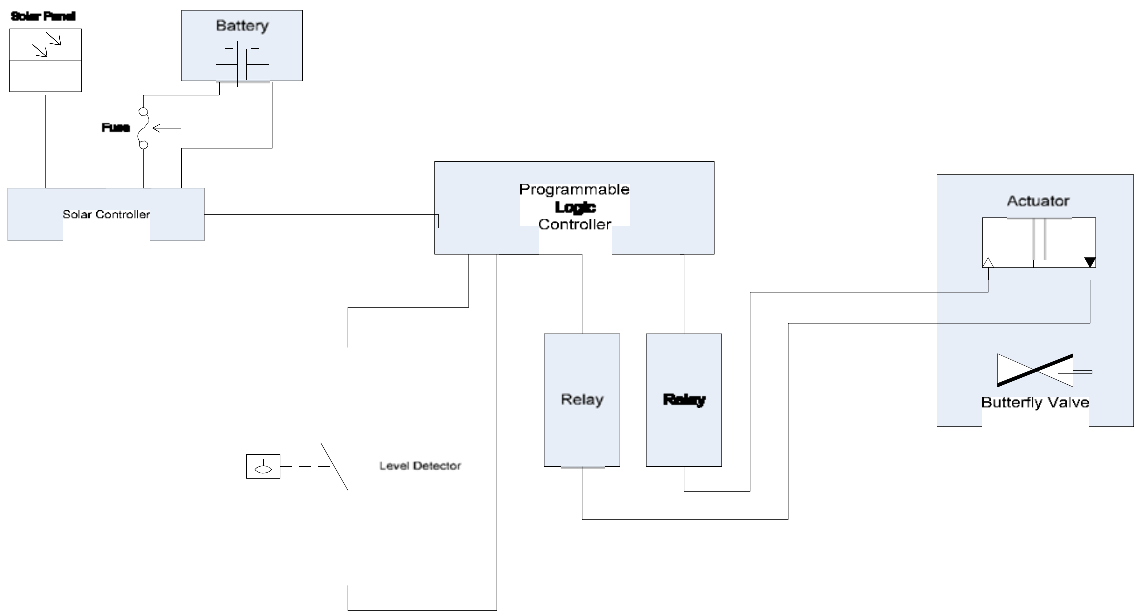
Basin geometry of a batch detention basin is not critical to performance allowing for flexible basin designs with ability to accommodate to the site's constraints and to incorporate aesthetic appeal. Basins can range from concrete lined to earthen lined designs. Some constraints, other than the existing topography, include, but are not limited to, the location of existing and proposed utilities, depth to bedrock, and location and number of existing trees. Batch detention basins do not require a long flow path to operate effectively, as do extended detention basins.

1) *Facility Sizing* - The required water quality volume is calculated and discussed in Section 3.3. This water quality volume should be increased by a factor of 20% to accommodate reductions in the available storage volume due to deposition of solids in the time between full-scale maintenance activities. A fixed vertical sediment depth marker should be installed in the first detention basin to indicate when sediment accumulation reaches a required removal depth of 6 inches.
2) *Basin Configuration* - The basin should maintain a longitudinal slope between 1.0 – 5.0 % with a lateral slope between 1.0 – 1.5%. A low flow channel can be provided, if desired, in order to improve drainage. No particular length to width ratio is required since all the runoff is detained for 12 hours. Maximum water depth for the water quality volume should not exceed 5 feet.
3) *Controller* - The controller consists of a level sensor in the detention basin, a valve (with a default closed position), an actuator, and the associated control logic. The controller detects water filling the basin from the level sensor and initiates a 12-hour detention time. At the end of the required detention time, the controller opens the valve and drains into the second basin. Subsequent rainfall events that occur prior to the basin draining should cause the valve to remain open and allow the additional stormwater runoff to pass through the basin. Once the basin is drained the controller closes the valve. The drawdown time of the

basin should not exceed 48 hours for a single storm event after the 12 hour required detention time. All cables should be protected by conduit and buried to prevent damage during maintenance activities. Information on the design and configuration of an existing system, including the system schematic, can be viewed at the Austin or San Antonio Regional Offices.

Other information to be submitted in the plan:

- *Power* – Indicate whether the system is line or solar powered, and the voltage of the controller and actuator. Also describe how the system will respond to a loss of power in the middle of a cycle if backup battery power is not provided;
- *Logic Controller* – Identify the model of controller selected and provide a general overview of cycles. The controller should be programmed to begin draining stormwater runoff from the basin 12 hours after the first stormwater runoff is sensed. The system should be programmed to have the valve remain open for two hours after the level sensor indicates the basin is empty to allow any remaining shallow water to be discharged. The system should provide the following: a test sequence, be able to deal with low battery/power outages, an on/off/reset switch, manual open/close switches (maintenance/spill), clearly visible external indicator to indicate a cycle is in progress without opening the box, and ability to exercise the valve to prevent seizing;
- *Parts Enclosure* – Provide a general description of the lockable parts enclosure;
- *Circuit* – Provide a block diagram of site specific controller circuit, such as the illustrated example found below;



- *Nature of Event Sensing* – Identify the type of sensor used to indicate the water level in the basin. In addition, the sensor must be located on a concrete pad or other location where vegetation and debris will not affect its operation. Mercury free float switches are an appropriate choice;

- *Valve* – Identify the model of valve proposed, size, type, pressures, and over-torque sensors. A manual override should be provided. A ball valve can be appropriate for smaller pipes (nothing to impede the flow or to capture trash and debris. On larger pipes compressed air driven bladder valves could be used;
- *Temperature/Weather* – Design the system to operate at 0 to 130ºF, and 10 to 90% humidity;
- *Reliability* — 40,000 hours (approximately 4.6 years) or greater;
- *Safety Precautions* – Alarm system clearly visible to indicate system malfunction, with sign posted with phone numbers of the owner and appropriate TCEQ regional office; and
- *Power Consumption* - Total wattage and W-hours of actuator, controller, and relay.

4) *Hazardous Material Threat (HMT) Operation* – The basin's outlet valve is normally closed and will detain a hazardous material spill. However, after a spill occurs, the manual controls on the controller or the actuator/valve are used to prevent the valve from automatically opening prior to removal of the hazardous material. Although not required by the Edwards Rules, the HMT operation can be used to comply with Appendix A of RG-348. If a spill does occur in the basin, all components of the controller must be inspected and checked for proper operation within 7 days.
5) *Pond Side Slopes* - Side slopes of the pond should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice.
6) *Basin Lining* – Basins must be constructed to prevent possible contamination of groundwater below the basin. Basin linings should conform to guidelines found in Section 3.4.2 of this document.
7) *Basin Inlet* – Energy dissipation is required at the basin inlet to reduce resuspension of accumulated sediment. Rock riprap or another filter system must be placed at the basin inlet to reduce velocities to less than 3 feet per second.
8) *Outflow Structure* – Batch extended detention facilities use the same outlet structures as extended detention basins with the replacement of an orifice with a single valve operated by an actuator. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes or of the valve (see Figure 3 for an example). The outflow structure should be sized to allow for complete drawdown of the water quality volume within 48 hours after the required detention time. Velocity controls are required at the discharge point to prevent erosion and scour.

For online facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard during the 25-year event and to safely pass the flow from 100-year storm.

Figure 4 Detail of Trash Rack

9) *Vegetation* - A plan should be provided indicating how the basin will be stabilized, with vegetation, stone, or concrete. If vegetation is used for stabilization, the facility should be planted and maintained to provide for a full and robust cover. Vegetation on the basin embankments should be mowed as appropriate to prevent the establishment of woody vegetation.

10) *Splitter Box* - When the basin is designed as offline, a splitter structure is used to isolate the water quality volume and bypass the remaining flow around the system once the entire water quality volume has been captured. The splitter box, or other flow diverting approach, should be designed to convey the 25-year storm event while providing at least 1.0 foot of freeboard along pond side slopes. Velocity controls are required at the bypass discharge point to prevent erosion and scour.

11) *Erosion Protection at the Outfall* - For online basins, special consideration should be given to the facility's outfall location. Flared pipe end sections that discharge at or near the stream invert are preferred. The channel immediately below the pond outfall should be modified to conform to natural dimensions, and lined with large stone riprap placed over filter cloth. A stilling basin may be required to reduce flow velocities from the primary spillway to non-erosive velocities.

12) *Safety Considerations* - Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by children. Outfall pipes more than 48 inches in diameter should be fenced.

Section 3.5.20

Maintenance Guidelines for Batch Detention Basins

Batch detention basins may have somewhat higher maintenance requirements than an extended detention basin since they are active stormwater controls. The maintenance activities are identical to those of extended detention basins with the addition of maintenance and inspections of the automatic controller and the valve at the outlet.

Inspections. Inspections should take place a minimum of twice a year. One inspection should take place during wet weather to determine if the basin is meeting the target detention time of 12 hours and a drawdown time of no more than 48 hours. The remaining inspections should occur between storm events so that manual operation of the valve and controller can be verified. The level sensor in the basin should be inspected and any debris or sediment in the area should be removed. The outlet structure and the trash screen should be inspected for signs of clogging. Debris and sediment should be removed from the orifice and outlet(s) as described in previous sections. Debris obstructing the valve should be removed. During each inspection, erosion areas inside and downstream of this BMP should be identified and repaired/revegetated immediately.

Mowing. The basin, basin side-slopes, and embankment of the basin must be mowed to prevent woody growth and control weeds. A mulching mower should be used, or the grass clippings should be caught and removed. Mowing should take place at least twice a year, or more frequently if vegetation exceeds 18 inches in height. More frequent mowing to maintain aesthetic appeal may be necessary in landscaped areas.

Litter and Debris Removal. Litter and debris removal should take place at least twice a year, as part of the periodic mowing operations and inspections. Debris and litter should be removed from the surface of the basin. Particular attention should be paid to floatable debris around the outlet structure. The outlet should be checked for possible clogging or obstructions and any debris removed.

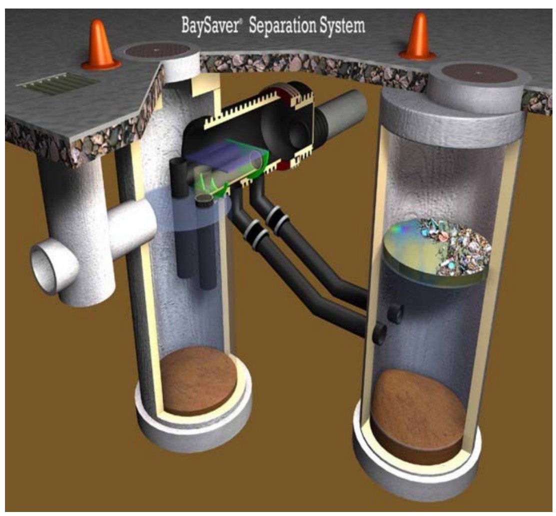
Erosion control. The basin side slopes and embankment all may periodically suffer from slumping and erosion. To correct these problems, corrective action, such as regrading and revegetation, may be necessary. Correction of erosion control should take place whenever required based on the periodic inspections.

Nuisance Control. Standing water or soggy conditions may occur in the basin. Some standing water may occur after a storm event since the valve may close with 2 to 3 inches of water in the basin. Some flow into the basin may also occur between storms due to spring flow and residential water use that enters the storm sewer system. Twice a year, the facility should be evaluated in terms of nuisance control (insects, weeds, odors, algae, etc.).

Structural Repairs and Replacement. With each inspection, any damage to structural elements of the basin (pipes, concrete drainage structures, retaining walls, etc.) should be identified and repaired immediately. An example of this type of repair can include patching of cracked concrete, sealing of voids, removal of vegetation from cracks and joints. The various inlet/outlet structures in a basin will eventually deteriorate and must be replaced.

Sediment Removal. A properly designed batch detention basin will accumulate quantities of sediment over time. The accumulated sediment can detract from the appearance of the facility and reduce the pollutant removal performance of the facility. The sediment also tends to accumulate near the outlet structure and can interfere with the level sensor operation. Sediment shall be removed from the basin at least every 5 years, when sediment depth exceeds 6 inches, when the sediment interferes with the level sensor or when the basin does not drain within 48 hours. Care should be taken not to compromise the basin lining during maintenance.

Logic Controller. The Logic Controller should be inspected as part of the twice yearly investigations. Verify that the external indicators (active, cycle in progress) are

	operating properly by turning the controller off and on, and by initiating a cycle by triggering the level sensor in the basin. The valve should be manually opened and closed using the open/close switch to verify valve operation and to assist in inspecting the valve for debris. The solar panel should be inspected and any dust or debris on the panel should be carefully removed. The controller and all other circuitry and wiring should be inspected for signs of corrosion, damage from insects, water leaks, or other damage. At the end of the inspection, the controller should be reset.	
Section 3.2.18	The BaySeparator is a patented water quality treatment device designed to capture sediment, oil, grease, and floatables commonly found in stormwater runoff and store them off-line. The BaySeparator™ system removes pollutants from the stormwater stream through one of two mechanisms: sedimentation or flotation. Engineers have relied on these two mechanisms in stormwater and wastewater treatment for years. The BaySeparator™ system applies these time tested principles to stormwater treatment in a configuration that prevents contaminant release or resuspension during high flow rates. The system is comprised of three main components: the BaySeparator™ unit, the Primary Manhole, and the Storage Manhole. Figure 1 displays a simple schematic of the BaySeparator™ system. Influent flow containing pollutants enters the system first by passing through the Primary Manhole. In this structure, coarse sediment settles while the flow passes over a weir into the BaySeparator™ Unit and is routed to the Storage Manhole. The influent flow, at this point, still contains pollutants of concern, such as fine sediments, oil, grease, floating trash, and other debris. Once in the Storage Manhole floatable trash, oils, and grease float to the surface, while fine sediments settle out and the influent separated flow returns to the outfall of the system back through the Separator Unit.  As the rate of flow increases through the system, the BaySeparator™ unit acts as a dynamic control to route the influent flow through the most effective flow path for treatment. For example, under low flow conditions the entire influent flow is treated as described above. Under moderate flows and up to the maximum treatment flow, water is continuously treated through both the Primary and Storage Manholes, with a portion of these flows diverted through the T-pipes and the remainder flowing into the Separator unit and then to the Storage Manhole. This flow path allows for removal of floatable pollutants, while still allowing sedimentation under moderate flow conditions. During maximum flow conditions, most of the influent flow passes over the bypass plate and will not be treated.	TCEQ Approval of Innovative Technology

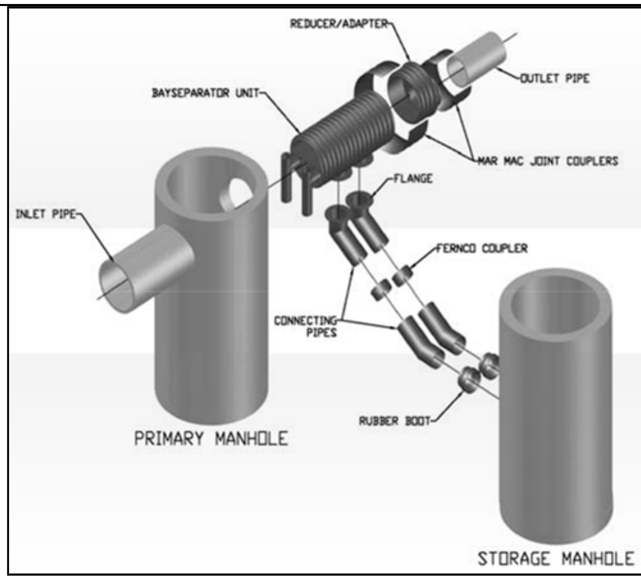


Figure 5 Schematic of the BaySeparator System

Selection Criteria

- Use only when space constraints make installation of a surface treatment system infeasible
- Appropriate for retrofits as well as new development
- Achieves greater than 80% TSS removal when properly sized
- Can be used as a stand-alone system or in a treatment train configuration

Limitations

- Requires annual removal of accumulated pollutants
- Cost for annual pumping and disposal of accumulated material in the facility is substantial
- Manhole cover must be removed to determine whether maintenance is required
- Below grade installation may inhibit maintenance access and require special equipment to remove accumulated sediment and other pollutants

Cost Considerations

The cost for a BaySeparator System, based on price/acre and the volume of runoff treated, may be significantly higher than many alternative technologies. Consequently, its primary use will be in space-constrained locations where surface systems such as sand filters may not be feasible.

Section 3.4.19

Design Criteria for BaySeparator System

The BaySeparator is available with several manhole configurations to provide ample options when sizing according to surface area. Table 1 below lists the BaySeparator units and manhole configurations currently available.

BaySeparator should be located as far upstream in the drainage system as possible. The frequency of the magnitude of a flow rate is dependent on the upstream drainage areas and the level of imperviousness of that drainage area. If the drainage area is too large, the required capture rate may exceed the capacity of a single unit; therefore, **the use of multiple units located on lateral storm lines rather than the main trunk line may be more beneficial both physically and economically.**

Table 1: BaySeparator Manhole size and surface area (ft^2)

Model Number	Surface Area (ft^2)	Model Number	Surface Area (ft^2)
1/2K-48”	25.13	5K-72”	56.54
1/2K-60”	39.26	5K-96”	100.53
1K-48”	25.13	10K-120”	157.07
1K-60”	39.26	10K-144”	226.19
3K-60”	39.26		
3K-72”	56.54		

Design Methodology

As a flow-based BMP, the BaySeparator is designed using the treatment flow rate for the site, as calculated using the Rational Method. The runoff rate from the tributary area is calculated using Equation 3.4:

$$Q = CIA$$

Where Q = flow rate (cfs)

C = runoff coefficient for the tributary area

I = design rainfall intensity (1.1 in/hr)

A = tributary area (ac).

The runoff coefficient is calculated as the weighted average of the impervious and pervious areas. Runoff coefficient for impervious areas is assumed to be 0.90 and runoff coefficient for pervious areas is assumed to be 0.03.

The overflow rate (hydraulic loading rate) is calculated using Equation 3.5:

$$V_{OR} = Q / A$$

Where VOR = overflow rate (ft/s)

Q = flow rate calculated using Equation 3.4

A = combined surface area of the primary and storage manholes

The overflow rate can then be used with Table 2 to determine the annual TSS removal for the proposed unit. Select the BaySeparator unit that provides the desired TSS removal.

The BaySeparator unit should be designed to treat the 1.1 in/hr storm, as well as passing the 4 in/hr storm through the unit. In this way, the system will treat virtually all of the annual runoff, and can be assumed to have a value of F = 1 (where F is the fraction of annual runoff treated by the BMP, in Equation 3.9).

For flows in excess of the 4 in/hr storm that may be required to meet local design requirements, the need for external bypass should be evaluated. External bypass needs should be evaluated on a case-by-case basis.

Table 2: BMP Efficiency and Overflow Rate (V_{OR})

Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)
40%	1.74E-02	55%	6.28E-03	70%	2.54E-03	85%	8.38E-04
41%	1.66E-02	56%	6.00E-03	71%	2.42E-03	86%	7.78E-04
42%	1.58E-02	57%	5.72E-03	72%	2.30E-03	87%	7.18E-04
43%	1.51E-02	58%	5.44E-03	73%	2.18E-03	88%	6.58E-04
44%	1.43E-02	59%	5.16E-03	74%	2.06E-03	89%	5.98E-04
45%	1.35E-02	60%	4.87E-03	75%	1.93E-03	90%	5.36E-04
46%	1.27E-02	61%	4.59E-03	76%	1.81E-03	91%	4.95E-04
47%	1.20E-02	62%	4.35E-03	77%	1.69E-03	92%	4.54E-04
48%	1.12E-02	63%	4.11E-03	78%	1.57E-03	93%	4.13E-04
49%	1.04E-02	64%	3.87E-03	79%	1.45E-03	94%	3.72E-04
50%	9.65E-03	65%	3.63E-03	80%	1.33E-03	95%	3.31E-04
51%	8.88E-03	66%	3.39E-03	81%	1.23E-03	96%	2.90E-04
52%	8.11E-03	67%	3.14E-03	82%	1.13E-03	97%	2.49E-04
53%	7.34E-03	68%	2.90E-03	83%	1.04E-03	98%	2.08E-04
54%	6.56E-03	69%	2.66E-03	84%	9.38E-04	99%	1.67E-04

Below is an example sizing using the sizing form required for the BaySeparator. This example shows a BaySeparator being sized for a 0.15 acre site with 0.10 acres of impervious cover.

PROJECT: BaySeparator 10K-120” OT Example Watershed: 1 Date: 3/19/09

EAPP BaySeparator EXAMPLE Compensation Worksheet (Rev. 3/19/09): Use additional sheets for additional catchment areas.

Table 1		
Effective Area (ac)	BaySeparator Model	Surface Area (ft2)
EA < 0.03	1/2K/1K-48”	25.13
0.03 < EA < 0.05	1/2K/1K-60”	39.26
0.05 < EA < 0.07	3K/5K-72”	56.54
0.07 < EA < 0.12	5K-96”	100.53
0.12 < EA < 0.19	10K-120”	157.07
0.19 < EA < 0.27	10K-144”	226.19

Use additional sheets for additional BMPs.

AI = Impervious Cover

Ap = Pervious Cover

A = Total Area

P = Avg. Annual Rainfall (33” for example)

ANI = Increase in impervious cover (new IC – existing IC)

TSS = LM = 27.2 x ANI x P

	List only the uncaptured area being compensated for in the BMP. TSS compensation for uncaptured areas can be divided up between multiple BMPs.

BMP Catchment Area A		Uncaptured/Untreated Areas (for compensation in BMP)	
AI1 =	0.10	AI2 =	0.00
AP1=	0.05	AP2=	0.00
A1 =	0.15	A2 =	0.00
ANI1 =	0.10	ANI2=	0.00
LM1=	90	LM2=	0.00

1 BaySeparator Model Sizing based on Individual Catchment Area to the BMP. Use additional sheets as necessary.

Effective Area (EA) = (0.9 x AI) + (0.03 x AP)

EA = (0.9 x 0.10_______) + (0.03 x____0.05________) =______0.0915________EA

Model (from Table 1to start) _5K-96”___________; Surface area (SA) of model (Table 2) __100.53_________Sq. Ft.

Required TSS Removal for Catchment Area

LM1= 27.2 x 0.10_______AI x______33______P” =_____90______#TSS

2 Overflow Rate

(EA) x 1.1 / Unit surface area (SA)

((____0.0915_________) x 1.1) / 100.53__________=______0.001__________f/s

3 BMP Efficiency (Table 2) If the overflow rate is between two percent efficiencies, use the smaller percent efficiency (round the overflow rate to the larger overflow value). Enter rounded overflow value:

Vor = .00104 f/s

BMP % = 83 % / 100 = 0.83 BMP Eff

4 Maximum TSS Removal of BMP: LR1

LR1 = (BMP Eff x P) x [(AI1 x 34.6) + (AP1 x 0.54)]

LR1 = (0.83 x _33__________”) x [(0.10 x 34.6) + (0.05 x 0.54)] = 96 #TSS

TSS Load Credit (LC) to be counted towards untreated areas = LR1 – LM1

LC = [(_______96__________________) – (____________90___________________)] = _______6__________________#TSS

5 Required TSS Removal for Uncaptured Area LM2 = 27.2 x_______0_______ac x _33________” = ______0_______#TSS

6 Treatment Available?

If TSSC > TSSUC; Model size is adequate.

	If TSSC < TSSUC; Model size is inadequate. Choose a larger model size or redefine the catchment areas. Repeat steps 1 - 6. __6_________TSSC (<, >, >, pick)_______0_____TSSUC Final Model Size:____5K-96"__________						
7	TSS Treatment per BMP TSSCA (step 1) + TSSC (step 5) = TSS Removal by BMP _____90_________#TSS +_______0___________#TSS =______90_____________#TSS						
8	Sub-catchment Area	Model Number	Drainage Area (Acres)	Impervious Cover (Acres)	Target TSS Removal (lb/yr)	BaySeparator Model	TSS Removal Provided (lb/yr)
	BMP Catchment	5K-96"	0.15	0.10	90	5K-96"	90
	Uncaptured/Untreated		0.00	0.00	0.00		0.00
	Total	---	0.15	0.10	90		90

BaySeparator Worksheet 3_9_09

Table 2: BMP Efficiency and Overflow Rate (VOR)

Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)	Eff (%)	Overflow (ft/s)
40%	1.74E-02	55%	6.28E-03	70%	2.54E-03	85%	8.38E-04
41%	1.66E-02	56%	6.00E-03	71%	2.42E-03	86%	7.78E-04
42%	1.58E-02	57%	5.72E-03	72%	2.30E-03	87%	7.18E-04
43%	1.51E-02	58%	5.44E-03	73%	2.18E-03	88%	6.58E-04
44%	1.43E-02	59%	5.16E-03	74%	2.06E-03	89%	5.98E-04
45%	1.35E-02	60%	4.87E-03	75%	1.93E-03	90%	5.36E-04
46%	1.27E-02	61%	4.59E-03	76%	1.81E-03	91%	4.95E-04
47%	1.20E-02	62%	4.35E-03	77%	1.69E-03	92%	4.54E-04
48%	1.12E-02	63%	4.11E-03	78%	1.57E-03	93%	4.13E-04
49%	1.04E-02	64%	3.87E-03	79%	1.45E-03	94%	3.72E-04
50%	9.65E-03	65%	3.63E-03	80%	1.33E-03	95%	3.31E-04
51%	8.88E-03	66%	3.39E-03	81%	1.23E-03	96%	2.90E-04
52%	8.11E-03	67%	3.14E-03	82%	1.13E-03	97%	2.49E-04
53%	7.34E-03	68%	2.90E-03	83%	1.04E-03	98%	2.08E-04
54%	6.56E-03	69%	2.66E-03	84%	9.38E-04	99%	1.67E-04

Table 3: BMP Summary Table for the Site

Complete this table to show the types of BMPs and TSS treatment amounts for the site. Provide additional, as needed.

BMP	BMP Type	Total	Impervious	Calculated TSS	TSS Treatment by

Catchment Area	or Model	Drainage Area (ac)	Cover (ac)	Removal (lb/yr) (Lm)	BMP (lb/yr)
A	5K-96”	0.15	0.10	90	90
B					
C					
D					
Uncaptured	---	0.00	0.00	0.00	---
Total	---	0.15	0.10	90	90

Section 3.5.21

Maintenance Guidelines for BaySeparator™ System

The BaySeparator system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. Like any system that collects pollutants, the BaySeparator™ systems must be periodically maintained for continued effectiveness. Maintenance is a simple procedure performed using a vacuum truck. One of the advantages of the BaySeparator™ systems is the ease of maintenance. The systems were designed to minimize the volume of water removed during routine maintenance, reducing disposal costs. Contractors can access the pollutants stored in each manhole through a 30” manhole cover. This allows them to gain unobstructed access to the full depth of the system. There is no confined space entry necessary for inspection or maintenance. Vacuum hoses can reach the entire sump area of both manholes to remove sediments and trash. The entire maintenance procedure typically takes less than an hour.

Local regulations may apply to the maintenance procedure. Safe and legal disposal of pollutants is the responsibility of the maintenance contractor. Maintenance should be performed only by a qualified contractor. Contact BaySaver Technologies Inc. at 1-800-229-7283 for a list of approved contractors in your area.

Inspection and Maintenance

Periodic inspection is required to determine the need for and frequency of maintenance. Inspections should be performed initially every six (6) months. Accumulated sediment and other pollutants must be removed at a minimum every 12 months or when 2 feet of sediment (1.5 feet for the 1/2K model) has accumulated in the bottom of either structure or when visual inspection shows a large accumulation of debris or oil, whichever comes first. Oil or gasoline/diesel spills should be cleaned out immediately.

Inspection Instructions

1. For each BaySeparator™ unit, there are 2 manholes to inspect: the Primary Manhole and Storage Manhole.
2. Remove the manhole covers to provide access to the pollutant storage.
3. Use a dipstick tube equipped with a ball valve (typically a Sludge Judge® or Core Pro®). Follow the proper operating instructions associated with the dipstick tube.
4. Measure the sediment depth in each manhole. After recording the sediment levels, let the dipstick tube drain back into the BaySeparator unit to ensure

pollutants do not leave the unit or the site. Conduct maintenance if necessary.

5. Conduct a visual observation of the unit for trash/debris and structural integrity (cracks, slumping pipes, etc.).
6. Replace the two manhole covers.
7. Conduct a visual observation of the discharge point for soil erosion.

Maintenance Instructions

1. For each BaySeparator™ system, there are 2 manholes to clean: the **Primary Manhole** and **Storage Manhole**.
2. Remove the manhole covers to provide access to the pollutant storage.
3. **Storage Manhole**: Use a vacuum truck to remove and collect all water, debris, oils, and sediment.
4. **Storage Manhole**: Use a high pressure hose to clean the manhole of all the remaining sediment and debris. Then, use the vacuum truck to remove the rinse water.
5. **Primary Manhole**: Use a submersible pump to pump the bulk of the water from the Primary Manhole into the clean Storage Manhole. Stop pumping when the water surface falls to one foot above the accumulated sediments.
6. **Primary Manhole**: Use a vacuum truck to remove and collect all remaining water, debris, and sediment.
7. **Primary Manhole**: Use a high pressure hose to clean the manhole of all the remaining sediment and debris. Then, use the vacuum truck to remove the rinse water.
8. **Both Manholes**: On sites with a high water table or other conditions which may cause flotation, it is necessary to fill the manholes with clean water after maintenance
9. Replace the two manhole covers.
10. Dispose of the polluted water, oils, sediment, and trash at an approved facility.
    - Most local regulations prohibit the discharge of solid material into the sanitary system. Check with the local sewer authority for any required permits and/or conditions to discharge the liquid.
    - Many places require the pollutants removed from BaySeparator™ systems to be treated in a leachate treatment facility. Check with local regulators about disposal requirements.
11. Additional local regulations may apply to the maintenance procedure.

This procedure is intended to remove all the collected pollutants from the system while minimizing the volume of water that must be disposed. Additional local regulations may apply to the maintenance procedure. Safe and legal disposal of pollutants is the responsibility of the maintenance contractor; therefore maintenance should be performed only by a qualified contractor.

Section 5.1.3	**<u>Caves</u>** According to the Instructions to Geologists (**TCEQ-0585 Instructions)** a cave is a natural underground open space formed by dissolution of limestone that is large enough for an average-sized person to enter. Caves are commonly found partly filled by breakdown, loose rocks, debris, or soil. A cave feature is not limited to just the cave opening(s). It includes the subsurface extent of the underground open space and could include associated sinkholes as well. An assessment of a cave requires sufficient investigation to delineate the dimensions of the feature defined by in-place bedrock. If caves are identified during the geologic site assessment, a map showing scale or dimensions should be made of its extent, including any associated cave openings, sinkholes, and subsurface extent. The cave footprint, as defined by **TCEQ-0585 Instructions, is the** horizontal or plan view map of the cave, projected up to the surface to show the area of the site underlain by cave passage. The projected surface, cave footprint, should be delineated on the site geologic map and proposed site plan. The natural buffer around the cave should extend a minimum of 50 feet in all directions around the delineated cave footprint as well as any associated openings and sinkholes. Where the boundary of the drainage area to the cave lies more than 50 feet from the footprint, the buffer should extend to the boundary of the drainage area or 200 feet, whichever is less. If a map of the cave footprint is not available, an assumed footprint of at least 150 feet around the entrance to a cave opening should be applied. According to **TCEQ-0585 Instructions,** ninety percent of mapped Edwards cave footprints lie within a 150 foot circle centered on the opening. The natural buffer around the cave should extend a minimum of 50 feet in all directions around the assumed footprint as well as any associated openings and sinkholes. Where the boundary of the drainage area to the cave lies more than 50 feet from the footprint, the buffer should extend to the boundary of the drainage area or 200 feet, whichever is less. Note that cave mapping to document the extent of cave passage is likely to produce a more accurate and smaller footprint.	**Clarify the definition of a cave**
Section 3.2.19	**Filterra® Bioretention Filtration Device** Filterra® Bioretention Filtration Device (Filterra®) is a manufactured soil, microbe and plant treatment system that uses the same complex physical, chemical and biological pollutant removal mechanisms as bioretention. Filterra® consists of a container filled with an engineered soil filter media, mulch layer, an under-drain and a plant (generally a tree or shrub). Filterra® is generally placed up-gradient of a storm drain inlet to intercept and treat the water quality volume before discharging the stormwater through the under drain and flowing back into the storm drain system. Filterra® uses a very high flow rate treatment media and can treat high volumes of runoff in much smaller areas than conventional bioretention devices. This makes the device a good fit for high density development where space limitations restrict the use of devices that use a large surface area. A schematic of Filterra® is presented in Figure 1.	TCEQ Approval of Innovative Technology

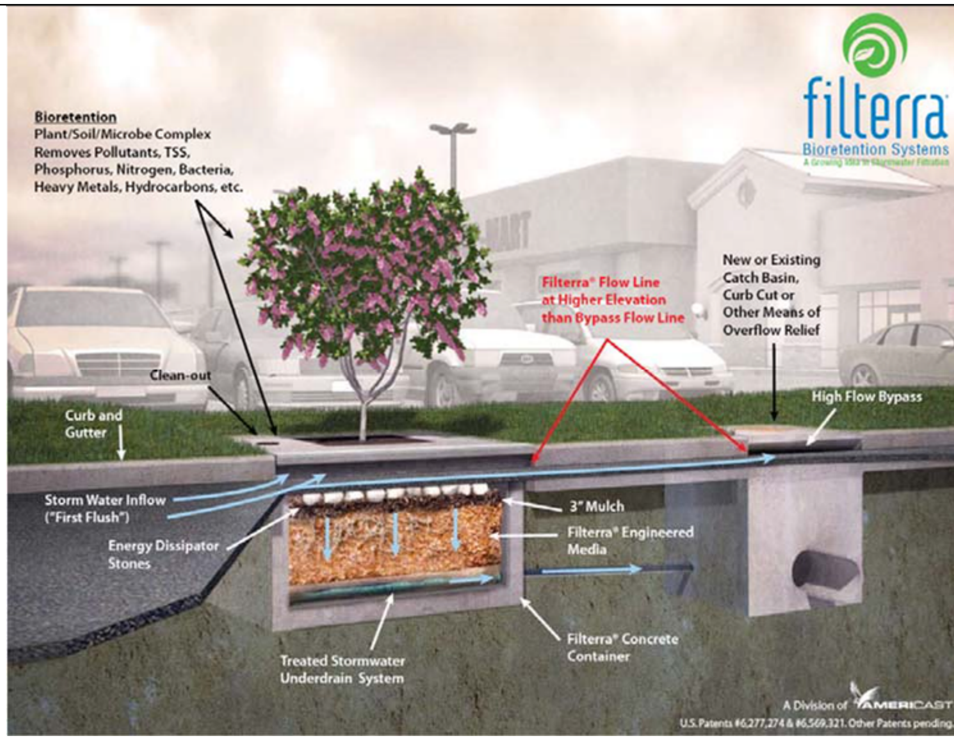


Figure 1 Filterra® Schematic

Selection Criteria

- Filterra® takes up little space and can be used in any type of commercial, industrial or residential development.
- Filterra® is a good choice for urban retrofit and infill development due to its flexible design and ease of construction that allows it to be installed within the existing green space or streetscapes along the curb line.
- Filterra® is a good option for water quality treatment to address a wide range of targeted pollutants such as TSS, heavy metals, phosphorus, oil/grease and bacteria.
- Filterra® provides ancillary benefits such as shade, wind breaks, noise absorption and enhances landscape aesthetics.

Limitations

- Filterra® is generally not used for attenuation of large volumes of runoff for stream channel erosion control and flood control purposes. However, some degree of volume/flow reduction can be achieved by combining Filterra® with an adjacent underground storage and or detention structures.
- It is difficult to use Filterra® on slopes greater than 10%.
- Filterra® must be free draining to a pond, stormwater system or other discharge point.
- Routine maintenance is required to replace the mulch and remove trash, debris and sediment generally once or twice per year depending on sediment load.

Cost Considerations

Filterra® is cost competitive with other manufactured devices; however, its annual maintenance costs are substantially less. There are no issues with confined space access, special tools or materials. Maintenance can be easily performed by the property owner since it only involves removing trash and debris and replacing the mulch (e.g. typical landscape care). The filter media must be obtained from the manufacturer if replacement is necessary. Check with the manufacturer for warranty and service information.

Section 3.4.18

Filterra® Bioretention System Design Procedure

Filterra® is a manufactured precast concrete structure that is delivered to the site complete and is specifically designed to treat runoff flows from small watersheds and functions as a flow through bioretention system with an 89% TSS removal efficiency. When sized to treat 90% of the total annual rainfall, Filterra® will provide 80% annual TSS load reduction. Ninety percent total annual rainfall is equivalent to treating a 1.1 inch/hour rainfall intensity. If the entire amount of proposed impervious cover drains to a single unit, then the required Filterra® model can be determined from Table 1, with:

Effective Area = $0.03 \times A_P + 0.9 \times A_I$

Where:

A_P = Pervious contributing drainage area (acres)

A_I = Impervious contributing drainage area (acres)

Table 1. Filterra® Sizing Table

Filterra® Size (ft)	Filter Surface Area (sqft)	Maximum Effective Area (acres)	Maximum Treatment Rate (cfs)
6x4	24	0.071	0.078
8x4	32	0.094	0.104
6x6	36	0.106	0.117
6x8	48	0.141	0.156
6x10	60	0.177	0.194
6x12	72	0.212	0.233
7x13	91	0.268	0.295

If there are multiple units on a site or there is a portion of the site that will not be treated, then the following procedure must be used to select the appropriate units to achieve the required TSS removal for the project.

Step (1) Determine the required TSS reduction.

L_M =27.2(A_N x P)

Where:

L_M = Required TSS reduction (lbs)

P = Average annual precipitation for select county (Table 3-3 in Edwards Aquifer Stormwater Manual)

A_N = Net increase in impervious area for the project

Step (2) For each proposed unit on the site, calculate maximum rainfall intensity that can be treated by:

i = Maximum Treatment Rate/Effective Area

Where:

Maximum Treatment Rate is determined from Table 1 for the selected model

Effective Area = As defined above for the area draining to the unit

Step (3) Determine the fraction of annual rainfall treated (F_r) from Table 2 for each unit.

Table 2 Relationship between Rainfall Intensity and Fraction of Runoff Treated

Rainfall Intensity (i)	F_r	Rainfall Intensity (i)	F_r	Rainfall Intensity (i)	F_r
0.10	0.450	0.44	0.738	1.20	0.920
0.12	0.482	0.46	0.749	1.25	0.923
0.14	0.514	0.48	0.759	1.30	0.927
0.16	0.546	0.50	0.770	1.35	0.930
0.18	0.578	0.55	0.782	1.40	0.933
0.20	0.610	0.60	0.793	1.45	0.937
0.22	0.621	0.65	0.805	1.50	0.940
0.24	0.631	0.70	0.817	1.60	0.946
0.26	0.642	0.75	0.828	1.70	0.952

0.28	0.653	0.80	0.840	1.80	0.958
0.30	0.663	0.85	0.850	1.90	0.964
0.32	0.674	0.90	0.860	2.00	0.970
0.34	0.685	0.95	0.870	2.50	0.978
0.36	0.695	1.00	0.880	3.00	0.985
0.38	0.706	1.05	0.890	3.50	0.993
0.40	0.717	1.10	0.900	4.00	1.000
0.42	0.727	1.15	0.910		

Step (4) For each proposed unit on the site, calculate the annual TSS removal LR by:

L_R = (BMP efficiency) x P x [(A_I x 34.6) + (A_P x 0.54)] x F_r

Where:

L_R = TSS load removed by Filterra® Bioretention System (lbs)

BMP efficiency = 0.89

P = Annual precipitation for select county (Table 3-3 in Edwards Aquifer Technical Guidance Manual)

A_I = Impervious contributing drainage area

A_P = Pervious contributing drainage area

F_r = Fraction of annual rainfall treated

If $L_R \geq L_M$, then the model selected achieve the required TSS reduction. If $L_R < L_M$ then a larger model must be selected for the location and the steps repeated until $L_R \geq L_M$.

In many cases there are areas on the site, such as driveways, which are graded in such a way that it is not technically feasible to capture and treat the runoff. On a case by case basis, TSS removal from the individual contributing areas that exceeds the required 80% can be used to compensate for the untreated area. To compute the total TSS removal on the site for all Filterra® units, select a unit from Table 1, whose maximum effective contributing area equals or exceeds the actual Effective Area draining to the unit. Then calculate the maximum rainfall intensity that the unit can treat without bypass using:

Max Rainfall Intensity = (Filter area (ft^2) x 140 in/hr)/Effective Area (ft^2)

From the Maximum Rainfall Intensity determine the fraction of annual rainfall treated (F_r) from Table 2. One can then calculate the actual TSS load removal for the unit as:

$$L(\text{lb TSS/yr}) = (\text{BMP efficiency}) \times F_r \times P \times (34.6A_I + 0.54A_P)$$

These loads can be summed for all installed units to demonstrate that the total TSS removal for the site exceeds L_M (the required removal for the entire site).

To ensure proper design, Filterra® must be designed according to the manufactures' detail design guidance. The manufacturer (Americast) provides a complete and comprehensive design assistance manual with the latest design, installation and maintenance information. This design manual can be obtained through their website at www.filterra.com. The manual provides details on a wide range of issues including design support services, sizing, site design scenarios, standard design details, pollutant removal, design options, installation, operation and maintenance. Several site design applications are provided which show how to use the device for both new development or urban retrofit for filtration or infiltration. Americast advises that the plans be submitted to them for review before permitting.

Some design considerations to follow include:

1) Add flow-line detail, gutter detail and plan notes to the site plans.
2) Do not place in a sump condition. Filterra® cannot be used as a standalone inlet – it will need effective bypass during higher intensity rainfall events.
    a. Plans must show Filterra® Top Curb (TC) and Flow Line (FL) spot elevations and also bypass TC (where applicable) and bypass FL spot elevations.
    b. The Filterra® TC and FL elevations must be higher than the bypass TC and FL elevations for effective bypass.
3) For proper trash collection ensure a minimum 4" and maximum 6" Filterra® throat opening depth.
4) Allow a nine inch separation distance from the top of the Filterra® engineered media soil to the bottom of the top slab.
5) Provide a three inch mulch layer followed by erosion stones on top of the Filterra® engineered media soil. The mulch is used in Filterra Systems as the surface component for pretreatment of stormwater runoff, protection of the Filterra® media and moisture control. The mulch used must adhere to the following technical specifications:

PROPERTY	**UNITS**	**REFERENCE VALUES**
Type	---------	Use ideally fir, cedar, hardwood mulch. Other types must first be tested by Filterra R&D Department.
Texture*	---------	Double shredded
Floatability**	---------	Passes

Phosphorus* **	ppm	0 – 15

*Mulch should be double shredded wood or bark mulch, but not bark nugget mulch

**Mulch must not float after 24 hours of soaking under laboratory testing.

***Ideally low phosphorus mulch for use in phosphorus sensitive watersheds.

6) Do not direct surface flow to the Filterra® in a "head-on" configuration. Use a grading design that encourages flow to enter a Filterra® in a cross linear flow – left-to-right or right-to-left in the gutter in front of the throat, which prevents system damage. During extreme storm events the excess flow should continue past Filterra® to a bypass inlet or other means of relief.
7) To calculate which size Filterra® is required use Table 1 above titled Filterra® Sizing Table. The entire contributing drainage area to the Filterra® should be considered and the minimum allowable C factors noted. The maximum contributing drainage area will vary with site conditions. For further information relating to sizing, please contact the manufacturer.
8) To ensure correct installation, include the Standard Filterra® Plan Notes on your Filterra® detail project sheet.
9) Positive drainage of each unit of the Filterra® effluent treatment pipe is required to prevent free standing water from accumulating in the system or under drain. This could occur due to tidal influences or improper connection of Filterra®'s effluent pipe to a bypass structure or other outfall.

Example Calculation

Assume site is 0.22 acres with 0.20 acres of new impervious cover located in Bexar County. Also, 0.205 acres drains to a Filterra® unit (0.02 acres pervious and 0.185 acres impervious), and that 0.015 acres is untreated (all impervious). Assume we only want to install one unit; i.e. we need to over treat to compensate for bypassed impervious cover.

Step (1) Determine the required TSS reduction.

$L_M = 27.2(A_N \times P)$

$L_M = 27.2(0.20 \times 30) = 163.2$ lbs/yr

Step (2) Calculate maximum rainfall intensity that can be treated by:

i = Maximum Treatment Rate/Effective Area

For first iteration, assume that 6 x12 unit is selected.

Effective Area = $0.03 \times A_P + 0.9 \times A_I$

Effective area = $(0.03 \times 0.02) + (0.9 \times 0.185) = 0.167$ ac

$i = 0.233/0.167 = 1.39$ in/hr

	Step (3) Determine the fraction of annual rainfall treated (F_r) from Table 2: 1.39 in/hr treats 0.932 of the annual rainfall (F_r is calculated by linear interpolation of values on Table 2) Step (4) Calculate the annual TSS removal L_R by: L_R = (BMP efficiency) x P x [(A_I x 34.6) + (A_P x 0.54)] x F_r L_R = (0.89) x 30 x [(0.185 x 34.6) + (0.02 x 0.54)] x 0.932 L_R = 160 lbs/yr $L_R < L_M$, so iterate from Step (2) with next larger unit (7 x 13) Step (2) Calculate maximum rainfall intensity that can be treated by: i = 0.295/0.167 = 1.77 in/hr Step (3) Determine the fraction of annual rainfall treated (F_r) from Table 2: 1.77 in/hr treats 0.956 of the annual rainfall (F_r is calculated by linear interpolation of values on Table 2) Step (4) Calculate the annual TSS removal LR by: L_R = (0.89) x 30 x [(0.185 x 34.6) + (0.02 x 0.54)] x 0.956 L_R = 163.6 lbs/yr $L_R \geq L_M$, so a single 7 x 13 unit provides sufficient treatment for the entire site.	
Section 3.5.22	**Maintenance** The manufacturer recommends that long-term maintenance be performed on at least a semiannual basis (generally spring and fall servicing). At a minimum, each maintenance session should include the following, • inspection of the unit structure and media; • removal of trash, silt and mulch from the filter surface; • after the removal of trash, silt and mulch, measure the distance from the top of the Filterra® engineered media soil to the bottom of the top slab. If this distance is greater than 12 inches, add Filterra® media (not top soil or other) to recharge the media to a 9 inch distance; • replace the mulch layer, to the design depth, with mulch that meets the technical specifications; • ensure correct repositioning of the erosion control stones by the Filterra® inlet to allow for the entry of trash during a storm event; • pruning of vegetation. If the vegetation is in dead or in poor health, it will require	

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replacement; and
• disposal of all removed items.

To ensure Filterra® is operating at the design flow rate of 140 inches/hr, the unit should be flow tested every three years by the project owner using a double-ring infiltrometer or other appropriate flow test method. Appropriate maintenance must be provided if the observed rate is less than 140 inches/hr. This might include replacement of the mulch or the surface soil layer. If this does not restore the unit to the design infiltration rate, all of the media may require replacement.

If standing water is observed for more than five to ten minutes within the system after a storm event or after a flow test, the Filterra® system will also require investigation. Trash, debris and mulch should be removed, and the mulch replaced. If this does not resolve the issue then the first few inches of media may need replacement to restore flow rates. Reduction in design flow rate may be caused by fine sediment accumulation from construction sediment, an oil or petroleum spill, grease from food fats, a blockage within or downstream of the discharge pipe, or simply a lack of maintenance for an extended period of time that has resulted in excessive sediment accumulation.

A serious oil, petroleum or hazardous substance spill, or other event that inundates the system beyond the ability to restore the design flow rate, will require removal and replacement of the media, mulch and plant. Media removal and replacement is normally performed with a vacuum truck. Only thoroughly tested, quality controlled media from Americast (the parent company that developed Filterra®) should be used as replacement media to ensure system water quality and flow rate performance. Americast should be contacted for replacement media. Americast, at an additional cost, can perform media replacement, or this can be contracted out.
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<td>Section 3.2.20</td>
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<u>Permeable Pavers</u>
Storm water management is a key component of urban infrastructure design. If properly designed and constructed, pavements made of permeable concrete pavers can help rainwater infiltrate into soils, decrease urban heating, reduce pollutant concentrations, and reduce storm water runoff. Permeable pavers allow precipitation to infiltrate and flow through the pavement surface where it can be temporarily stored, possibly infiltrate into in situ soils, delay the return into the local stormwater infrastructure or retain on site for future use. Appropriate pavers are available from Pavestone and other manufacturers.

The benefits of permeable paver pavement are well documented and its useis encouraged through the Leadership in Energy and Environmental Design (LEED®) Green Building Rating System™. On the recharge zone permeable pavers must be underlain with an impermeable liner and installed with an underdrain system to collect the filtered runoff for surface discharge. The TSS removal of a properly constructed permeable paver pavement is 89%.

<u>Selection Criteria</u>

Permeable paver pavements are a good choice for recreational trails, sidewalks, parking areas and low volume roadways to assist in storm water management. Advantages of permeable pavements include:
• increased infiltration in percolating soils for unlined configurations on the Contributing Zone;
• reduced stormwater volume and peak flows;
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	• reduced stormwater pollutant load; and • decreased downstream erosion. Limitations In order to make permeable paver pavements permeable, it is necessary to sacrifice some of the strength characteristics of dense graded materials used for conventional pavements. • Permeable paver pavements are typically designed for low volume traffic with limited heavy vehicle loading and speeds less than 35mph. Vehicle loading is typically expressed in terms of the number of Equivalent Single Axle Loads (ESALs) to which the pavement is exposed. Typical upper limits on ESALs are in the range of 750,000 over the design life of the pavement. • Permeable paver pavements should not be constructed with grades exceeding 5 percent. With higher grades, and intense storms, water tends to sheet flow off the pavement with reduced infiltration into the paver joints. • Permeable paver pavements can become clogged if contaminated during construction or not maintained during the pavement life. • Spills of hazardous materials may require removal of the pavement section to facilitate clean up. Cost Considerations For pedestrian traffic, the cost of a permeable paver pavement section will be higher than conventional asphaltic or concrete pavements that have no sustainable function. For vehicular traffic, the cost of a permeable paver pavement may be two to three times higher than a conventional asphaltic or concrete pavement. This is primarily due to the fact that the permeable paver pavement's jointing and base materials are designed to hydraulically filter and store water as well as provide structural capacity to accommodate vehicle loading. Cost comparison of the entire permeable paver pavement system needs to be compared to a conventional asphaltic or concrete pavement system that employs additional swales, on site filtering systems and/or detention ponds. For an overall site economic comparison, the purchase cost of land dedicated to stormwater treatment needs to be included.	
Section 3.4.19	**Permeable Pavers** Permeable pavers are constructed of relatively impermeable concrete so the infiltration of rainfall is dependent on the surface open area (joint size) and the type of material used to fill the paver joints. Paver joints should have a nominal width of approximately ¼". When sand is used as the bedding material and to fill the openings between pavers, it tends to rapidly clog from accumulated sediment and other material. Consequently, what makes this configuration appropriate for stormwater management is use of ASTM No. 8 or 9 aggregate in the openings and as a bedding course. Typical permeable paver pavements are shown below in Figure 6 andFigure 7. On the recharge zone these pavements must be underlain with an impermeable liner and installed with an underdrain system to collect the filtered runoff for surface discharge. Only rainfall that falls directly on the pavement may be treated; consequently, runoff from other portions of the site must be directed away from the permeable pavers.	

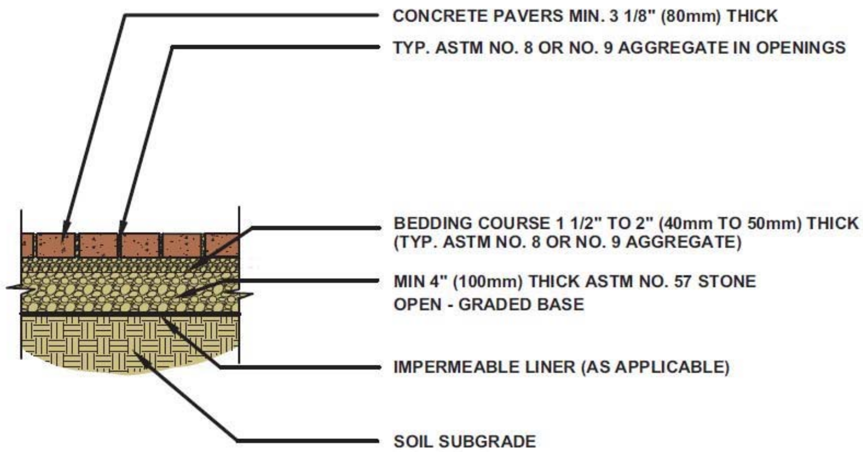


Figure 6   Permeable Pavers – Pedestrian

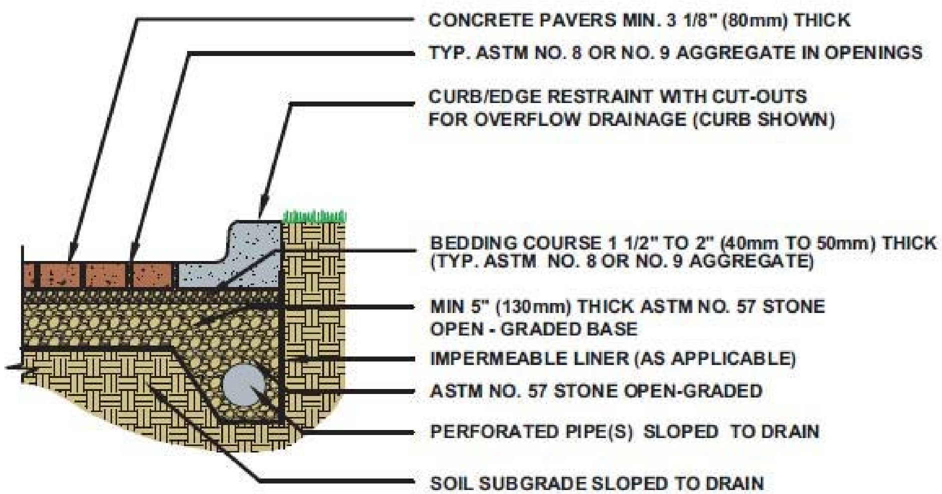


Figure 7   Permeable Pavers – Vehicular

Design Criteria

There are two elements that must be considered in the design of permeable paver systems for stormwater treatment: hydrologic capacity and structural integrity. The hydrologic constraints include a minimum infiltration rate, sufficient storage for the design storm within the base material, and a drainage system sized to restore the water quality volume within 72 hours after a rainfall.

The design process for permeable paver pavements also requires consideration of structural capacity to ensure that the pavement materials and thicknesses are sufficient to withstand the anticipated traffic loadings. Ensuring that the design provides the necessary structural capacity is the responsibility of the engineer and those calculations will not be submitted to or reviewed by TCEQ. Design procedures for the structural elements of permeable paver design use the methodology and approach of the 1993 *AASHTO Guide for the Design of Pavement Structures under the Flexible Pavement Design Procedure section.*

Parking lots and roads must be provided with curbs. These curbs must be configured in such a way as to store the required rainfall treatment depth (1.64 inches) on the surface of the parking lot in case the paver system becomes plugged. When pavers are used for sidewalks or residential driveways no edging is required. In no case should runoff from other portions of the tract including roofs and landscaped areas be allowed to run onto the paver surface.

1) *Drainage Rate* – The newly constructed pavement infiltration rate through the surface shall be a minimum of 100 in/hr. Permeability testing of the pavement system should be conducted with a double ring infiltrometer in one representative location for each 2,000 ft^2 of pavement.

2) *Storage Capacity* – The storage capacity of the stone reservoir underneath the pavement should be sufficient to capture a 1.5 inch storm depth. Assuming an average porosity of 30%, this will result in a minimum reservoir thickness depth of about five inches.

3) *Liner* – When permeable paver pavements are used on the recharge zone, an impermeable liner must be used to prevent infiltration of the runoff. The lining must conform to the specifications provided in Section 3.4.2. If geomembrane is used between the base and subbase material, it should be either PE or PVC (minimum 16 mils thick). A geotextile fabric should be placed on top of the liner as per manufacturer's recommendation. In most cases, walkways and courtyards for pedestrian use only can be excluded from the recharge zone liner requirement provided they meet all other applicable criteria.

4) *Underdrain* – An underdrain system to collect the filtered runoff for surface discharge must be used when a liner is required. The underdrain piping should consist of a main collector pipe and two or more lateral branch pipes, each with a minimum diameter of 4 inches. The pipes should have a minimum slope of 1% (1/8 inch per foot) and the laterals should be spaced at intervals of no more than 10 feet. There should be no fewer than two lateral branch pipes. All piping must be Schedule 40 PVC. The maximum spacing between rows of perforations should not exceed six inches. On the contributing zone, the underdrains in permeable paver pavements may be installed at some elevation above the subgrade to encourage lesser storms to drain into the ground rather than into stormwater systems.

   ADA Compliance – All permeable paver surface joint widths should be a nominal ¼″ (7 mm) installation width to comply with being less than a ½″ (13 mm) installation width. Permeable paver units shall have a maximum 1/16″ (1.5 mm) chamfer to minimize wheelchair vibrations and calm traffic noise in the trafficked surface. See, *ADA and ABA Accessibility Guidelines for Buildings and Facilities* (July 23, 2004), Part III: Technical Chapters, Chapter 3: Building Blocks, 302 Floor or Ground Surfaces, 302.3 Openings. Materials - Permeable paver units should comply with ASTM C 936. Bedding and base materials should conform to the specifications below.

Crushed Stone Filler, Bedding, Base and Subbase:

- Crushed stone with 90% fractured faces, LA Abrasion < 40 per ASTM C 131, minimum CBR of 80% per ASTM D 1883.
- Do not use rounded river gravel.
- All stone materials *shall be washed* with less than 1% passing the No. 200 sieve.
- Joint/opening filler, bedding, base and subbase: conforming to ASTM D 448 gradation as shown in Tables 1, 2, 3 and 4 below:

Notes: Locally available materials may vary somewhat from below requirements.

Table 1
ASTM No. 8 Grading Requirements
Bedding and Joint/Opening Filler

Sieve Size	Percent Passing
12.5 mm (1/2 in.)	100
9.5 mm (3/8 in.)	85 to 100
4.75 mm (No. 4)	10 to 30
2.36 mm (No. 8)	0 to 10
1.16 mm (No. 16)	0 to 5

Table 2
ASTM No. 9 Grading Requirements
Bedding and Joint/Opening Filler

Sieve Size	Percent Passing
12.5 mm (1/2 in.)	100
9.5 mm (3/8 in.)	100
4.75 mm (No. 4)	85 to 100
2.36 mm (No. 8)	10 to 40
1.16 mm (No. 16)	0 to 10

Table 3
ASTM No. 57 Base
Grading Requirements

Sieve Size	Percent Passing
37.5 mm (1 1/2 in.)	100
25 mm (1 in.)	95 to 100
12.5 mm (1/2 in.)	25 to 60
4.75 mm (No. 4)	0 to 10
2.36 mm (No. 8)	0 to 5

5) *Gradation criteria for the bedding and base* – D_x is the particle size at which x percent of the particles are finer. For example, D_{15} is the particle size of the aggregate for which 15% of the particles are smaller and 85% are larger. When selecting appropriate aggregate the D_{15} base stone /D_{50} bedding stone must be less than 5 and D_{50} base stone/D_{50} bedding stone must be greater than 2.

Section 3.5.23	**<u>Permeable Pavers Maintenance Guidelines</u>** The primary threat to the performance of permeable paver systems is clogging. The largest clogging threats to the system occur during construction and from landscaping. During construction, contractors may use pavement areas to store materials such as sand, gravel, soil, or landscape materials containing fines. The owner or supervising contractor must require all contractors to protect the pavement using heavy visqueen or plywood under these materials. The same materials are to be covered in order to prevent blowing and or washing away of such materials during wind and or rain events. It is recommended that protection of the permeable paver system be discussed at the project pre-construction meeting and be reinforced during interim construction. During construction and post construction of the permeable paver pavement, it is suggested that signs be posted in landscape areas and at entrances to the property as reminders of an ecologically sensitive pavement structure and that certain guidelines be adhered to including: • Dirt, sand, gravel, or landscape material must not be piled without first covering the pavement with a durable cover to protect the integrity of the pervious surface; • all landscape cover must be graded to prevent washing and/or floating of such materials onto or through the pervious surface; and • all chemical spills (including petrochemicals, hydrocarbons, pesticides, and herbicides) should be reported to the owner so the owner can prevent uncontrolled migration. Chemical migration control may require flushing, or the introduction of microbiological organisms to neutralize any impacts to the soil or water. Permeable paver pavements should be swept at least twice yearly to remove fine particles that has accumulated in the joints and reduced their permeability. Other periodic maintenance such as replacing cracked or worn pavers, minor settlement repairs, etc., assists in extending the service life of the pavement. Permeability testing of the pavement system should occur at least every three years to determine whether the pavement has become clogged. The test should be conducted with a double ring infiltrometer in one representative location for each 2000 ft2 of pavement. A minimum infiltration rate of five inches/hour is required. If the joints in the permeable pavers become clogged, the joint's aggregate and clogged materials can be vacuumed clean (removed) by a utility vacuum truck. The joint's aggregate and clogged materials are then replaced by spreading and vibrating new aggregate into the joints thereby restoring the permeability of the permeable paver system. All waste, including the removed materials, must be disposed of in accordance with local, state, and federal laws and regulations.	
Section 3.2.21	**<u>StormTrooper®</u>** StormTrooper® is a patented stormwater treatment system used as a best management practice to intercept free oils, grease, TSS, debris, and other pollutants commonly found in storm water runoff. StormTrooper is manufactured in Texas by ParkUSA and is third-party tested by Southwest Research Institute (SwRI) in San Antonio.	TCEQ Approval of Innovative Technology

Figure 1. The StormTrooper® Stormwater Separator

The StormTrooper Storm Water Treatment System utilizes "Enhanced" Gravity Separation. Enhanced Gravity Separation has been predominantly used in industrial applications of the separation of free oil and suspended solids from effluent water.

Enhanced Gravity Separation is an improvement over "gravity separation." Gravity separation is the phenomenon where a phase with higher density will settle and the phase with lower density will float to the surface of fluid. Enhanced Gravity Separation is achieved by utilizing CMP technology (coalescing media plates).

CMP technology introduces multi layer separation which provides an extensive reduction in surface area and ultimately smaller separators. Surface area requirements are reduced according to the number of CMP plates utilized. The StormTrooper System makes it feasible to achieve high levels of separation not typically achieved by a larger surface area separator.

Operation of StormTrooper® Storm Water Treatment System

Untreated storm water enters the first chamber of the unit known as the "grit chamber." Larger particles, as well as semi-buoyant material, are captured in this chamber to prevent excessive clogging and obstruction of the frontal area of the coalescing media plates. This reduces the potential for short circuiting and higher velocities through the plates. The "diffusion baffle," which separates the two chambers, works to perform two vital functions. First, it distributes flow evenly through the entire cross-section of the unit allowing for a more uniform delivery of pollutants through the plate. Next, a water quality orifice regulates flow through the plates and lower section of unit to prevent re-suspension of pollutants. Each StormTrooper has a specific maximum flow rate that has been pre-calibrated. Higher flow rates by-pass the system once the pre-calibrated flow rates are exceeded.

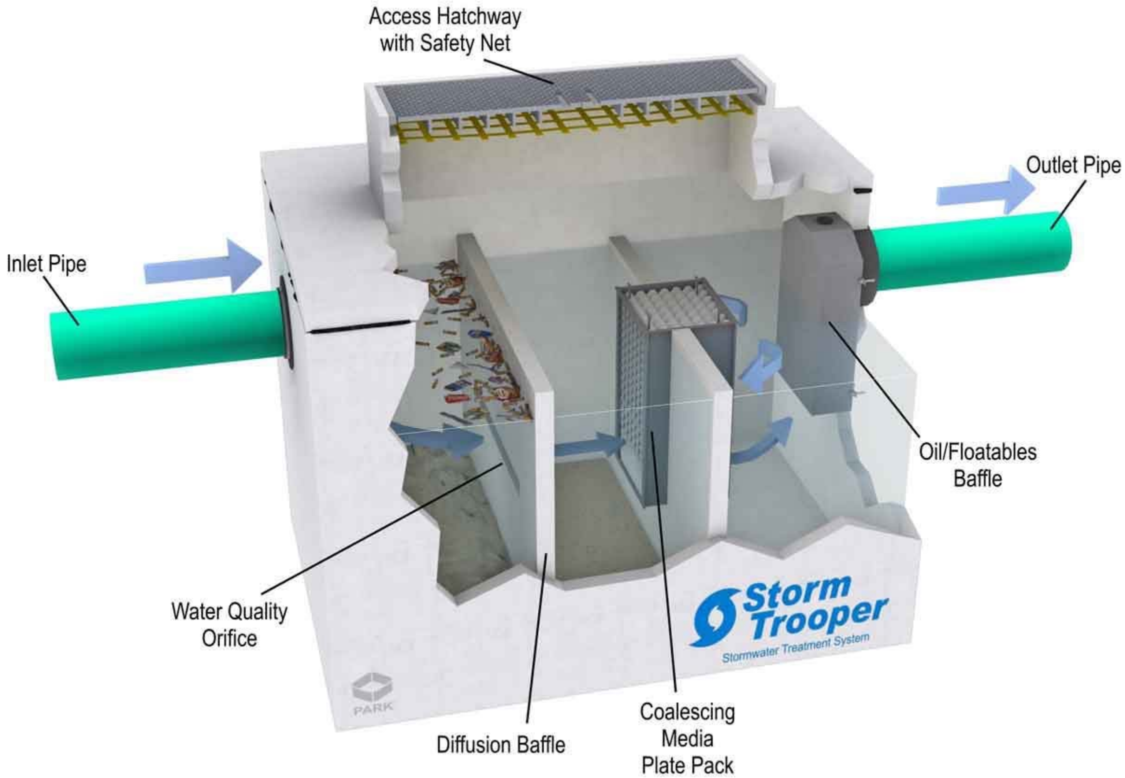


Figure 2. StormTrooper® Components

As the treatable flow of pollutants travel through the CMP (coalescing media plate pack) oil rises to the top and solids drop to the bottom through dedicated surfaces and weep holes. Plate supports at the bottom allow for easy removal of the solids that collect beneath the plates. Because of the steep angles and short travel distances, oils and solids are quickly released eventually floating to the surface of the StormTrooper unit or settling to the bottom of the unit.

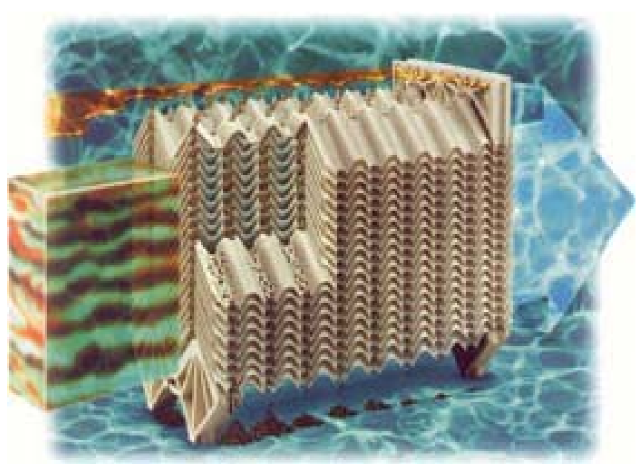


Figure 3. Coalescing Media Plates

	A submerged oil/floatable baffle is located around the effluent pipe to allow for the capture and containment of these pollutants. Collected pollutants will remain in the interceptor until removal. Because no filter cartridges are required operating costs are minimal. Furthermore, the StormTrooper System has no moving parts substantially reducing maintenance costs. <u>Selection Criteria</u> • Use when space constraints make installation of a surface treatment system infeasible • Achieves greater than 80% TSS removal when properly sized, so can be used as a standalone BMP, as well as in a treatment train • Provides smallest footprint possible and safest entry • Appropriate for retrofits as well as new development <u>Limitations</u> • Below grade installation requires pump out to remove accumulated sediment and other pollutants • Manhole covers must be removed to determine whether maintenance is required • Requires regular maintenance for optimum efficiently	
3.4.20	**<u>StormTrooper® Design Criteria</u>** As a flow-based BMP, the StormTrooper is designed using the treatment flow rate for the site, as calculated using the Rational Method. The runoff rate from the tributary area is calculated using Equation 3.4: $$Q = CIA$$ Where: Q = flow rate (ft^3/s) C = runoff coefficient for the tributary area I = design rainfall intensity (1.1. in/hr) A = drainage area (ac) The runoff coefficient is calculated as the weighted average of the impervious and pervious areas. Runoff coefficient for impervious areas is assumed to be 0.90 and the runoff coefficient for pervious areas is assumed to be 0.03. The overflow rate (hydraulic loading rate) is calculated using Equation 3.5: $$V_{OR} = Q/A$$ Where: V_{OR} = overflow rate (ft/s) Q = runoff rate calculated with Equation 3.4 (ft^3/s)	

A = surface Area of Unit (ft^2)

The overflow rate can then be used with Table 3 to determine the StormTrooper unit that provides the desired TSS removal.

The StormTrooper system is available in several models. The table below summarizes the various unit models and their corresponding dimensions.

Table 1. StormTrooper® *SWAQ* Models

Storm Trooper Model SWAQ	System Length (in)	System Width (in)	Minimum Settling Depth (in)	Vault Surface Area (sf)	Number of Plate Columns	Number of Stack Feet / Column	Projected Surface Area of Plates (sf)	Total Surface Area of System (sf)
05	84	36	48	21	1	2	79	100
10	90	48	48	30	1	3	119	149
20	120	60	48	50	2	2.5	198	248
25	144	72	48	72	3	2.5	297	369
40	180	90	48	113	4	3	475	588
70	204	96	48	136	5	3	594	730
110	240	120	48	200	6	3	713	913

The characteristics of the catchment area are defined as Effective Area (EA). The Effective Area is the number of acres draining to a single treatment unit and is calculated using the following equation:

$$EA = (A_i * 0.9) + (A_p * 0.3)$$

Where:

EA = Effective Area (ac)

A_i = Impervious Area (ac)

A_p = Pervious Area (ac)

StormTrooper models can be selected from Table 2 below that will achieve an 80% TSS reduction at the corresponding Effective Areas shown.

Table 2. StormTrooper® Sizing Chart (for 80% Reduction)

Effective Area - EA Acres	StormTrooper® Model
Less than 0.13	SWAQ-05
0.14 - 0.20	SWAQ-10
0.21 - 0.33	SWAQ-20
0.34 – 0.50	SWAQ-25
0.51 – 0.79	SWAQ-40
0.80 – 0.98	SWAQ-70
0.99 – 1.23	SWAQ-110

The **StormTrooper® SWAQ** system for the Edwards Aquifer is designed using the overflow rates provided in Table 3. These were calculated based on the surface area of the vault alone and a rainfall intensity of 1.1 in/hr.

Table 3. StormTrooper® BMP Efficiency vs. Overflow Rate (V_{OR})

Eff (%)	V_{OR} (fps)	Eff (%)	V_{OR} (fps)	Eff (%)	V_{OR} (fps)	Eff (%)	V_{OR} (fps)
40%	1.74E-02	55%	6.28E-03	70%	2.54E-03	85%	8.38E-04
41%	1.66E-02	56%	6.00E-03	71%	2.42E-03	86%	7.78E-04
42%	1.58E-02	57%	5.72E-03	72%	2.30E-03	87%	7.18E-04
43%	1.51E-02	58%	5.44E-03	73%	2.18E-03	88%	6.58E-04
44%	1.43E-02	59%	5.16E-03	74%	2.06E-03	89%	5.98E-04
45%	1.35E-02	60%	4.87E-03	75%	1.93E-03	90%	5.36E-04
46%	1.27E-02	61%	4.59E-03	76%	1.81E-03	91%	4.95E-04
47%	1.20E-02	62%	4.35E-03	77%	1.69E-03	92%	4.54E-04
48%	1.12E-02	63%	4.11E-03	78%	1.57E-03	93%	4.13E-04
49%	1.04E-02	64%	3.87E-03	79%	1.45E-03	94%	3.72E-04
50%	9.65E-03	65%	3.63E-03	80%	1.33E-03	95%	3.31E-04
51%	8.88E-03	66%	3.39E-03	81%	1.23E-03	96%	2.90E-04
52%	8.11E-03	67%	3.14E-03	82%	1.13E-03	97%	2.49E-04
53%	7.34E-03	68%	2.90E-03	83%	1.04E-03	98%	2.08E-04

Example:

A civil engineer is designing a 1.0 acre office park located over the Edward's Aquifer. 0.90 acres, which is 90% impervious, is draining to a single StormTrooper unit. 0.10 Acres, which is 10% impervious, cannot be treated and therefore TSS removal must be compensated within the single unit. Below is a detailed example of how to calculate annual load reduction of the StormTrooper model chosen.

PROJECT: StormTrooper® SWAQ - 40 Example AREA #: 1 DATE: 6/10/2011

Table 2. Sizing Chart for 80% Reduction

Effective Area (Ac.)	StormTrooper® Model	Total Surface Area (ft^2)
E.A. < 0.13	SWAQ - 05	100
0.14 < E.A. < 0.20	SWAQ - 10	149
0.21 < E.A. < 0.33	SWAQ - 20	248
0.34 < E.A. < 0.50	SWAQ - 25	369
0.51 < E.A. < 0.79	SWAQ - 40	588
0.80 < E.A. ≤ 0.98	SWAQ - 70	730
0.99 < E.A. ≤ 1.23	SWAQ - 110	913

Use additional sheets for additional units.
A_I = Impervious Cover (Acres)
A_P = Pervious Cover (Acres)
A = Total Area (Acres)
P = Avg. Annual Rainfall (33" for Example)
A_N = Net Impervious Cover (Acres)

List only the uncaptured area being compensated for in the unit. TSS compensation for uncaptured areas can be divided up between multiple units or BMP's.

BMP Catchment Area "A"

$A_{I1} =$ 0.81
$A_{P1} =$ 0.09
$A_1 =$ 0.90
$A_{N1} =$ 0.81
$L_{M1} =$ 1534.90

Untreated Catchment Area "A" - Compensation Req'd

$A_{I2} =$ 0.01
$A_{P2} =$ 0.09
$A_2 =$ 0.1
$A_{N2} =$ 0.01
$L_{M2} =$ 8.98

	1 StormTrooper® Model Sizing based on Individual Catchement Areas to the BMP. *Effective Area (EA) = (0.9 x A_I) + (0.03 x A_P)* EA = (0.9 x 0.81) + (0.03 x <u>0.09</u>) = 0.7317 <u>Acres</u> — ***Page 3-27 "RG-348" (C=0.90 Imp. Area, C=0.03 for Perv. Area)*** From Table 2 choose an initial Model: <u>SWAQ - 40</u> Surface Area of Model: 588 <u>Sq. Ft.</u> Required TSS removal for catchment area: $L_{M1} = 27.2 \times A_N \times P$ — ***Equation 3.3 "RG-348"*** $L_{M1} = 27.2 \times 0.81 \times 33 = 727.06$ **2 Overflow Rate** *V_{OR} = Q/S.A. where: Q = i(EA)* — ***Equation 3.4 & 3.5 "RG-348"*** ***Page 3-30 "RG-348" (i = 1.1 in./hr., 90% Volume Treated)*** *Q = (i x EA)/Model Surface Area* Q = (1.1 x 0.7317) / 588 = <u>0.00137 fps</u> **3 BMP efficiency (Table 3). If the overflow rate is between two percent efficiencies, use the smaller.** V_{OR} = 0.00133 fps BMP Eff. (%) = 80 % **4 Maximum TSS Removal of BMP: L_{R1}** *L_r = (BMP Efficiency) x P x (A_i x 34.6 + A_p x 0.54)* — ***Equation 3.8 "RG-348"*** L_r = Load Removed by BMP BMP Efficiency = TSS Removal Efficiency (expressed as a decimal fraction from Table 3) L_{R1} = <u>0.80</u> x 33 x (0.81 x 34.6 + <u>0.09</u> x 0.54) = 741.17 <u>#TSS</u> ***TSS removal exceeding required L_M to be counted towards untreated area = L_C*** *$L_C = L_{R1} - L_{M1}$* LC = 741.17 - 727.06 = 14.11 <u>#TSS</u> Required TSS removal for untreated area: L_{M2} = 27.2 x <u>0.01</u> x 33 = <u>8.98 #TSS</u> < <u>14.11 #TSS</u> => O.K. **UNIT IS SUFFICIENTLY SIZED TO REMOVE REQUIRED TSS FROM BOTH CAPTURED AND UNCAPTURED AREAS!!**	
3.5.24	**<u>StormTrooper® Maintenance Guidelines</u>** A preventative maintenance cleanout schedule is the most valuable tool for maintaining the proper operation of StormTrooper. Separator maintenance costs will be greatly reduced if a good housekeeping plan for the property is developed i.e., trash pickup, lawn maintenance, dumpster control, etc. StormTrooper separators have no moving parts and no filter cartridges. The manufacturer recommends quarterly ongoing inspections for accumulated pollutants. Pollutant deposition may vary from year to year. Quarterly inspections ensure that the system is serviced at the appropriate times. Table 4 lists recommended maximum capacities of oil and sediment. Professional vacuum services should be considered when capacities exceed these recommended levels. **Table 4. StormTrooper®**	

	Maintenance Levels	
Model Number	**Oil Depth**	**Sediment Depth**
SWAQ-05	12"	12"
SWAQ-10	12"	12"
SWAQ-20	12"	12"
SWAQ-25	12"	12"
SWAQ-40	12"	12"
SWAQ-70	12"	12"
SWAQ-110	12"	12"

It is very useful to keep a record of each inspection.

Inspection Procedures

1. Easiest observation and maintenance is best accomplished during non-flow (dry weather) conditions 3-4 days after the most recent rain.
2. Remove interceptor covers or open hatchway to observe conditions. Remove hatchway safety net ("EnterNet"). Observe for trash and debris and remove if necessary. This is the most important maintenance requirement. If absorbent pillows are utilized, observe their condition. Uniform browning or gray color of the pillow means they should be replaced. Observe baffle debris screen and clean if necessary.
3. Coalescing plates are self-cleaning and seldom require maintenance unless damaged. Do not walk on or stand on plate packs. Call ParkUSA (888-611-PARK) for replacement parts.
4. Check of the depth (level) of oil and sediment with a tank sampler device designed for this purpose.

3.2.22 Jellyfish® Filter

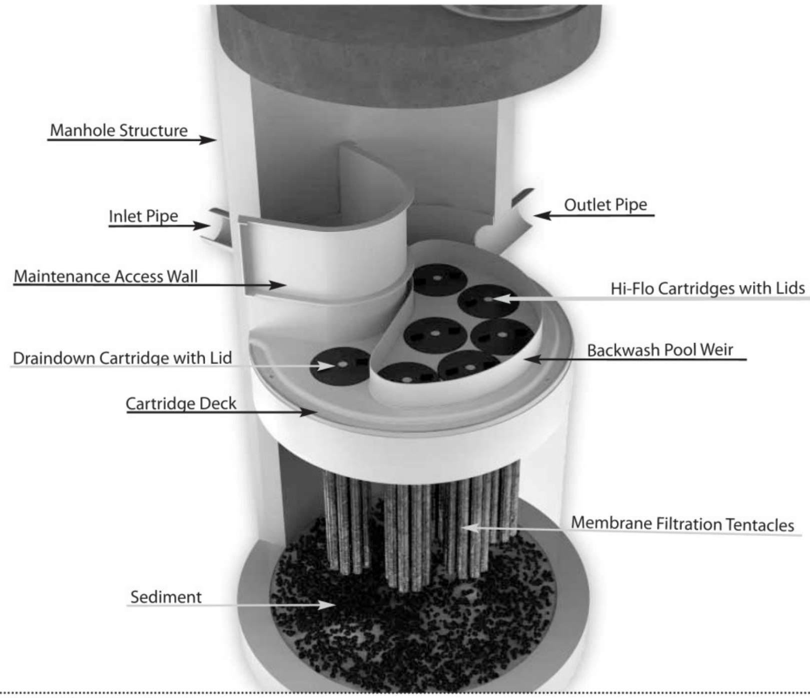
New Innovative Technology

The Jellyfish® Filter is an engineered stormwater quality treatment technology featuring unique membrane filtration in a compact stand-alone treatment system that removes a wide variety of stormwater pollutants. The Jellyfish® Filter integrates pre-treatment and filtration with passive self-cleaning mechanisms. The system utilizes membrane filtration cartridges with very high filtration surface area and flow capacity, which provide the advantages of high sediment capacity and low filtration flux rate (flow per unit surface area) at relatively low driving head compared to conventional filter systems.

Each lightweight Jellyfish® Filter cartridge consists of multiple detachable membrane-encased filter elements ("filtration tentacles") attached to a cartridge head plate. The Jellyfish® Filter and components are depicted in Figure 1 (6-ft diameter system shown).

FIGURE 1

Jellyfish Filter and Components



Note: Separator Skirt Not Shown

The Jellyfish® Filter can be used as a stand-alone device to treat stormwater or in a treatment train with other BMPs. Field testing of the Jellyfish® Filter has demonstrated capture of high levels of stormwater pollutants, including:

- 86% of the total suspended solids (TSS) load, including particles less than 5 microns;
- Some Phosphorus Nitrogen; and
- Metals, and additional particulate-bound pollutants such as hydrocarbons, and bacteria, free oil and floatable trash and debris.

Selection Criteria

- Use when space constraints make installation of a surface treatment system infeasible
- Appropriate for space-limited areas
- Appropriate for various size drainage basins
- Requires a minimal amount of land since underground
- Appropriate for retrofits and new development
- Appropriate to combine with low impact development (LID) applications and Green Infrastructure

Limitations

- Typically requires 18 inches of drop across the system (can be as low as 9 inches)
- Requires regular (minimum annually) inspection and/or maintenance

	Cost Considerations Cost of the Jellyfish® Filter is generally equal to or less than that of a sand filter and other granular media-filled cartridge systems, particularly when installation and maintenance costs are included. **Performance Claim** "The Jellyfish® Filter with standard membrane filtration cartridges designed for a maximum treatment flow rate consistent with a filtration flux rate (flow per unit surface area) of 0.21 gpm/ft2 (0.14 Lps/m2) for the hi-flo cartridge and 0.11 gpm/ft2 (0.07 Lps/m2) for the draindown cartridge, demonstrated removal of 86% of TSS, 99% of SSC, 59% of Total Phosphorus, 51% of Total Nitrogen, and greater than 50% of Total Copper and Total Zinc from urban rainfall-runoff, based on median pollutant removal efficiencies developed from the TARP and VTAP field monitoring study with a duration from 28 May 2010 through 27 June 2011."	
3.4.20	**Design Criteria** Design Rainfall Depth – The design rainfall depth is dependent on the characteristics of the contributing drainage area. The method for calculation of the fraction of annual rainfall to be treated and the design rainfall depth is specified in Section 3.3 of this manual. Standard length (54 inches) Jellyfish membrane filtration cartridges have a design treatment flow rate of 80 gpm for the hi-flo cartridge and 40 gpm for the draindown cartridge. A high-flow bypass located upstream of the Jellyfish® Filter is recommended to divert flows in excess of the design storm around the filtration system. A weir 18 inches higher than the outlet pipe invert or deck elevation of the Jellyfish is typically installed in the diversion structure to provide 18 inches of driving head to the treatment unit. In-line systems are also available. Table 1 shows standard manhole configurations and flow rates. Rectangular catch basin models with top inlet or curb inlets are available for small drainage areas as well as large rectangular vaults for drainage areas that exceed the capacity of largest standard manhole model listed. Standard cartridges lengths are 54 inches, 40 inches, 27 inches and 15 inches. **Table 1 Design Flow Capacities of the Jellyfish Filter**	

Table 1
Design Flow Capacities
Standard Jellyfish Filter Manhole Configurations

Manhole Diameter (ft / m)[1]	Model No.	Hi-Flo Cartridges[2] 54 in / 1372 mm	Draindown Cartridges[2] 54 in / 1372 mm	Treatment Flow Rate (gpm / cfs)	Treatment Flow Rate (L/S)
4 / 1.2	**JF4-2-1**	**2**	**1**	**200 / 0.45**	**12.6**
6 / 1.8	**JF6-3-1**	**3**	**1**	**280 / 0.62**	**17.7**
	JF6-4-1	4	1	360 / 0.80	22.7
	JF6-5-1	5	1	440 / 0.98	27.8
	JF6-6-1	6	1	520 / 1.16	32.8
8 / 2.4	**JF8-6-2**	**6**	**2**	**560 / 1.25**	**35.3**
	JF8-7-2	7	2	640 / 1.43	40.4
	JF8-8-2	8	2	720 / 1.60	45.
	JF8-9-2	9	2	800 / 1.78	50.5
	JF8-10-2	10	2	880 / 1.96	55.5
10 / 3.0	**JF10-11-3**	**11**	**3**	**1000 / 2.23**	**63.1**
	JF10-12-3	12	3	1080 / 2.41	68.1
	JF10-12-4	12	4	1120 / 2.50	70.7
	JF10-13-4	13	4	1200 / 2.67	75.7
	JF10-14-4	14	4	1280 / 2.85	80.8
	JF10-15-4	15	4	1360 / 3.03	85.8
	JF10-16-4	16	4	1440 / 3.21	90.8
	JF10-17-4	17	4	1520 / 3.39	95.9
	JF10-18-4	18	4	1600 / 3.56	100.9
	JF10-19-4	19	4	1680 / 3.74	106
12 / 3.6	**JF12-20-5**	**20**	**5**	**1800 / 4.01**	**113.6**
	JF12-21-5	21	5	1880 / 4.19	118.6
	JF12-22-5	22	5	1960 / 4.37	123.7
	JF12-23-5	23	5	2040 / 4.54	128.7
	JF12-24-5	24	5	2120 / 4.72	133.8
	JF12-25-5	25	5	2200 / 4.90	138.8
	JF12-26-5	26	5	2280 / 5.08	143.8
	JF12-27-5	27	5	2360 / 5.26	148.9

[1] Smaller and larger systems may be custom designed
[2] Shorter length cartridge configurations are available

Jellyfish Cartridges and Membrane Properties

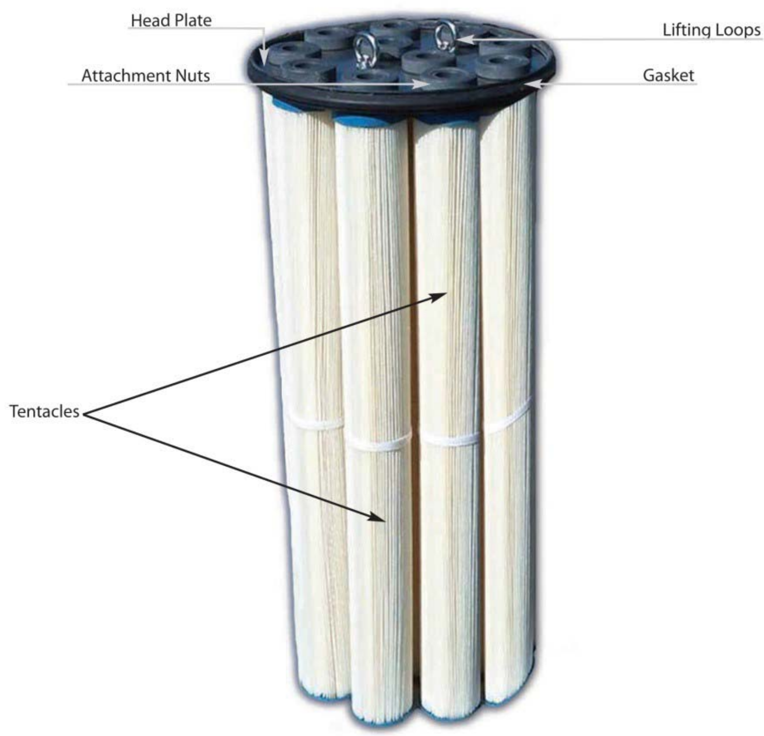
The filtration tentacle membranes provide a large amount of surface area, resulting in superior flow capacity and suspended sediment removal capacity. A typical Jellyfish cartridge with eleven 54-inch (1372 mm) long filtration tentacles has 381 ft2 (35.4 m2) of membrane surface area. Hydraulic testing on a clean 54-inch (1372 mm) filter cartridge has demonstrated a flow rate of 180 gpm (11.3 L/s) at 18 inches (457 mm) of driving head. In addition, the filtration tentacle membrane has anti-microbial characteristics that inhibit the growth of bio-film that might otherwise prematurely occlude the pores of the membrane and restrict hydraulic conductivity.

The cylindrical membrane filtration tentacle has a threaded pipe nipple at the top and is sealed at the bottom with an end cap. A cluster of tentacles is attached to a head plate by inserting the top pipe nipples through the head plate holes and securing with removable nuts. A removable oil-resistant polymeric rim gasket is attached to the head plate to impart a watertight seal when the cartridge is secured into the cartridge receptacle with the cartridge lid. A Jellyfish membrane filtration cartridge is depicted in Figure 2.

The dry weight of a new cartridge is less than 20 pounds (9 kg), and the wet weight of a used cartridge is less than 50 pounds (23 kg), making a cartridge easy to install and remove by hand. No heavy lifting equipment is required.

FIGURE 2

Jellyfish Membrane Filtration Cartridge



3.5.25 **<u>Jellyfish® Filter Inspection and Maintenance</u>**

Jellyfish cartridges are passively backwashed automatically after each storm event, which removes accumulated sediment from the membranes and significantly extends the service life of the cartridges and the maintenance interval. If required, the cartridges can be easily manually backwashed without removing the cartridges. Additionally, the lightweight cartridges can be removed by hand and externally rinsed, and rinsed cartridges then re-installed. These simple maintenance options allow for cartridge regeneration, thereby minimizing cartridge replacement costs and life-cycle treatment costs while ensuring long-term treatment performance.

Regular inspection and maintenance are proven, cost-effective ways to maximize water resource protection for all stormwater pollution control practices, and are required to insure proper functioning of the Jellyfish® Filter. Inspection of the Jellyfish® Filter is performed from the surface, while proper maintenance requires a combination of procedures conducted from the surface and with worker entry into the structure.

Please refer to the following information and guidelines before conducting inspection and maintenance activities:

- **When is inspection needed?**

Post-construction inspection is required prior to putting the Jellyfish Filter into service.

Routine inspections are recommended quarterly during the first year of operation to accurately assess the sediment and floatable pollutant accumulation, and to ensure that the automatic backwash feature is functioning properly.

Inspection frequency in subsequent years is based on the maintenance plan developed in the first year, but must occur annually at a minimum.

Inspections should also be performed immediately after oil, fuel or other chemical spill.

- **When is maintenance service needed?**

The unit must be cleaned annually. This cleaning includes removal and appropriate disposal of all water, sediment, oil and grease, and debris that has accumulated within the unit. The Jellyfish Filter is inspected and maintained by professional vacuum cleaning service providers with experience in the maintenance of underground tanks, sewers and catch basins. Since some of the maintenance procedures require manned entry into the Jellyfish structure, only professional maintenance service providers trained in confined space entry procedures should enter the vessel. Service provider companies typically have personnel who are trained and certified in confined space entry procedures according to local, state, and federal standards.

Filter cartridges should be tested for adequate flow rate, every 12 months and cleaned and re-commissioned, or replaced if necessary. A manual backflush must be performed on a single draindown cartridge using a Jellyfish Cartridge Backflush Pipe (described in the Jellyfish® Filter Owner's Manual). If the time required to drain 14 gallons of backflush water from the Backflush Pipe (from top of pipe to the top of the open flapper valve) exceeds 15 seconds, it is recommended to perform a manual backflush on each of the cartridges. After the manual backflush, the draindown test should be repeated on a single cartridge to determine if the cartridge can drain 14 gallons of water in 15 seconds. If the cartridge still does not achieve the design flow rate, it must be replaced.

The unit should be cleaned out immediately after an oil, fuel or chemical spill.

- **External Rinsing**

This cartridge cleaning procedure is performed by removing the cartridge from the cartridge deck and externally rinsing the filtration tentacles using a low-pressure water sprayer, as described in the Jellyfish® Filter Owner's Manual. If this procedure is performed within the structure, the cartridge or individual filtration tentacles should be rinsed while safely suspended over the maintenance access wall opening in the cartridge deck, such that rinsate flows into the lower chamber of the Jellyfish® Filter. If the rinsing procedure is performed outside the structure, the cartridge or individual filtration tentacles should be rinsed in a suitable basin such as a plastic barrel or tub, and rinsate subsequently poured into the maintenance access wall opening in the cartridge deck. Sediment is subsequently removed from the lower chamber by standard vacuum service.

Inspection / Maintenance Completion - Summary

Company Name:____

Company Address:____

City/State/Zip:____

Phone:____

Engineer:____

Engineers Address:____

City/State/Zip:____

Phone:____

Property Owner:____

*Jellyfish Model

Monitoring / Maintenance Table

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Oil Depth (inches)												
Sediment Depth (inches)												
Completed By												
Date												
Floatables (optional)												

I hereby certify that the monitoring and maintenance of the Jellyfish Filter unit was completed in accordance with the directions of the Jellyfish inspection and maintenance plan.

____

(Signed by property owner or designee)

Modular Wetland System (MWS) Linear - Biofiltration Device

Modular Wetland System Linear (MWS Linear) is a stormwater biofiltration treatment system utilizing a horizontal flow media bed. It consists of a three-chambered concrete structure, with a pre-treatment, biofiltration and discharge chamber. The biofiltration chamber utilizes an "organic free" ion exchange media which can be vegetated with grasses and/or shrubs. The MWS Linear is designed to treat runoff in two ways. First, treating at the source by integrating multiple devices throughout the site at each catch basin or second, by using a single large unit positioned end-of-the-line. The MWS Linear can be placed up stream of catch basins or attached to a downspout to intercept and treat the water quality flow or volume before discharging to the storm drain system or infiltration system. The TSS removal efficiency is 85%.

Standard height units are approximately 4 ft tall but can be made deeper allowing it to accept inflow pipes more than 10 ft deep. Because of this feature, the MWS Linear can also be installed end-of-line in a flow based configuration or in a standard volume based configuration downstream of storage BMPs (such as detention basins, ponds or underground structures). The MWS Linear uses a high flow rate media and can treat large volumes of runoff in much smaller areas. The MWS Linear also offers a pre-treatment chamber containing pre-filter cartridges. These cartridges protect the biofiltration chamber from clogging. A schematic of the MWS Linear is presented in Figure 1.

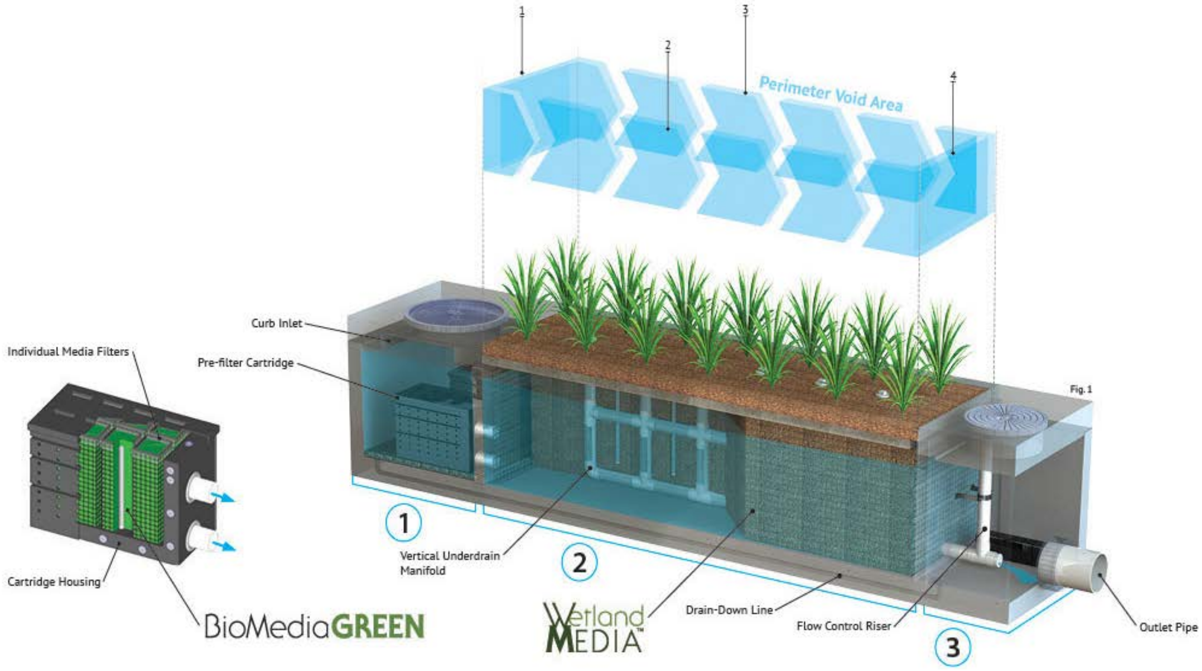


Figure 1 MWS Linear Schematic

Selection Criteria

- The MWS Linear is space efficient.

- The system can accept runoff via built-in curb inlet, grate inlet, or piped to from upstream basins. This allows it to be easily retrofitted to existing catch basins, green street projects or other streetscape applications.
- The "pipe to" ability of the system allows it to be used in various configurations such as end-of-the-line set ups in which a single larger unit can treat several acres of area.
- The MWS Linear allows for various types of vegetation to be used from grasses, to shrubs and even small trees to enhance the aesthetics of the project.

Limitations

- The MWS Linear should not be used for flood control or stream erosion control.
- The system does require fall between the inflow pipe and outflow pipe to generate enough hydraulic head for the system to operate properly.
- A full assessment of the peak flow rates expected to occur through the system must be conducted before designing the unit with an internal bypass. Internal bypass may also not be available on all models and sizes.
- Heavy sediment loads will clog the pre-filter. When soil disturbing construction activities are expected to occur within the unit's drainage area, inspection frequencies must be increased to once per month *and* after every 0.5" rain event.
- Site designers should use a conservative approach when determining unit size. If size selection is borderline, the next larger unit should be selected.
- Inspection and maintenance is required to remove trash, debris and sediment. The required maintenance interval is dependent upon the degree of pollutant loading.
- Revisions to any or all of the BMP maintenance requirements for MWS-Linear must be promptly communicated to TCEQ. In addition, site owners/responsible parties who have MWS-Linear products included in an approved Edwards Aquifer Protection Plan may be required to submit a revised and properly completed Inspection, Maintenance, Repair, and Retrofit Plan (TCEQ-0600; Attachment G) to the appropriate TCEQ Region Office upon implementation of revised maintenance procedures.

Cost Considerations

The configurations offered by MWS-Linear horizontal flow may provide potential reductions in capital and installation costs. The pre-treatment chamber may reduce maintenance cost and frequency by removing trash, debris and sediments before reaching the biofiltration chamber. Since the system can be piped to, a single larger unit can be used to treat several acres and may reduce cost when compared to decentralized designs which require multiple systems.

Design Criteria for Modular Wetland System Linear

The MWS Linear is used to treat stormwater runoff as a flow or volume based biofiltration BMP and removes 85% of the TSS in the volume of runoff treated. It can be used as either a distributed, upstream control, per the design principles of low impact development (LID) stormwater management or as a centralized end-of-the-line treatment control BMP. As such it can accept inflow pipes several feet below the surface and therefore allowing it to be used as a centralized type system. Because the system can intercept inflow pipes it can also be installed downstream of storage BMPs such as detention basins or underground storage system. In this set up it is designed as a volume based BMP.

The MWS Linear is designed with a flow rate of 1 gpm/ft^2 (0.0022 cfs/ft^2) biofiltration media surface area for both flow and volume based designs. When sized to treat 90% of the total annual rainfall, the MWS Linear will provide 85% annual TSS load reduction. 90% total annual rainfall is equivalent to treating a 1.1 inch/hour rainfall intensity. If the entire project area drains to a single unit, then the required MWS Linear model can be determined from Table 1, with:

Tributary Area Runoff Rate (Rational Method):
Q = C x I x A
Where:
Q = treatment flow rate in CFS
C = runoff coefficient = (Impervious Cover within Drainage Basin/Drainage Basin Area)*0.90 + (Pervious Cover within Drainage Basin/Drainage Basin Area)*0.03
I = intensity (in/hr)
A = total drainage area in acres
IC = impervious cover fraction within drainage area

Table 1 MWS Linear Flow Based Quick Sizing Table

MWS Linear Model #	Filter Area (ft^2)	Max Treatment Flow Rate (cfs)
MWS-L-4-4	23	0.051
MWS-L-4-6	32	0.071
MWS-L-4-8	50	0.112
MWS-L-6-8	64	0.142
MWS-L-4-13	63	0.139
MWS-L-4-15	76	0.170
MWS-L-4-17	90	0.200
MWS-L-4-19	103	0.230
MWS-L-4-21	117	0.261
MWS-L-8-8	101	0.224
MWS-L-8-12	151	0.336
MWS-L-8-16	201	0.448
MWS-L-8-20	252	0.561
MWS-L-8-24	302	0.673

If there are multiple units on a site or there is a portion of the site that will not be treated, then the following procedure must be used to select the appropriate units to achieve the required TSS removal for the project.

Step (1) Determine the required TSS reduction.

$L_M = 27.2(A_N \times P)$

Where:

L_M = Required TSS reduction (lbs)

P = Average annual precipitation for select county

A_N = Net increase in impervious area for the project

Step (2) For each proposed unit on the site, calculate maximum rainfall intensity that can be treated by:

i = Maximum Treatment Rate/Effective Area

Where:

Maximum Treatment Rate is determined from Table 1 for the selected model

Effective Area = $0.03 \times A_P + 0.9 \times A_I$

A_P = Pervious contributing drainage area (acres)

A_I = Impervious contributing drainage area (acres)

Step (3) Determine the fraction of annual rainfall treated (F_r) from Table 2 for each unit.

Table 2 Relationship between Rainfall Intensity and Fraction of Runoff Treated

Rainfall Intensity (i)	F_r	Rainfall Intensity (i)	F_r	Rainfall Intensity (i)	F_r
0.10	0.450	0.44	0.738	1.20	0.920
0.12	0.482	0.46	0.749	1.25	0.923
0.14	0.514	0.48	0.759	1.30	0.927
0.16	0.546	0.50	0.770	1.35	0.930
0.18	0.578	0.55	0.782	1.40	0.933
0.20	0.610	0.60	0.793	1.45	0.937
0.22	0.621	0.65	0.805	1.50	0.940
0.24	0.631	0.70	0.817	1.60	0.946
0.26	0.642	0.75	0.828	1.70	0.952
0.28	0.653	0.80	0.840	1.80	0.958
0.30	0.663	0.85	0.850	1.90	0.964
0.32	0.674	0.90	0.860	2.00	0.970
0.34	0.685	0.95	0.870	2.50	0.978
0.36	0.695	1.00	0.880	3.00	0.985
0.38	0.706	1.05	0.890	3.50	0.993
0.40	0.717	1.10	0.900	4.00	1.000
0.42	0.727	1.15	0.910		

Step (4) For each proposed unit on the site, calculate the annual TSS removal L_R by:

L_R = (BMP efficiency) x P x $[(A_I \times 34.6) + (A_P \times 0.54)] \times Fr$

Where:

L_R = TSS load removed by MWS Linear (lbs)

BMP efficiency = 0.85

P = Annual precipitation for select county

A_I = Impervious contributing drainage area

A_P = Pervious contributing drainage area

Fr = Fraction of annual rainfall treated

If the sum of $L_R \geq L_M$, then the models selected achieve the required TSS reduction. If $L_R < L_M$ then a larger model must be selected for one or more of the locations and the steps repeated until $L_R \geq L_M$.

For volume based designs, the required water quality volume is calculated using the methodology described in the TSS Removal and BMP Sizing Calculations section of the Technical Guidance Manual and a TSS removal efficiency of 85%. Table 3 provides a list of the maximum volumes that can be treated by specific models based on the approved flow rate and a 48 hour drain time. A safety factor is added to the loading rate to adjust for the large volume of water the unit will be treating over an extended period of time. It should be noted that for open and underground storage capture basins located on the Edward's Aquifer recharge zone, an impervious liner shall be used for basins.

Table 3 MWS Linear Volume Based Quick Sizing Table

MWS Linear Model #	Filter Area (ft^2)	Max Treatment Volume with 48 Hr Drain Down Time (cu ft)
MWS-L-4-4	23	4473
MWS-L-4-6	32	6276
MWS-L-4-8	50	9881
MWS-L-6-8	64	12552
MWS-L-4-13	63	12285
MWS-L-4-15	76	14955
MWS-L-4-17	90	17626
MWS-L-4-19	103	20296
MWS-L-4-21	117	22967
MWS-L-8-8	101	19762
MWS-L-8-12	151	29643
MWS-L-8-16	201	39524
MWS-L-8-20	252	49405
MWS-L-8-24	302	59286

NOTE: Utilizes a safety factor of 2 in loading rate.

Other design considerations include:

1. To calculate which size MWS Linear is required use Table 1 or 2 above. The entire contributing drainage area to the MWS Linear should be considered and the minimum allowable C factors noted. The maximum contributing drainage area will vary with site conditions.
2. The unit should be sized at a hydraulic loading rate of 1 gallon per minute per square foot of wetland cell surface area. For moderate pollutant loading rates (low to medium density residential basins), size the Pre-filters at 3.0 gpm/ft^2 of cartridge surface area. For high loading rates (commercial and industrial basins), size the Pre-filters at 2.1 gpm/ft^2 of cartridge surface area.
3. Site designers should use a conservative approach when determining unit size. If size selection is borderline, the next larger unit should be selected.
4. Positive drainage of each MWS Linear unit's effluent treatment pipe is required to prevent free standing water from accumulating in the system or underdrain. This could occur due to tidal influences or improper connection of MWS Linear's effluent pipe to a bypass structure or other outfall.
5. Plan sheets should include grading, drainage areas, design, profile, and details and all other information required by 30 TAC 213.5(b) and/or 30 TAC 213.24.

<u>Maintenance on MWS Linear</u>

Due to the high level of pollutant variation and specifically sediment loading, the unit shall be inspected at least every other month during the first year of operation to determine loading and required maintenance intervals. This information can be used to establish an appropriate maintenance schedule for subsequent years. If soil disturbing activities are being conducted within the unit's drainage area, inspection frequencies must be increased to once each month and after rain events of 0.5" and larger. Replacement of media in the pre-filter cartridges should be completed as-needed. Each maintenance session should include, at a minimum, the following:

- Inspection of the unit structure and media. Indications of the need for maintenance include:
    - Effluent flow decreasing to below the design flow rate or decrease in treatment below required levels.
    - Standing water remains in the vault between rain events
    - Bypass occurs during storms small than the design storm
    - If excessive floatables (trash and debris) are present (but no standing water or excessive sedimentation), perform a minor maintenance consisting of gross solids removal, not pre-filter media replacement.

- Removal of trash and silt from the pretreatment chamber;
- Pruning of vegetation. If the vegetation is dead or in poor health, it will require replacement; and
- If needed, replacement of media in pre-filter cartridges.
- All sediment and/or media removed from the MWS-Linear during maintenance activities shall be properly disposed of in accordance with 30 TAC 330 or 30 TAC 335, as applicable.
- Revisions to any or all of the BMP maintenance requirements for MWS-Linear must be promptly communicated to TCEQ. In addition, site owners/responsible parties who have MWS-Linear products included in an approved Edwards Aquifer Protection Plan may be required to submit a revised and properly completed Inspection, Maintenance, Repair, and Retrofit Plan (TCEQ-0600; Attachment G) to the appropriate TCEQ Region Office upon implementation of revised maintenance procedures.

Maintenance on Open Basin (extended detention basin)

Extended detention basins have moderate to high maintenance requirements, depending on the extent to which future maintenance needs are anticipated during the design stage. Responsibilities for both routine and non-routine maintenance tasks need to be clearly understood and enforced. If regular maintenance and inspections are not undertaken, the basin will not achieve its intended purposes.

There are many factors that may affect the basin's operation and that should be periodically checked. These factors can include mowing, control of pond vegetation, removal of accumulated bottom sediments, removal of debris from all inflow and outflow structures, unclogging of orifice perforations, and the upkeep of all physical structures that are within the detention pond area. One should conduct periodic inspections and after each significant storm. Remove floatables and correct erosion problems in the pond slopes and bottom. Pay particular attention to the outlet control perforations for signs of clogging. If the orifices are clogged, remove sediment and other debris. The generic aspects that must be considered in the maintenance plan for a detention facility are as follows:

- *Inspections.* Basins should be inspected at least twice a year (once during or immediately following wet weather) to evaluate facility operation. When possible, inspections should be conducted during wet weather to determine if the pond is meeting the target detention times. In particular, the extended detention control device should be regularly inspected for evidence of clogging, or conversely, for too rapid a release. If the design drawdown times are exceeded by more than 24 hours, then repairs should be scheduled immediately. The upper stage pilot channel, if any, and its flow path to the lower stage should be checked for erosion problems. During each inspection, erosion areas inside and downstream of the BMP should be identified and repaired or revegetated immediately.

- *Mowing.* The upper stage, side slopes, embankment, and emergency spillway of an extended detention basin must be mowed regularly to discourage woody growth and control weeds. Grass areas in and around basins should be mowed at least twice annually to limit vegetation height to 18 inches. More frequent mowing to maintain aesthetic appeal may be necessary in landscaped areas. When mowing of grass is performed, a mulching mower should be used, or grass clippings should be caught and removed.

- *Debris and Litter Removal.* Debris and litter will accumulate near the extended detention control device and should be removed during regular mowing operations and inspections. Particular attention should be paid to floating debris that can eventually clog the control device or riser.

- *Erosion Control.* The pond side slopes, emergency spillway, and embankment all may periodically suffer from slumping and erosion, although this should not occur often if the soils are properly compacted during construction. Re-grading and revegetation may be required to correct the problems. Similarly, the channel connecting an upper stage with a lower stage may periodically need to be replaced or repaired.

- *Structural Repairs and Replacement.* With each inspection, any damage to the structural elements of the system (pipes, concrete drainage structures, retaining walls, etc.) should be identified and repaired immediately. These repairs should include patching of cracked concrete, sealing of voids, and removal of vegetation from cracks and joints. The various inlet/outlet and riser works in a basin will eventually deteriorate and must be replaced. Public works experts have estimated that corrugated metal pipe (CMP) has a useful life of about 25 yr, whereas reinforced concrete barrels and risers may last from 50 to 75 yr.

- *Nuisance Control.* Standing water (not desired in an extended detention basin) or soggy conditions within the lower stage of the basin can create nuisance conditions for nearby residents. Odors, mosquitoes, weeds, and litter are all occasionally perceived to be problems. Most of these problems are generally a sign that regular inspections and maintenance are not being performed (e.g., mowing, debris removal, clearing the outlet control device).

- *Sediment Removal.* When properly designed, dry extended detention basins will accumulate quantities of sediment over time. Sediment accumulation is a serious maintenance concern in extended detention dry ponds for several reasons. First, the sediment gradually reduces available stormwater management storage capacity within the basin. Second, unlike wet extended detention basins (which have a permanent pool to conceal deposited sediments), sediment accumulation can make dry extended detention basins very unsightly. Third, and perhaps most importantly, sediment tends to accumulate around the control device. Sediment deposition increases the risk that the orifice will become clogged, and gradually reduces storage capacity reserved for pollutant removal. Sediment can also be re-suspended if allowed to accumulate over time and escape through the hydraulic control to downstream channels and streams. For these reasons, accumulated sediment needs to be removed from the lower stage when sediment buildup fills 20% of the volume of the basin or at least every 10 years.

Maintenance on Underground Basin (storage vault)

Underground detention vaults are similar in function as open detention basins. They have moderate to high maintenance requirements, depending on the extent to which future maintenance needs are anticipated during the design stage. Responsibilities for both routine and non-routine maintenance tasks need to be clearly understood and enforced. If regular maintenance and inspections are not undertaken, the basin will not achieve its intended purposes.

There are many factors that may affect the basin’s operation and that should be periodically checked. These factors can include removal of accumulated bottom sediments, removal of debris from all inflow and outflow structures, unclogging of orifice perforations, and the upkeep of structure that are within the storage vault. One should conduct periodic inspections and after each significant storm. Remove floatables and pay particular attention to the outlet control perforations for signs of clogging. If the orifices are clogged, remove sediment and other debris. The generic aspects that must be considered in the maintenance plan for a detention facility are as follows:

- *Inspections.* Storage vaults should be inspected at least twice a year (once during or immediately following wet weather) to evaluate facility operation. When possible, inspections should be conducted during wet weather to determine if the vault is meeting the target detention times. In particular, the vault’s flow control device should be regularly inspected for evidence of clogging, or conversely, for too rapid a release. If the design drawdown times are exceeded by more than 24 hours, then repairs should be scheduled immediately.

- *Debris and Litter Removal.* Debris and litter will accumulate near the vault’s flow control device. Particular attention should be paid to floating debris that can eventually clog the control device or riser or orifice.

- *Structural Repairs and Replacement.* With each inspection, any damage to the structural elements of the system (pipes, concrete drainage structures, etc.) should be identified and repaired immediately.

- *Nuisance Control.* Standing water within the bottom of the basin can create nuisance conditions for nearby residents. Odors, mosquitoes, and litter are all occasionally perceived to be problems. Most of these problems are generally a sign that regular inspections and maintenance are not being performed.

- *Sediment Removal.* When properly designed, storage vaults will accumulate quantities of sediment over time. Sediment accumulation is a serious maintenance concern in vaults for several reasons. First, the sediment gradually reduces available stormwater management storage capacity within the vault. Second sediment tends to accumulate around the control device. Sediment deposition increases the risk that the orifice will become clogged, and gradually reduces storage capacity reserved for pollutant removal. Sediment can also be re-suspended if allowed to accumulate over time and escape through the hydraulic control to downstream MWS Linear. For these reasons, accumulated sediment needs to be removed from the lower stage when sediment buildup fills 20% of the volume of the vault or at least every 10 years.

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