Wetland

Description

A manufactured wetland is similar to public domain stormwater wetlands. In a manufactured wetland, gravel substrate and subsurface flow of the stormwater through the root systems force the vegetation to remove nutrients and dissolved pollutants from the stormwater.

Only one company currently manufactures a pre-engineered wetland: It consists of a standard module, about 9.5 feet in diameter and 4 feet in height. The module is constructed of recycled polyethylene. The number of units is varied to meet the design volume of the site.

California Experience

There are currently only a few installations in California.

Advantages

- Constructed wetlands remove dissolved pollutants unlike many of the other treatment technologies, whether manufactured or in the public domain.
- Gravel substrate and subsurface flow of the stormwater through the root systems forces the vegetation to remove nutrients and dissolved pollutants from the stormwater.
- Unlike standard constructed wetlands (TC-21), there is no standing water in the manufactured wetland between storms (after emptying with each storm). This minimizes but does not entirely eliminate the opportunity for mosquito breeding.
- Can be incorporated into the landscaping of the development.
- The gravel substrate likely provides a good environment for bacteria, facilitating the removal of nitrogen and the degradation of oil and greases, and other organic compounds.
- The gravel substrate can be augmented with media that is specifically effective at removing dissolved pollutants, increasing further the performance of the system.
- Vegetation is more easily harvested in comparison to a wet pond or standard constructed wetland (TC-21).
- Provides modest habitat for insects and other small invertebrates which in turn provide food for birds and other small animals.

Design Considerations

- Drainage Area Size
- Potential Pretreatment Requirements

Targeted Constituents

- ✓ Sediment
- ✓ Nutrients
- ✓ Trash
- ✓ Metals
- ✓ Bacteria
- ✓ Oil and Grease
- ✓ Organics

Removal Effectiveness

See New Development and Redevelopment Handbook-Section 5.

CASQA California Stormwater Quality Association

Limitations

- Not likely suitable for drainage areas greater than an acre due to the number of units that is required for larger sites.
- May attract invasive wetland species
- May require irrigation during the dry season
- With an emptying time as much as 5 days, a breeding ground for mosquitoes may occur during and immediately following each storm
- If site development requirements of local government also includes detention for flow control, the drawdown characteristics of the system must be compatible with the detention system.
- Where many units are required, the pattern of circular plastic covers of the center wells may not be appealing.

Design and Sizing Guidelines

The unit consists of two concentric chambers, analogous to a doughnut. The inner chamber is open whereas the outer chamber is filled with gravel in which the wetland plants reside. The water enters a center well, moving in a circular motion around nearly the entire circumference of the well. Via floating surface skimmers the water then enters the outer chamber. The flow rate is controlled at the outlet with a valve. The substrate for the vegetation is small gravel. Gravel substrate encourages the wetland vegetation to use nutrients and metals in the stormwater. The concept of subsurface flow through gravel has its parentage with subsurface flow constructed wetlands used to treat wastewater.

The unit includes a burlap bag over the inlet to remove debris, and screens within the center well for the same purpose. However, the upstream drainage system is considered the primary remover of coarse solids and debris. If the drainage system lacks drain inlets with sumps where coarse sediments and floatables are removed, it is desirable to include a pretreatment unit for this purpose such as a manhole or wet vault of suitable size.

Table 1 Supplemental Media

Targeted Pollutant	Alternative Media	References
Complex organics (e.g., pesticides)	Activated carbon	Metcalf and Eddy (2002), Minton (2002)
Petroleum hydrocarbons	Activated carbon, organoclay, granular polymer	Minton (2002)
Dissolved metals	Zeolite, activated carbon	Minton (2002), Groffman, et al. (1997), Netzer and Hughes (1984), Stormwater Management Inc. technical memos
Dissolved phosphorus	Blast furnace slag, iron-ore, iron wool, limestone, aluminum oxide, dolomite, iron-infused resin	James, et al. (1992), Minton (2002), Shapiro (1999), Ayoub, et al. (2001), Storm-water Management Inc memos

The design water quality volume is determined by local governments or sized so that 85% of the annual runoff volume is treated.

Construction/Inspection Considerations
Refer to manufacturer guidelines.

Performance

There is little operating data for the manufactured wetland, although these data indicate very high removal efficiencies, similar to created stormwater wetlands. An advantage of wet ponds and standard constructed wetlands over most other treatment technologies is the removal of dissolved pollutants. However, this occurs only to the extent that the stormwater pollutants are able to diffuse into the soil where they are removed by the soil or the plants. Except for non-rooted plants, pollutant uptake by vegetation does not occur in the overlying wet pool (Minton, 2002). Placement of wetland plants in gravel with the stormwater flowing directly through the root system forces uptake by the vegetation. To maintain performance therefore requires annual or harvesting of the vegetation (See Maintenance). However, the removal of dissolved phosphorus, metals, and complex organics like pesticides in earthen-lined ponds and wetlands is primarily by chemical sorption or precipitation with the soil, not uptake by plants (Minton, 2002). Gravel substrate does not provide ideal conditions for these chemical processes. There are currently no operating data for the manufactured wetland with respect to the removal of dissolved pollutants and therefore whether uptake solely by plants is sufficient is unknown. It may be desirable to augment the gravel with media capable of removing dissolved pollutants. The supplemental media can be specific for the pollutant that is to be removed. Table 1 lists media that have been evaluated in either stormwater or wastewater constructed wetlands or filtration systems.

The gravel substrate likely provides a good environment for bacteria, facilitating the removal of nitrogen (its primary mechanism of removal) and the degradation of petroleum and other organic compounds. While this has been confirmed to occur in the manufactured product discussed here, experience with constructed wetlands used for wastewater treatment (Minton, 2002) suggests that it likely occurs

Siting Criteria

While not stated by the manufacturer, the system is likely most appropriate for small drainage areas of an approximately an acre or less, given the number of units required per acre.

Additional Design Guidelines

As noted previously, the number of units installed is the function of the volume of water to be treated: multiple units are installed in parallel with incoming stormwater split via a manifold. The storage volume of one unit is approximately 185 ft3. The recommended emptying rate is 0.25 gallons per minute (average). To illustrate sizing, assume a development site of one acre and the design event is 0.75 inches. The total volume of the design event is 2,722 cubic feet. Thus, a minimum of 15 units is required, ignoring throughput during the storm. At this rate, a unit drains in approximately 3.8 days.

However, the emptying time must be considered with respect to the inter-event time between storms. If the emptying time is too great there is a statistical probability of some water being present in the units when the next storm occurs. If so, the full volume of the design event is not treated over the long term. The manufacturer currently does not provide a design method that considers this factor. The recommended approach is to use the method presented in TC-22 for Extended Detention systems inasmuch as the Storm Treat is a "fill-and-draw" system that functions like Extended Detention and should be expected to capture and treat the same stormwater volume over time.

Fewer units are possible if the upstream drainage system is able to store water, although this extends the emptying time. If a detection facility is required for flow control, it can provide the necessary storage and the number of wetland units is reduced, but not substantially given the need to drain the system in a timely fashion. Furthermore, if a detention facility is included it must control the release rate, not the manufactured wetland. This may require a more rapid release rate than recommended by the manufacturer. However, there are no data relating emptying rate with performance. Since the system also functions in effect as a horizontal filter, throughput rates higher than what is recommended by the manufacturer may be possible without a significant reduction in performance.

Maintenance

To maximize the benefits of wetland vegetation in its removal of pollutants, the vegetation must be harvested each growth season. Harvesting is particularly important with respect to the removal of phosphorus and metals, less so nitrogen. Harvesting should occur by mid-summer before the plants begin to transfer phosphorus from the aboveground foliage to subsurface roots, or begin to lose metals that desorb during plant die-off. While not stated by the manufacturer, it is also desirable that every few years the entire plant mass including roots is harvested. This is because the belowground biomass constitutes a significant reservoir (possibly half) of the nutrients and metals that are removed from the stormwater by plants (Minton, 2002). Annual maintenance is typical.

If debris and floatable material is not effectively removed in the pretreatment unit, premature clogging of the debris bag may occur.

- Crop vegetation near end of each growth season to capture the nutrients and pollutants removed by the wetland vegetation.
- Inspect periodically to ensure that invasive species of wetland plants is not occurring
- Conduct inspection during the dry season to determine if irrigation of plants is necessary
- Clean center well periodically.

Cost

Manufacturers provide costs for the units including delivery. Installation costs are generally on the order of 50 to 100 % of the manufacturer's cost.

Cost Considerations

- If the drainage system lacks drain inlets with sumps where coarse sediments and floatables are removed, it is desirable to include a pretreatment unit for this purpose such as a manhole or wet vault of suitable size. This should be factored in the cost-analysis when comparing to other treatment BMPs. If already a requirement of the local government, a detention facility for flow control can serve this purpose.

- In comparison to public domain wet ponds (TC-20) and constructed wetlands (TC-21), vegetation harvesting is simpler, and therefore less costly.

References and Sources of Additional Information

Ayoub, G.M., B. Koopman, and N. Pandya, 2001, Iron and aluminum hydroxy (oxide) coated filter media for low-concentration phosphorus removal, Water Environ. Res., 73, 7, 478

Groffman, A., S. Peterson, D. Brookins, 1997, The removal of lead and other heavy metals from wastewater streams using zeolites, zeocarb, and other natural materials as a sorption media, presented to the 70th Annual Conference, Water Environment Federation, Alexandria, Virginia

James, B.R., M.C. Rabvenhorst, and G.A. Frigon, 1992, Phosphorus sorption by peat and sand amended with iron oxides or steel wool, Water Environ. Res., 64, 699. Manufacturer's literature Metcalf and Eddy, Inc., 2002, Wastewater Engineering: Treatment, Disposal, Reuse, McGraw-Hill, New York, New York. Minton, G.R., 2002, Stormwater Treatment: Biological, Chemical, and Engineering Principles, RPA Press, Seattle, Washington, 416 pages. Netzer, A., and D.E. Hughes, 1984, Adsorption of copper, lead, and cobalt by activated carbon, Water Res., 18, 927. Shapiro and Associates and the Bellevue Utilities Department, 1999, Lakemont stormwater treatment facility monitoring report, Bellevue, Washington.

Description

Stormwater media filters are usually two-chambered including a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering media in the second chamber.

There are currently three manufacturers of stormwater filter systems. Two are similar in that they use cartridges of a standard size. The cartridges are placed in vaults; the number of cartridges a function of the design flow rate. The water flows laterally (horizontally) into the cartridge to a centerwell, then downward to an underdrain system. The third product is a flatbed filter, similar in appearance to sand filters.

California Experience

There are currently about 75 facilities in California that use manufactured filters.

Advantages

- Requires a smaller area than standard flatbed sand filters, wet ponds, and constructed wetlands.
- There is no standing water in the units between storms, minimizing but does not entirely eliminate the opportunity for mosquito breeding.
- Media capable of removing dissolved pollutants can be selected.
- One system utilizes media in layers, allowing for selective removal of pollutants.
- The modular concept allows the design engineer to more closely match the size of the facility to the design storm.

Limitations

- As some of the manufactured filter systems function at higher flow rates and/or have larger media than found in flatbed filters, the former may not provide the same level of performance as standard sand filters. However, the level of treatment may still be satisfactory.
- As with all filtration systems, use in catchments that have significant areas of non-stabilized soils can lead to premature clogging.

Design Considerations

- Design Storm
- Media Type
- Maintenance Requirement

Targeted Constituents

✓	Sediment
✓	Nutrients
✓	Trash
✓	Metals
	Bacteria
✓	Oil and Grease
✓	Organics

Removal Effectiveness

See New Development and Redevelopment Handbook-Section 5.

CASQA California Stormwater Quality Association

Design and Sizing Guidelines

There are currently three manufacturers of stormwater filter systems.

Filter System A: This system is similar in appearance to a slow-rate sand filter. However, the media is cellulose material treated to enhance its ability to remove hydrocarbons and other organic compounds. The media depth is 12 inches (30 cm). It operates at a very high rate, 20 gpm/ft2 at peak flows. Normal operating rates are much lower assuming that the stormwater covers the entire bed at flows less than the peak rate. The system uses vortex separation for pretreatment. As the media is intended to remove sediments (with attached pollutants) and organic compounds, it would not be expected to remove dissolved pollutants such as nutrients and metals unless they are complexed with the organic compounds that are removed.

Filter System B: It uses a simple vertical filter consisting of 3 inch diameter, 30 inch high slotted plastic pipe wrapped with fabric. The standard fabric has nominal openings of 10 microns. The stormwater flows into the vertical filter pipes and out through an underdrain system. Several units are placed vertically at 1 foot intervals to give the desired capacity. Pretreatment is typically a dry extended detention basin, with a detention time of about 30 hours. Stormwater is retained in the basin by a bladder that is automatically inflated when rainfall begins. This action starts a timer which opens the bladder 30 hours later. The filter bay has an emptying time of 12 to 24 hours, or about 1 to 2 gpm/ft2 of filter area. This provides a total elapsed time of 42 to 54 hours. Given that the media is fabric, the system does not remove dissolved pollutants. It does remove pollutants attached to the sediment that is removed.

Filter System C: The system use vertical cartridges in which stormwater enters radially to a center well within the filter unit, flowing downward to an underdrain system. Flow is controlled by a passive float valve system, which prevents water from passing through the cartridge until the water level in the vault rises to the top of the cartridge. Full use of the entire filter surface area and the volume of the cartridge is assured by a passive siphon mechanism as the water surface recedes below the top of the cartridge. A balance between hydrostatic forces assures a more or less equal flow potential across the vertical face of the filter surface. Hence, the filter surface receives suspended solids evenly. Absent the float valve and siphon systems, the amount of water treated over time per unit area in a vertical filter is not constant, decreasing with the filter height; furthermore, a filter would clog unevenly. Restriction of the flow using orifices ensures consistent hydraulic conductivity of the cartridge as a whole by allowing the orifice, rather than the media, whose hydraulic conductivity decreases over time, to control flow.

The manufacturer offers several media used singly or in combination (dual- or multi-media). Total media thickness is about 7 inches. Some media, such as fabric and perlite, remove only suspended solids (with attached pollutants). Media that also remove dissolved include compost, zeolite, and iron-infused polymer. Pretreatment occurs in an upstream unit and/or the vault within which the cartridges are located.

Water quality volume or flow rate (depending on the particular product) is determined by local governments or sized so that 85% of the annual runoff volume is treated.

Construction/Inspection Considerations

- Inspect one or more times as necessary during the first wet season of operation to be certain that it is draining properly.

Performance

The mechanisms of pollutant removal are essentially the same as with public domain filters (TC -40) if of a similar design. Whether removal of dissolved pollutants occurs depends on the media. Perlite and fabric do not remove dissolved pollutants, whereas for examples, zeolites, compost, activated carbon, and peat have this capability.

As most manufactured filter systems function at higher flow rates and have larger media than found in flatbed filters, they may not provide the same level of performance as standard sand filters. However, the level of treatment may still be satisfactory.

Siting Criteria

There are no unique siting criteria.

Additional Design Guidelines

Follow guidelines provided by the manufacturer.

Maintenance

- Maintenance activities and frequencies are specific to each product. Annual maintenance is typical.
- Manufactured filters, like standard filters (TC-40), require more frequent maintenance than most standard treatment systems like wet ponds and constructed wetlands, typically annually for most sites.
- Pretreatment systems that may precede the filter unit should be maintained at a frequency specified for the particular process.

Cost

Manufacturers provide costs for the units including delivery. Installation costs are generally on the order of 50 to 100 % of the manufacturer's costs.

Cost Considerations

- Filters are generally more expensive to maintain than swales, ponds, and basins.
- The modularity of the manufactured systems allows the design engineer to closely match the capacity of the facility to the design storm, more so than with most other manufactured products.

References and Sources of Additional Information

Minton, G.R., 2002, Stormwater Treatment: Biological, Chemical, and Engineering Principles, RPA Press, 416 pages.

Design Considerations

- Hydraulic Capacity
- Sediment Accumulation

Targeted Constituents

✓	Sediment
✓	Nutrients
✓	Trash
✓	Metals
	Bacteria
✓	Oil and Grease
✓	Organics

Removal Effectiveness

See New Development and Redevelopment Handbook-Section 5.

Description

A wet vault is a vault with a permanent water pool, generally 3 to 5 feet deep. The vault may also have a constricted outlet that causes a temporary rise of the water level (i.e., extended detention) during each storm. This live volume generally drains within 12 to 48 hours after the end of each storm.

California Experience

There are currently several hundred stormwater treatment facilities in California that use manufactured wet vaults currently in operation in California.

Advantages

- Internal baffling and other design features such as bypasses may increase performance over traditional wet vaults and/or reduce the likelihood of resuspension and loss of sediments or floatables during high flows.
- Head loss is modest.

Limitations

- Concern about mosquito breeding in standing water
- The area served is limited by the capacity of the largest models.
- As the products come in standard sizes, the facilities will be oversized in many cases relative to the design treatment storm, increasing the cost.
- Do not remove dissolved pollutants.
- A loss of dissolved pollutants may occur as accumulated organic matter (e.g., leaves) decomposes in the units.

Design and Sizing Guidelines

Water quality volume or flow rate (depending on the particular product) is determined by local governments or sized so that 85% of the annual runoff volume is treated. There are three general configurations of wet vaults currently available, differing with the particular manufacturer.

Vault System A: This system consists of two standard precast manholes, the size varying to achieve the desired capacity. Stormwater enters the first (primary) manhole where coarse solids are removed. The stormwater flows from the first to the second (storage) manhole, carrying floatables where they are captured and retained. Further sedimentation occurs in this second manhole. The off-line serves as a storage reservoir for floatables as stormwater flows though at flow rates less than the design flow. A patented device controls the flow into the storage manhole. All flows above the stated treatment flow rate bypass through the device. The bypass prevents resuspension or loss of sediment and floatables that have accumulated in the second manhole. It is important to recognize that has storage of accumulated sediment occurs directly in the operating area of the manholes; treatment efficiency will decline over time given the reduction in treatment volume

The manufacturer currently provides 4 models, with treatment capacities (flow rate above which bypass occurs) from 2.4 to 21.8 cfs. The hydraulic capacities range from 10 to 100 cfs. As such, all stormwater achieves at least partial treatment through essentially all but the most extreme storm flows since some settling occurs in the first manhole. The manufacturer provides information on the total system (water) volume, sediment capacity, and floatable capacities. The size of the storage manhole can be varied with each of the four models to increase storage capacity as desired, following recommendations of the manufacturer. The footprint of this system ranges from about 200 to 350 ft2, with heights of about 11.5 to 13.5 feet (excluding minimum soil cover and access port extenders), depending on the model. Head loss ranges from 5 to 12 inches, depending on the model. Sediment and floatable capacities range up to 201 cf and 150 gallons, respectively. The recommended point of maintenance is when about 25% of the wet pool volume is supplanted by sediment. The affect of the accumulation of sediment on performance is not given

Vault System B: This wet vault has outward appearance of a standard, rectangular wet vault, but with its own unique design for internal baffles. Included is an entrance baffle, presumably to reduce the energy of the flow entering the unit. Baffles are also affixed to the floor, purportedly to reduce resuspension of settled sediments improve performance. A floating sorbent pad may be placed near the outlet to remove free oil floating on the surface. The vault includes both a permanent wet pool, 3 feet in depth, and live storage volume that is filled during each storm. The live storage volume is accomplished by restricting the outlet. The system is modular: that is, it consists of standard units that are added to increase the length, thereby providing the desired volume. Presumably for very large sites there is a practical total length. Further capacity could be accomplished by having two or more vaults in parallel. The capacity of the system is therefore essentially unlimited, Being modular may allow the design engineer to more closely match facility size to the design event.

Vault System C: This system is like System A, but differs in two primary respects. The Stormceptor module consists of only one circular structure. Hence, standard precast manholes can be used for the smaller models but larger models are non-standard sizes. Like System A, System C has an internal bypass, involving a unique design. The purpose of the bypass is to prevent resuspension of previously suspended material. All stormwater up to the bypass rate is diverted downward into the center well where removal occurs. Flows in excess of the treatment capacity are diverted directly across the top of the device to the outlet. According to the manufacturer there is also some storage capacity for floatables immediately beneath the bypass structure.

Twelve models are available. The treatment capacity of each is not indicated for the Stormceptor as it is a function of the removal efficiency specified by the designer. The manufacturer provides a methodology for the calculation of efficiency as a function of flow rate (see Design Guidelines). Hydraulic capacities range up to approximately 63 cfs. The head requirement is a function of the model and desired hydraulic flow rate, ranging up to 21 inches.

Diameters range from 4 to 12 feet, and minimum heights up to about 13 feet plus the diameter of the incoming pipe. Sediment and floatable capacities range up to 1,470 cf and 3,055 gallons, respectively. The recommended point of maintenance is when about 15% of the wet pool volume is supplanted by sediment. The affect of the accumulation of sediment on performance is not given but can be estimated using the manufacturer's sizing methodology.

Construction/Inspection Considerations

Refer to guidelines provided by the manufacturer.

Performance

A manufactured wet vault can be expected to perform similarly to large catch basins in that its wet volume (dead storage) is similar to that determined by methodology provided in TC-20 for wet ponds. Hence, the engineer should compare the volume of the model s/he intends to select to what the volume of a constructed wet vault would be for the site. Conceivably, manufactured vaults may give better performance than standard catch basins, given the inclusion of design elements that are intended to minimize resuspension. Given this benefit, it could be argued that manufactured wet vaults can be smaller than traditional catch basins, to achieve similar performance. However, there are no data indicating the incremental benefit of the particular design elements of each manufactured product.

Siting Criteria

There are no unique siting criteria. The size of the drainage area that can be served by a manufactured wet vault is directly related to the capacities of the largest models.

Additional Design Guidelines

Refer to guidelines of the manufacturers.

Maintenance

Maintenance consists of the removal of accumulated material with an eductor truck. It may be necessary to remove and dispose the floatables separately due to the presence of petroleum product. Annual maintenance is typical.

It is important to recognize that as storage of accumulated sediment occurs directly in the operating area of the wet vault, treatment efficiency will decline over time given the reduction in treatment volume. Whether this is significant depends on the design capacity. If the total volume of the wet pool is similar to that determined by the method on TC-20, the effect on performance is minor.

Maintenance Requirements

- Each manufacturer provides storage capacities with respect to sediments and floatables, with recommendations on the frequency of cleaning as a function of the percentage of the volume in the unit that has been filled by these materials.

- The recommended frequency of cleaning differs with the manufacturer, ranging from one to two years. It is prudent to inspect the unit twice during the first wet season of operation, setting the cleaning frequency accordingly.

Cost

Manufacturers provide costs for the units including delivery. Installation costs are generally on the order of 50 to 100 % of the manufacturer's cost.

Cost Considerations

- The different geometries of the several manufactured separators suggest that when comparing the costs of these systems to each other, that local conditions (e.g., groundwater levels) may affect the relative cost-effectiveness.

- Subsurface facilities are more expensive to construct than surface facilities of similar size. However, the added cost of construction is in many developments offset by the value of continued use of the land.

- Some of the manufactured vaults may be less expensive to maintain than public domain vaults as the former may be cleaned without the need for confined space entry.

- Subsurface facilities do not require landscaping, reducing maintenance costs accordingly.

References and Sources of Additional Information

Manufacturers literature.

Description

Vortex separators: (alternatively, swirl concentrators) are gravity separators, and in principle are essentially wet vaults. The difference from wet vaults, however, is that the vortex separator is round, rather than rectangular, and the water moves in a centrifugal fashion before exiting. By having the water move in a circular fashion, rather than a straight line as is the case with a standard wet vault, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space. Vortex separators were originally developed for combined sewer overflows (CSOs), where it is used primarily to remove coarse inorganic solids. Vortex separation has been adapted to stormwater treatment by several manufacturers.

California Experience

There are currently about 100 installations in California.

Advantages

- May provide the desired performance in less space and therefore less cost.
- May be more cost-effective pre-treatment devices than traditional wet or dry basins.
- Mosquito control may be less of an issue than with traditional wet basins.

Limitations

- As some of the systems have standing water that remains between storms, there is concern about mosquito breeding.
- It is likely that vortex separators are not as effective as wet vaults at removing fine sediments, on the order 50 to 100 microns in diameter and less.
- The area served is limited by the capacity of the largest models.
- As the products come in standard sizes, the facilities will be oversized in many cases relative to the design treatment storm, increasing the cost.
- The non-steady flows of stormwater decreases the efficiency of vortex separators from what may be estimated or determined from testing under constant flow.
- Do not remove dissolved pollutants.
- A loss of dissolved pollutants may occur as accumulated organic

Design Considerations

- Service Area
- Settling Velocity
- Appropriate Sizing
- Inlet Pipe Diameter

Targeted Constituents

	Constituent	Removal
✓	Sediment	▲
✓	Nutrients	●
✓	Trash	
✓	Metals	●
	Bacteria	
✓	Oil and Grease	
✓	Organics	

Legend ***(Removal Effectiveness)***

● Low ■ High

▲ Medium

matter (e.g., leaves) decomposes in the units.

Design and Sizing Guidelines

The stormwater enters, typically below the effluent line, tangentially into the basin, thereby imparting a circular motion in the system. Due to centrifugal forces created by the circular motion, the suspended particles move to the center of the device where they settle to the bottom. There are two general types of vortex separation: free vortex and dampened (or impeded) vortex. Free vortex separation becomes dampened vortex separation by the placement of radial baffles on the weir-plate that impede the free vortex-flow pattern

It has been stated with respect to CSOs that the practical lower limit of vortex separation is a particle with a settling velocity of 12 to 16.5 feet per hour (0.10 to 0.14 cm/s). As such, the focus for vortex separation in CSOs has been with settleable solids generally 200 microns and larger, given the presence of the lighter organic solids. For inorganic sediment, the above settling velocity range represents a particle diameter of 50 to 100 microns. Head loss is a function of the size of the target particle. At 200 microns it is normally minor but increases significantly if the goal is to remove smaller particles.

The commercial separators applied to stormwater treatment vary considerably with respect to geometry, and the inclusion of radial baffles and internal circular chambers. At one extreme is the inclusion of a chamber within the round concentrator. Water flows initially around the perimeter between the inner and outer chambers, and then into the inner chamber, giving rise to a sudden change in velocity that purportedly enhances removal efficiency. The opposite extreme is to introduce the water tangentially into a round manhole with no internal parts of any kind except for an outlet hood. Whether the inclusion of chambers and baffles gives better performance is unknown. Some contend that free vortex, also identified as swirl concentration, creates less turbulence thereby increasing removal efficiency. One product is unique in that it includes a static separator screen.

- Sized is based on the peak flow of the design treatment event as specified by local government.
- If an in-line facility, the design peak flow is four times the peak of the design treatment event.
- If an off-line facility, the design peak flow is equal to the peak of the design treatment event.
- Headloss differs with the product and the model but is generally on the order of one foot or less in most cases.

Construction/Inspection Considerations

No special considerations.

Performance

Manufacturer's differ with respect to performance claims, but a general statement is that the manufacturer's design and rated capacity (cfs) for each model is based on and believed to achieve an aggregate reduction of 90% of all particles with a specific gravity of 2.65 (glacial sand) down to 150 microns, and to capture the floatables, and oil and grease. Laboratory tests of two products support this claim. The stated performance expectation therefore implies that a lesser removal efficiency is obtained with particles less than 150 microns, and the lighter, organic settleables. Laboratory tests of one of the products found about 60% removal of 50 micron sand at the expected average operating flow rate

Experience with the use of vortex separators for treating combined sewer overflows (CSOs), the original application of this technology, suggests that the lower practical limit for particle removal are particles with a settling velocity of 12 feet per hour (Sullivan, 1982), which represents a particle diameter of 100 to 200 microns, depending on the specific gravity of the particle. The CSO experience therefore seems consistent with the limited experience with treating stormwater, summarized above

Traditional treatment technologies such as wet ponds and extended detention basins are generally believed to be more effective at removing very small particles, down to the range of 10 to 20 microns. Hence, it is intuitively expected that vortex separators do not perform as well as the traditional wet and dry basins, and filters. Whether this matters depends on the particle size distribution of the sediments in stormwater. If the distribution leans towards small material, there should be a marked difference between vortex separators and, say, traditional wet vaults. There are little data to support this conjecture

In comparison to other treatment technologies, such as wet ponds and grass swales, there are few studies of vortex separators. Only two of manufactured products currently available have been field tested. Two field studies have been conducted. Both achieved in excess of 80% removal of TSS. However, the test was conducted in the Northeast (New York state and Maine) where it is possible the stormwater contained significant quantities of deicing sand. Consequently, the influent TSS concentrations and particle size are both likely considerably higher than is found in California stormwater. These data suggest that if the stormwater particles are for the most part fine (i.e., less than 50 microns), vortex separators will not be as efficient as traditional treatment BMPs such as wet ponds and swales, if the latter are sized according to the recommendations of this handbook.

There are no equations that provide a straightforward determination of efficiency as a function of unit configuration and size. Design specifications of commercial separators are derived from empirical equations that are unique and proprietary to each manufacturer. However, some general relationships between performance and the geometry of a separator have been developed. CSO studies have found that the primary determinants of performance of vortex separators are the diameters of the inlet pipe and chamber with all other geometry proportional to these two.

Sullivan et al. (1982) found that performance is related to the ratios of chamber to inlet diameters, $D2/D1$, and height between the inlet and outlet and the inlet diameter, $H1/D1$, shown in Figure 3. The relationships are: as $D2/D1$ approaches one, the efficiency decreases; and, as the $H1/D1$ ratio decreases, the efficiency decreases. These relationships may allow qualitative comparisons of the alternative designs of manufacturers. Engineers who wish to apply these concepts should review relevant publications presented in the References.

Siting Criteria

There are no particularly unique siting criteria. The size of the drainage area that can be served by vortex separators is directly related to the capacities of the largest models.

Additional Design Guidelines

Vortex separators have two capacities if positioned as in-line facilities, a treatment capacity and a hydraulic capacity. Failure to recognize the difference between the two may lead to significant under sizing; i.e., too small a model is selected. This observation is relevant to three of the five products. These three technologies all are designed to experience a unit flow rate of about 24 gallons/square foot of separator footprint at the peak of the design treatment event. This is the horizontal area of the separator zone within the container, not the total footprint of the unit. At this unit flow rate, laboratory tests by these manufacturers have established that the performance will meet the general claims previously described. However, the units are sized to handle 100 gallons/square foot at the peak of the hydraulic event. Hence, in selecting a particular model the design engineer must be certain to match the peak flow of the design event to the stated treatment capacity, not the hydraulic capacity. The former is one-fourth the latter. If the unit is positioned as an off-line facility, the model selected is based on the capacity equal to the peak of the design treatment event.

Maintenance

Maintenance consists of the removal of accumulated material with an eductor truck. It may be necessary to remove and dispose the floatables separately due to the presence of petroleum product.

Maintenance Requirements

Remove all accumulated sediment, and litter and other floatables, annually, unless experience indicates the need for more or less frequent maintenance.

Cost

Manufacturers provide costs for the units including delivery. Installation costs are generally on the order of 50 to 100 % of the manufacturer's cost. For most sites the units are cleaned annually.

Cost Considerations

The different geometry of the several manufactured separators suggests that when comparing the costs of these systems to each other, that local conditions (e.g., groundwater levels) may affect the relative cost-effectiveness.

References and Sources of Additional Information

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Sullivan, R.H., et al., 1982, Design manual – swirl and helical bend pollution control devices, EPA-600/8-82/013, U.S. Environmental Protection Agency, Washington, D.C.

Sullivan, R.H., M.M. Cohn, J.E. Ure, F.F. Parkinson, and G. Caliana, 1974, Relationship between diameter and height for the design of a swirl concentrator as a combined sewer overflow regulator, EPA 670/2-74-039, U.S. Environmental Protection Agency, Washington, D.C.

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Drain Inserts MP-52

Description
Drain inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris. There are a multitude of inserts of various shapes and configurations, typically falling into one of three different groups: socks, boxes, and trays. The sock consists of a fabric, usually constructed of polypropylene. The fabric may be attached to a frame or the grate of the inlet holds the sock. Socks are meant for vertical (drop) inlets. Boxes are constructed of plastic or wire mesh. Typically a polypropylene "bag" is placed in the wire mesh box. The bag takes the form of the box. Most box products are one box; that is, the setting area and filtration through media occur in the same box. Some products consist of one or more trays or mesh grates. The trays may hold different types of media. Filtration media vary by manufacturer. Types include polypropylene, porous polymer, treated cellulose, and activated carbon.

California Experience
The number of installations is unknown but likely exceeds a thousand. Some users have reported that these systems require considerable maintenance to prevent plugging and bypass.

Advantages
- Does not require additional space as inserts as the drain inlets are already a component of the standard drainage systems.
- Easy access for inspection and maintenance.
- As there is no standing water, there is little concern for mosquito breeding.
- A relatively inexpensive retrofit option.

Limitations
Performance is likely significantly less than treatment systems that are located at the end of the drainage system such as ponds and vaults. Usually not suitable for large areas or areas with trash or leaves than can plug the insert.

Design and Sizing Guidelines
Refer to manufacturer's guidelines. Drain inserts come any many configurations but can be placed into three general groups: socks, boxes, and trays. The sock consists of a fabric, usually constructed of polypropylene. The fabric may be attached to a frame or the grate of the inlet holds the sock. Socks are meant for vertical (drop) inlets. Boxes are constructed of plastic or wire mesh. Typically a polypropylene "bag" is placed in the wire mesh box. The bag takes the form of the box. Most box products are

Design Considerations
- Use with other BMPs
- Fit and Seal Capacity within Inlet

Targeted Constituents
✓ Sediment
✓ Nutrients
✓ Trash
✓ Metals
Bacteria
✓ Oil and Grease
✓ Organics

Removal Effectiveness

See New Development and Redevelopment Handbook-Section 5.

California Stormwater Quality Association one box; that is, the setting area and filtration through media occurs in the same box. One manufacturer has a double-box. Stormwater enters the first box where setting occurs. The stormwater flows into the second box where the filter media is located. Some products consist of one or more trays or mesh grates. The trays can hold different types of media. Filtration media vary with the manufacturer: types include polypropylene, porous polymer, treated cellulose, and activated carbon.

Construction/Inspection Considerations

Be certain that installation is done in a manner that makes certain that the stormwater enters the unit and does not leak around the perimeter. Leakage between the frame of the insert and the frame of the drain inlet can easily occur with vertical (drop) inlets.

Performance

Few products have performance data collected under field conditions.

Siting Criteria

It is recommended that inserts be used only for retrofit situations or as pretreatment where other treatment BMPs presented in this section area used.

Additional Design Guidelines

Follow guidelines provided by individual manufacturers.

Maintenance

Likely require frequent maintenance, on the order of several times per year.

Cost

- The initial cost of individual inserts ranges from less than $100 to about $2,000. The cost of using multiple units in curb inlet drains varies with the size of the inlet.

- The low cost of inserts may tend to favor the use of these systems over other, more effective treatment BMPs. However, the low cost of each unit may be offset by the number of units that are required, more frequent maintenance, and the shorter structural life (and therefore replacement).

References and Sources of Additional Information

Hrachovec, R., and G. Minton, 2001, Field testing of a sock-type catch basin insert, Planet CPR, Seattle, Washington

Interagency Catch Basin Insert Committee, Evaluation of Commercially-Available Catch Basin Inserts for the Treatment of Stormwater Runoff from Developed Sites, 1995

Larry Walker Associates, June 1998, NDMP Inlet/In-Line Control Measure Study Report

Manufacturers literature

Santa Monica (City), Santa Monica Bay Municipal Stormwater/Urban Runoff Project - Evaluation of Potential Catch basin Retrofits, Woodward Clyde, September 24, 1998

Woodward Clyde, June 11, 1996, Parking Lot Monitoring Report, Santa Clara Valley Nonpoint Source Pollution Control Program.