2005 Data Report

University of New Hampshire
Stormwater Center

Dedicated to the protection of water resources through effective stormwater management

CICEET

About this Report

In 1998, Phase II of the Clean Water Act broke over U.S. towns and cities a bit like a storm. The purpose of the new regulations was to reduce the impact of nonpoint source pollution carried by stormwater runoff—the single greatest threat to water quality nationwide. Under Phase II, governments of communities under 100,000, as well as commercial enterprises, are required to develop stormwater programs to improve water quality and reduce the volume of runoff.

To create the infrastructure for these programs, there is no lack of stormwater treatments from which to choose—from long, winding swales that sweep along roads and highways to manufactured systems that fit neatly in a manhole. The challenge that land use decision makers face is choosing an approach that will do the best job of protecting local water quality, is within their budgets, has a proven operations and maintenance record, and will meet regulatory requirements.

The information needed to make these decisions is not readily available, particularly for emerging stormwater treatments. Unfamiliar with new technologies, and lacking access to performance data, engineers, planners, and regulators are often slow to adopt them.

At the same time, the reliability of traditional approaches is in question. A three-year study of nine New Hampshire sites in the 1990's found that using conventional stormwater treatment practices degraded water quality with regard to at least one contaminant at least two-thirds of the time. When it comes to manufactured stormwater treatments, end users must rely on vendor claims about product performance—much of which is based on data collected in the laboratory, not the field.

The University of New Hampshire Stormwater Center was created to address this critical lack of information. This inaugural report is a compilation of data from our first year of monitoring the effectiveness of stormwater treatment systems in addressing water quality and the volume of runoff. We hope that it will become a valued resource for those who must comply with Phase II rules. It is, however, only the beginning. We will continue to refine our methods and broaden the scope of our evaluation to meet both the needs of stormwater managers and the rigorous scrutiny of the research community.

UNH Stormwater Center

The University of New Hampshire (UNH) Stormwater Center was established in 2004 to help land use decision makers develop stormwater management programs to protect water quality. The Center is supported by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), a partnership of UNH and the National Oceanic and Atmospheric Administration (NOAA). It is housed within the University's Environmental Research Group.

Center researchers operate a field facility that evaluates the effectiveness of different stormwater treatments in a side-by-side setting, under strictly controlled conditions. It is the only testing facility of its kind in the nation. Alongside evaluation of conventional treatment systems, researchers are also examining innovative stormwater management approaches such as a gravel wetland and an all-porous asphalt parking lot.

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Bioretention System

Performance evaluations indicated that several Low Impact Development (LID) designs, such as this bioretention system [left] have high pollutant removal efficiencies, ranging from 80 to 99 percent. In contrast, the riprap swale, the most common treatment system, performed poorly for most evaluation criteria.

Retention Pond

Second only to swales, ponds are a popular stormwater treatment choice. Their greatest drawback is seasonal. During warm summer months, ponds elevate the temperature of already heated surface runoff before it flows into small receiving streams. Thermal pollution negatively impacts the health of macro invertebrates and cold water fish. The retention pond [left] performed moderately well for most evaluation criteria.

In Cold Climates

Stormwater runoff in colder regions may have flow and mass loading characteristics different from warmer climates. Stormwater treatment design criteria needs to account for cold weather performance issues such as increased seasonal sediment loading and the impact of chloride from salting roads.

Melting snow can significantly increase peak flows and runoff quantities during warm winter rains. Our evaluations indicate that LIDs function well during winter months. Frost depth monitoring consistently demonstrated that melt water readily thaws filter media. Trends in chloride treatment are complex, and will be the subject of future study.

The field site's conglomeration of stormwater treatments makes it an ideal location for technology demonstrations, workshops, and training exercises. Last year, 15 demonstration workshops drew more than 500 participants from around the Northeast.

The Center engages the advice and experience of representatives from every sector involved in stormwater management. Its Technical Advisory Board includes industry representatives, state and federal regulators, academic scientists and engineers, and local government officials. Researchers also solicit comment from stormwater treatment vendors, manufacturers, regulatory agencies, system designers, and those required to comply with Phase II of the Clean Water Act.

Field Test Site

The UNH Stormwater Center's field site is adjacent to a nine-acre commuter parking lot in Durham, New Hampshire. The contributing drainage area—curbed and almost completely impervious—generates stormwater runoff typical of developed urban and suburban subcatchments. Installed in 1996, the lot is composed of standard, dense-mix asphalt. For nine months every year, it is used near capacity by a combination of passenger vehicles and bus traffic. The pavement is frequently plowed, salted, and sanded during the winter.

Literature review indicates that the lot's contaminant concentrations are above, or equal to, national norms for parking lot runoff. The runoff time of concentration is 22 minutes, with slopes ranging from 1.5 to 2.5 percent. Local climate is coastal, cool temperate forest. Average annual precipitation is 48 inches, uniformly distributed throughout the year with monthly averages of 4.1 (+/- 0.5) inches. The mean annual temperature is 48°F, with an average low of 15.8°F in January, and an average high of 82°F in July.

The adjacent field site contains three classes of stormwater treatments: conventional Best Management Practices (BMPs) such as swales and retention ponds; Low Impact Development (LID) designs such as treatment wetlands, and filtration and infiltration designs; and manufactured BMPs such as filtration and infiltration units, and hydrodynamic separators.

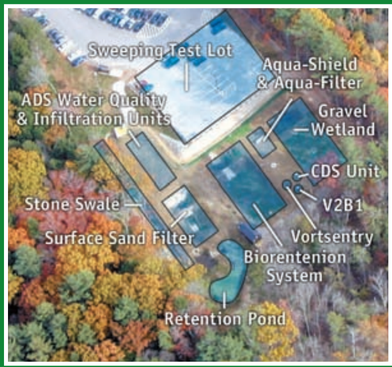
Since prior research has demonstrated that stormwater treatment performance varies widely in response to site-specific contaminant loading, the site was designed to test treatments under similar conditions. The parallel but separate configuration normalizes the stormwater treatment processes for rain event and watershed-loading variations. Each treatment is uniformly sized to address a Water Quality Volume (WQV) that targets a rainfall-runoff depth equivalent to 90 percent of annual volume of rainfall, or one inch of rainfall.

Rainfall runoff from the lot is channeled into a distribution box with a floor that rests slightly higher than the outlet invert elevations. This insures that runoff will scour the floor, thereby preventing sedimentation. From the distribution box, runoff flows into a network of pipes that distribute an equal quantity into each stormwater treatment. Effluent from the treatments is then piped into a centralized sampling gallery. There, automated samplers are programmed to test water quality and monitor flow volume from each treatment. A detailed quality assurance project protocol governs all analyses.

Manufactured Devices

Removal efficiencies of manufactured systems varied widely and were dependent on design, removal mechanism, and the pollutant of concern. This subsurface infiltration system was a top performer, exhibiting 99 percent removal efficiency for all pollutants except nitrate.

Field Test Site



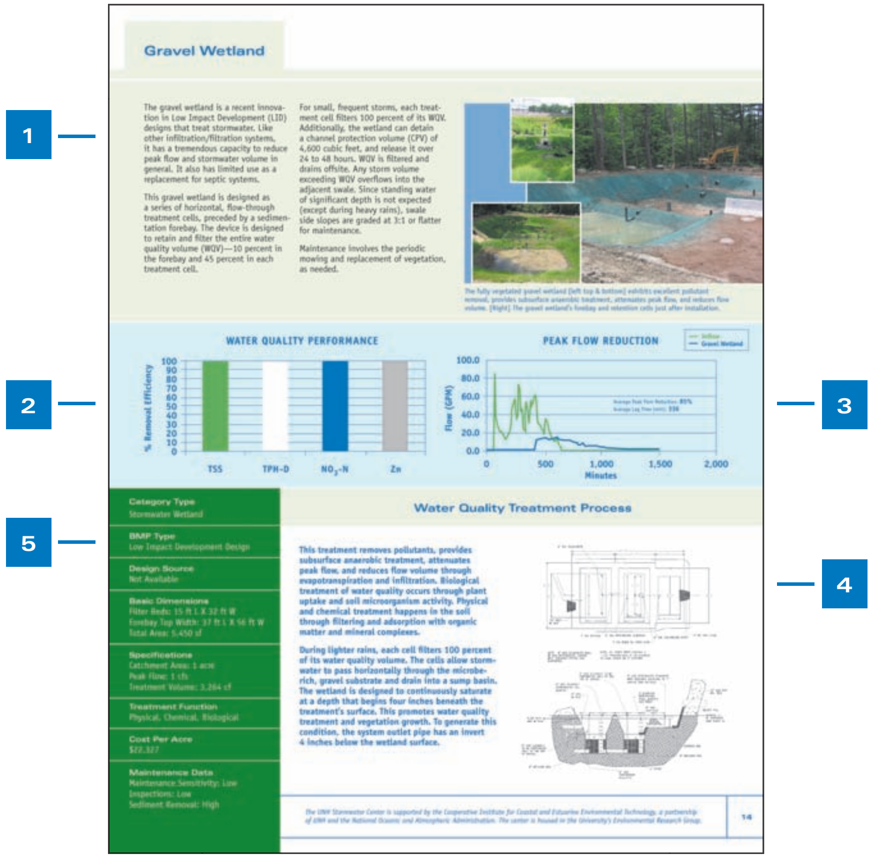
The UNH Stormwater Center's nine-acre field site is designed to test the effectiveness of different stormwater treatments in addressing water quality under similar conditions. The site's conglomeration of stormwater treatments in one setting makes it an ideal location for workshops, technology demonstrations, and training exercises.

How to Read this Report

Between September 2004 and August 2005, researchers evaluated 12 stormwater treatments for water quality performance and storm volume reduction during 11 rainfall-runoff events with a range of characteristics. This analysis assessed water quality parameters such as pH, temperature, dissolved oxygen, specific conductivity, and turbidity, as well as pollutant removal, peak flow reduction, maintenance, cost of installation, and materials.

The evaluation revealed distinctive trends. Several LID designs exhibited pollutant removal efficiencies of 80 to 99 percent. In contrast, traditional approaches did poorly to moderately. Manufactured system performance varied—systems with storage volumes were the most effective, those without, the least. The treatment of total suspended solids (TSS) depends largely on the size of particles and their concentration in influent. A TSS annual event mean concentration of 37 milligrams per liter was observed with particle sizes (D50) suspected to be less than 100 microns. This will be the subject of further research. Certain design elements, regardless of the treatment, promoted pollutant removal. These included increased hydraulic residence time, infiltration and filtration mechanisms, low turbulence, and using dense root mats and herbaceous plants.

We have summarized the analysis for each stormwater treatment in the following pages. However, this data should not be interpreted to mean that there is one treatment that is appropriate for all situations. Treatment size, site constraints, cost, operations, maintenance, and performance all must be taken into account.



Key

1. Overview

Describes the stormwater treatment application, its structure, general process, and maintenance requirements.

2. Pollutant Removal

Charts the treatment's efficiency in removing four common pollutants: total suspended solids (TSS), total petroleum hydrocarbons-diesel (TPH-D), nitrate (NO_3-N), and total zinc (Zn).

3. Flow Reduction

Traces the treatment's peak flow reduction—the percent difference between the maximum influent and the maximum effluent flow rates in gallons per minute (GPM). The green line charts influent, the blue line traces effluent.

4. Water Quality Treatment Process

Describes the principal mechanisms by which the treatment addresses water quality and offers a diagram of its structure.

5. Fast Facts

Offers a quick rundown on each stormwater treatment's design details.

- Category: Type of stormwater treatment
- BMP Type: Refers to whether the treatment is a conventional, structural Best Management Practice (BMP), a Low Impact Development (LID) design, or a manufactured device.
- Design Source: Cites manufacturer or design manual that provided the treatment's design.
- Dimensions: Details the stormwater treatment size in feet (ft) or square feet (sf).
- Specifications: Describes catchment area in acres, peak flow in cubic feet per second (cfs), and the treatment volume in cubic feet (cf).
- Treatment Function: Describes whether the treatment's process is physical, chemical, biological, or a combination of these.
- Cost: Presents total material and installation costs as cost per acre of treated watershed. These costs do not include the expense of lifecycle maintenance and inspection, which will be the subject of future study.
- *Maintenance Data: Each system was ranked for its maintenance sensitivity, a measure of how well the treatment performed when not maintained as recommended. Rankings were adapted from the Connecticut Department of Environmental Protection's *2004 Stormwater Quality Manual*.

** Regular maintenance is required for the successful long-term operation of any stormwater treatment system. Accumulated sediment and floating debris can reduce pollutant removal efficiency, increase the potential for sediment resuspension, and impact optimal flow reduction. This will be an area of further study in the coming year.*

Summary Table

This chart offers an overview of the water quality treatment and runoff volume reduction of the 12 stormwater treatments analyzed in this report. It includes percent pollutant removal efficiencies expressed as median values; percent average peak flow reduction; and the average lag time for each treatment. (Lag time is the difference in minutes between the influent and effluent volume center of mass.) Blue bars present data from the UNH Stormwater Center; white bars show comparative data on the same, or similar treatments, from alternate sources. "N/T" signifies "no treatment," indicating that the stormwater treatment did not remove the pollutant(s) in question.

Treatment Unit Description	Reference	TSS (%)	NO_3-N (%)	Zn (%)	TPH-D (%)	Average Peak Flow Reduction (%)	Average Lag Time (Min.)
ADS Water Quality Unit	**UNH**	**66**	N/T	**74**	**47**	N/T	N/T
	www.ads-pipe.com	80	N/T	N/T			
ADS Infiltration Unit	**UNH**	**99**	N/T	**99**	**99**	**83**	**364**
Surface Sand Filter	**UNH**	**49**	**6**	**81**	**94**	**60**	**220**
	EPA: Sand Filters	70	N/T	45			
Sand Filter	Clayton & Schueler, 1996	85	N/T	71			
	Bell, W., et al, 1995	61–70	N/T	> 82			
Retention Pond	**UNH**	**81**	**64**	**92**	**61**	**85**	**554**
	EPA: Wet Detention Ponds	50–90	N/T	40–50			
	Winer, 2000	80 ± 27	43 ± 38				
Bioretention System	**UNH**	**97**	**44**	**99**	**99**	**85**	**615**
	EPA: Bioretention	90	N/T	N/T			
	Davis, et al, 1998	81	38				
	Winogradoff, 2001	N/T	N/T	87–99			
Aqua-Swirl and Aqua-Filter	**UNH**	**66**	**10**	**61**	**42**	N/T	N/T
	EPA website	84	N/T	N/T			
VortSentry	**UNH**	**29**	**37**	**42**	**53**	N/T	N/T
	Technical Bulletin 1	80	N/T	N/T			
V2B1 Structural System	**UNH**	**38**	**-43**	**35**	**40**	N/T	N/T
	www.env21.com	80					
Continuous Deflec-tive Separation Unit	**UNH**	**41**	N/T	**26**	**26**	N/T	N/T
	various	52–84					
Gravel Wetland	**UNH**	**99**	**99**	**99**	**99**	**85**	**336**
	Clayton & Schueler, 1996	80–93	75–87	55–90			
Stone (Riprap) Swale	**UNH**	**52**	**-74**	**66**	**33**	N/T	N/T
Vegetated Swale	EPA: Vegetated Swales	81	38	71			
	Clayton & Scheuler, 1996	30–90	0–80	N/T			

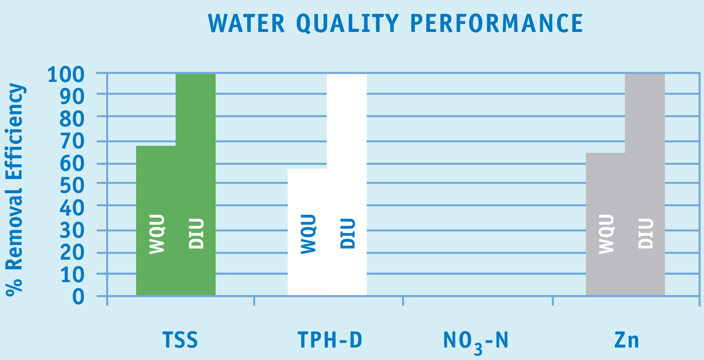
Advanced Drainage Systems (ADS) Water Quality & Underground Detention/Infiltration Units

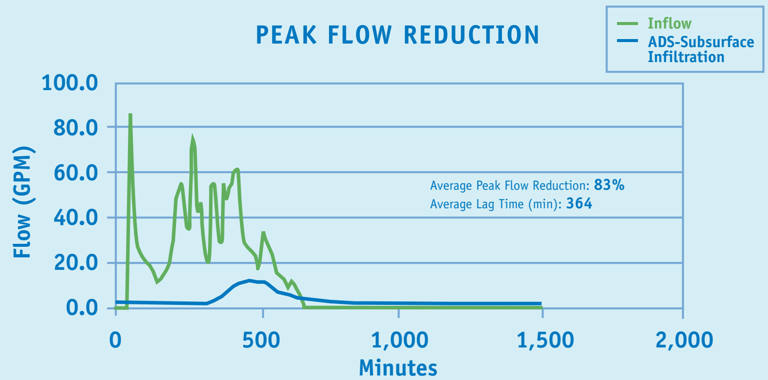
This treatment is commonly used beneath parking lots. Like other infiltration/detention treatments, it has a tremendous capacity to reduce peak flow. Since it does not require an associated retention pond, more land is available for parking. It can be used for detention and infiltration, depending on subbase and groundwater characteristics.

It is comprised of two units in series: a water quality unit (WQU) and a larger detention/infiltration unit (DIU). Both are made of high-density polyethylene pipe. The WQU is a series of weirs constructed from 60-inch diameter pipe. The DIU consists of three, 40-foot sections of 48-inch diameter perforated pipe, connected by headers. The top and sides of the excavation basin are wrapped in geotextile. Stormwater flows of 1 cubic foot per second (cfs) go first through the WQU and then into the DIU. Flows exceeding 1 cfs bypass the WQU through a pipe leading into the DIU. This prevents re-suspension of solids. From the DIU, stormwater infiltrates into the sandy subbase.

The WQU has two manholes for access and cleanout. Its maintenance includes removal of accumulated solids and floatables. DIU maintenance is minimal as pretreatment occurs in the WQU. Proper maintenance of the WQU prevents costly maintenance of the larger DIU.

The ADS treatment system during [left] and after installation [right]. Stormwater is pretreated for sediment and floatables in the black HDPE pipes, and then flows into the adjacent storage infiltration unit, where a sandy subbase is critical to pollutant removal.





Category Type
Underground Storage & Infiltration

BMP Type
Manufactured Device

Design Source
Advanced Drainage Systems (ADS)

Basic Dimensions
Water Quality Unit: 5 ft x 20 ft
Infiltration Unit: 22 ft x 40 ft

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs
Treatment Volume: 3,264 cf

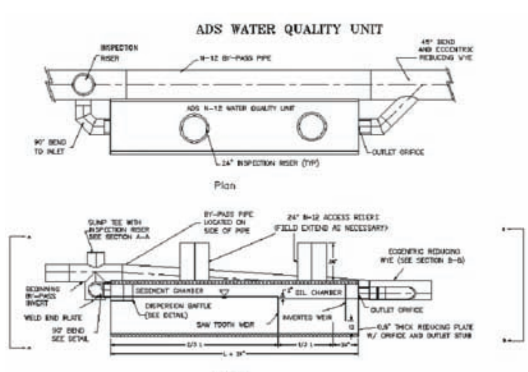
Treatment Function
Physical (1)
Physical / Chemical (2)

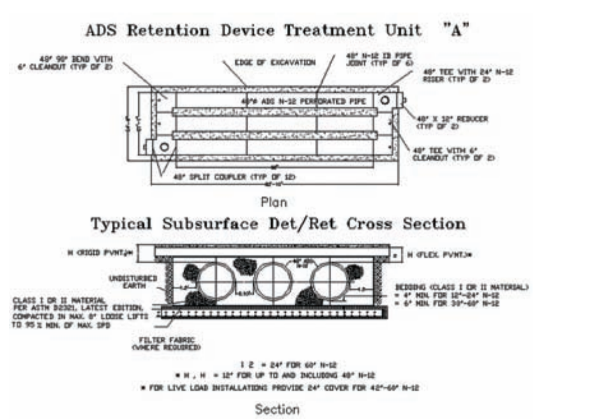
Cost Per Acre
$50,008.57

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

Water Quality Treatment Process

The WQU pretreats stormwater by allowing solids to settle in a large chamber and overflow weir, and by skimming floatables with an inverted weir. Predominant treatment occurs during infiltration from the DIU. Adequate separation from groundwater and a proper sandy subbase is essential in preventing groundwater contamination. During heavy rains, stormwater bypasses the WQU and fills the DIU's detention chamber. This unit filters and stores water up to the chamber volume, and then releases it over 24 to 48 hours.





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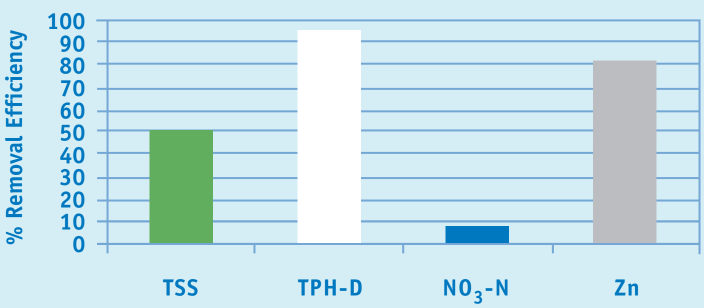
The coarse sand [center] used in this surface sand filter [left] provides physical and chemical water quality treatment. Erosion control matting protects the treatment after installation [right] until surrounding slopes are vegetated.

Surface sand filters, like other infiltration/filtration systems, have a tremendous capacity to reduce peak flow. This treatment is a Low Impact Development (LID) design comprised of a sedimentation forebay and an adjacent filter basin. The bottom of the basin is lined with two feet of sand that acts as a filter.

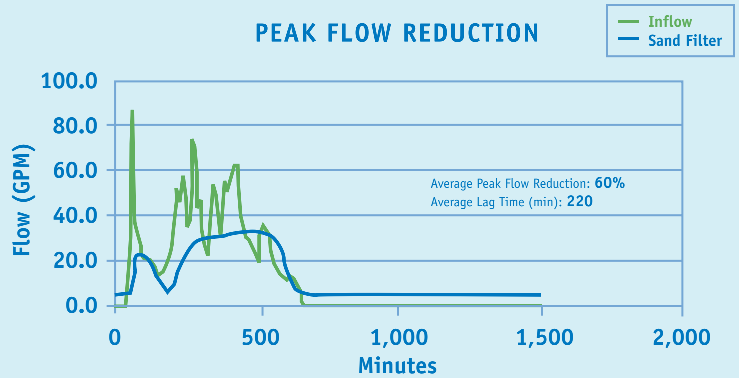
Stormwater flows into the forebay, which holds 25 percent of the water quality volume (WQV), and serves to remove solids that may clog the filter basin. Water then drains through a standpipe into the adjacent sand filter basin, which holds the remaining 75 percent WQV. When the forebay reaches capacity, overflow spills across a weir and into the filter basin. Heavier rains may saturate the subsurface and cause temporary ponding. The system is designed to drain within 24 to 48 hours. Influent exceeding the design volume overflows into a nearby swale.

Maintenance typically involves removing up to one inch of clogged sand from the surface of the filter bed, and fine particles from the pretreatment forebay. After repeated maintenance, sand may need to be added to the filter bed to maintain two feet of media. Depending on the size of the basin, sediment removal can be done by hand or with heavy machinery.

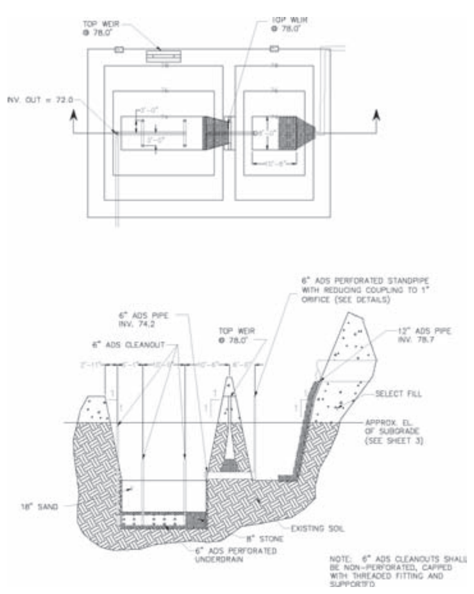
WATER QUALITY PERFORMANCE



PEAK FLOW REDUCTION



Water Quality Treatment Process



The surface sand filter uses coarse to medium grain sand to provide physical and chemical filtration of stormwater. As with many stormwater management approaches, pretreatment is important to prevent clogging of the filter media.

Physical settling of particles occurs in the sedimentation forebay. This is facilitated by slow stormwater drainage through a standpipe and into the sand filter basin.

Physical and chemical water quality treatment occurs in the basin. As stormwater infiltrates the pores of the sand filter bed, it is physically filtered by the sand particles and chemically adsorbed to particle surfaces.

Over time, the sand clogs and reduced rates of infiltration are observed. Typically, sand filters are very good water quality performers. The factors that most impact their performance are the depth and thickness of the filter media, the drainage to filter area ratio, and proper maintenance.

Category Type
Filtration

BMP Type
Low Impact Development Design

Design Source
New York State Stormwater Management Design Manual

Basic Dimensions
Filter Bed: 8 ft X 20 ft
Top Width: 31 ft X 41 ft

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs
Treatment Volume: 3,264 cf

Treatment Function
Physical / Chemical

Cost Per Acre
$12,417.14

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

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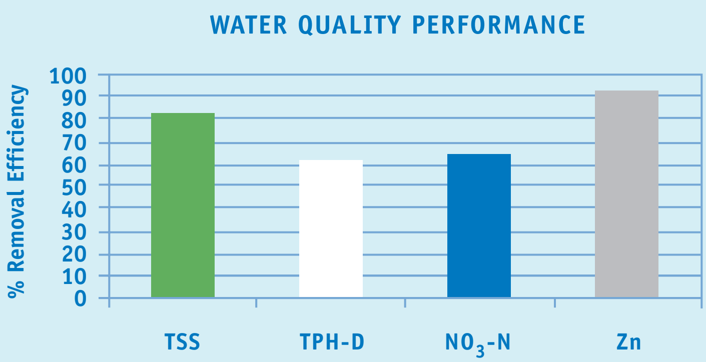
Retention Pond

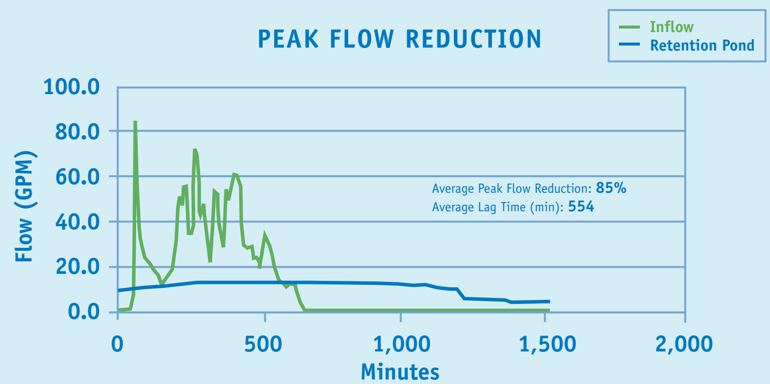
The retention pond (or wet pond) is among the most common stormwater treatments used for flood control in the world. These ponds are generally comprised of a sedimentation forebay and a larger basin sized to hold the water quality volume (WQV). They retain larger storm volumes for 24 to 48 hours, which protects the channels (streams, etc.) that receive the effluent. They also can be designed to retain larger volumes generated by 10- to 100-year rain events.

Treatment occurs when particles settle along the flow path between the pond's inlet and outlet, and between storms when additional settling occurs. Nutrient removal occurs between storms via plant uptake. Rain events provide a fresh influx of stormwater runoff, which forces standing water out of the system.

Maintenance requirements include the periodic removal of sediment and vegetation to restore storage capacity. Sediment removal occurs primarily in the forebay, which can be designed for easy equipment access.

A pond's [left] water quality performance is a function of storage volume and retention time. Erosion control matting [center] protects slopes with a grade of 2:1 or steeper. Green water [right] is a sign of eutrophication, a water quality issue associated with retention ponds.





Category Type
Stormwater Pond

BMP Type
Structural Conventional

Design Source
New York State Stormwater Management Design Manual

Basic Dimensions
Overall: 46 ft X 70 ft (varies)

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs
Treatment Volume: 3,264 cf

Treatment Function
Physical Settling/Biological

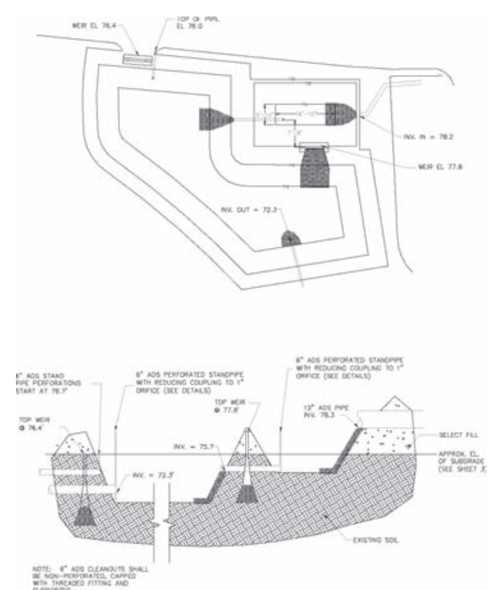
Cost Per Acre
$13,662.48

Maintenance Data
Maintenance Sensitivity: Low
Inspections: Low
Sediment Removal: Low

Water Quality Treatment Process

A retention pond's water quality treatment is a function of its large volume and high retention time, which allows for the physical settling of sediment. There are significant questions regarding the impact of retention ponds on water quality. Its ability to remove sediments—and nutrients when properly vegetated—is well documented. However, a pond may also present problems.

The human health risks associated with standing water include drowning and the creation of a habitat for mosquitoes that may carry disease. Nutrient-rich ponds also appear to be prime habitat for disease-causing bacteria, and elevated bacterial concentrations have been observed in retention ponds. In hot weather, ponds can superheat already warm parking lot runoff. Superheated effluent from retention ponds can impact small receiving streams, aquatic habitats, and fisheries that depend on cooler temperatures. Some innovative retention pond outlet designs include the use of gravel under-drains as a cooling mechanism.



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Hydroseeding and erosion control matting protect this system after installation [center]. Native species were planted along the installed system's [left] forebay and bioretention cell. Vegetation and appropriate soil media combine for effective water quality treatment [right].

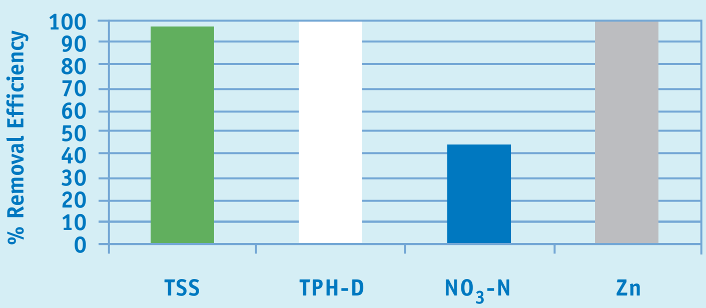
This bioretention system is the most common Low Impact Development (LID) stormwater treatment strategy. Like other infiltration/filtration systems, it has a tremendous capacity to reduce peak flow.

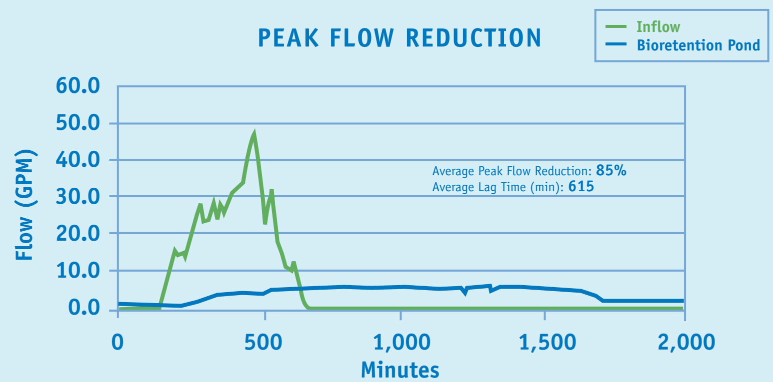
It is comprised of a sedimentation forebay and a bioretention basin. The filter media, also known as bioretention soil mix (BSM), typically ranges from two-and-one-half to five feet in thickness, and consists of sand, compost, and native soils. The treatment is well vegetated to provide a thick root mat for contaminant removal.

The forebay holds 25 percent of the water quality volume (WQV), and drains slowly through a standpipe into the bioretention basin, which holds the remaining 75 percent of the WQV. When forebay capacity is reached, overflow spills across a weir into the basin. The basin's filter media is designed to accommodate a moderately high infiltration rate of one cubic foot per day. The system allows for eight inches of above-ground ponding. The BSM and the vegetation remove nutrients and pollutants. Vegetation also reduces stormwater volume through evapotranspiration.

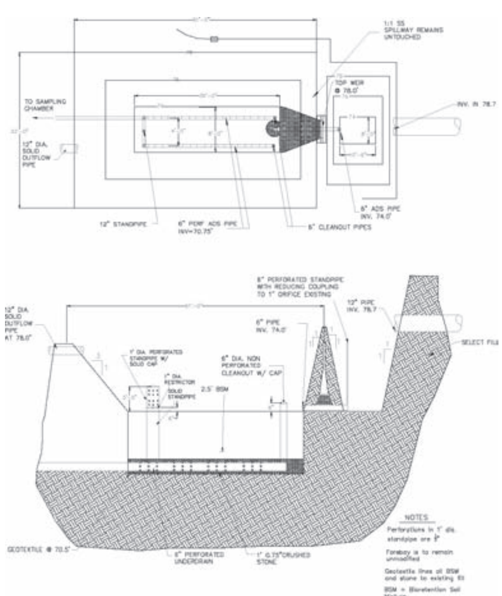
Maintenance involves the periodic mowing and replacement of vegetation, as needed.

WATER QUALITY PERFORMANCE





Water Quality Treatment Process



A recent innovation in stormwater management, this system removes pollutants, attenuates peak flow, and reduces flow volume through evapotranspiration and infiltration.

Biological treatment occurs through the uptake of pollutants by vegetation and soil microorganisms. Physical and chemical treatment, which occur in the soil media, includes filtering and adsorption with organic matter and mineral complexes.

Water quality treatment performance is high, however, the treatment's hydraulic efficiency and tendency to fail by clogging may be problematic. Early designs with bioretention soil mix (BSM) clay content as high as five percent, and geotextile filter fabrics between the BSM and subdrains, would fail prematurely due to "blinding," or filter fabric clogging. Modern designs have clay contents of less than one percent and do not use fabric beneath the unit, or between the BSM and the subdrain. This reduces clogging and maintains high water quality treatment efficiency.

Category Type
Filtration

BMP Type
Low Impact Development Design

Design Source
New York State Stormwater Management Design Manual

Basic Dimensions
Bioretention Cell: 67 ft L X 35 ft W
Forebay Top Width: 71 ft L X 46 ft W
Total Area: 4,100 sf

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs
Treatment Volume: 3,264 cf

Treatment Function
Physical, Chemical, Biological

Cost Per Acre
$25,104

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

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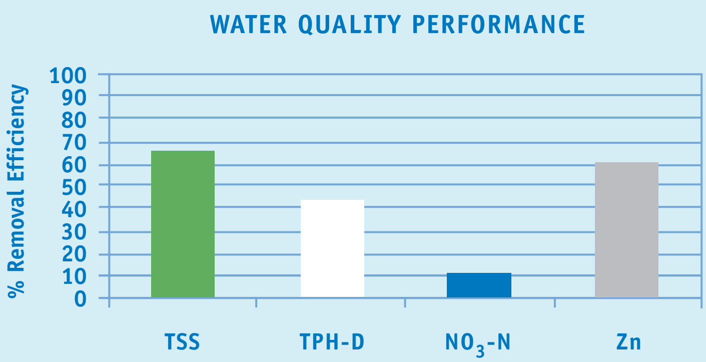
Aqua-Swirl™ and Aqua-Filter™ System

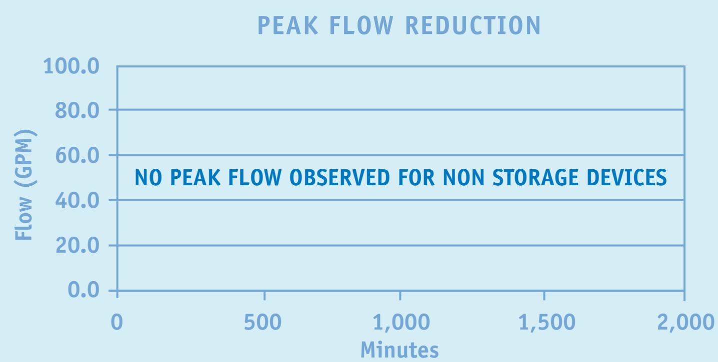
This compact subsurface treatment is well suited for space-constrained sites, where a larger, surface treatment is impractical. Depending on regulations, these devices are used by themselves, or as pretreatments with other stormwater systems. The system is comprised of two devices in series. The first, Aqua-Swirl, is a four-foot diameter hydrodynamic separator. The second, Aqua-Filter, is a larger chamber with 24, one-cubic foot, nylon bags filled with perlite beads that act as a filter. Both are made from recycled high-density polyethylene pipe.

The Aqua-Swirl uses vortex settling to remove sediment, trap debris and trash, and separate floating oil and grease. The Aqua-Filter has internal spillways that direct influent across a suspended platform and through its filter media. Stormwater collects in the lower half of the Aqua-Filter chamber, and then exits when water levels reach outlet elevation. Presumably, the manufacturer can alter the filter to target specific contaminants.

Unobstructed access to the Aqua-Swirl and lack of moving parts enable easy maintenance. In the Aqua-Filter, frequency of filter replacement depends on site contaminant loading characteristics. Maintenance includes the periodic removal of solids by a vacuum truck.

The Aqua-Swirl [right] uses a vortex and baffle to remove sediment, oils, and trash. The Aqua-Filter [top left] uses a physical and chemical process to remove sediment and other pollutants. These units can be used independently, or combined as a system [bottom left].





Category Type
Manhole Retrofit and Filtration

BMP Type
Manufactured Device

Design Source
AquaShield, Inc.

Basic Dimensions
AF-4.2 Component Sizes
Aqua-Swirl (vertical):
4.5 ft diameter, 8 ft tall
Aqua-Filter (horizontal):
6.75 ft diameter, 12 ft long

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs

Treatment Function
Physical (Aqua-Swirl)
Physical / Chemical (Aqua-Filter)

Cost Per Acre
$31,322.08

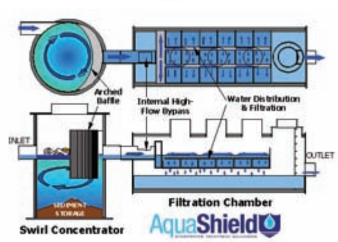
Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

Water Quality Treatment Process

These devices function in series to remove coarse and fine particles from stormwater. The Aqua-Swirl relies on vortex separation and an internal baffle to settle out particles. The filter media in the Aqua-Filter provides physical and chemical treatment to remove suspended sediments and other contaminants. The filter system has enhanced pollutant removal capacity, and in some cases, nearly doubles that of a lone hydrodynamic separator.

The primary contaminant addressed by hydrodynamic separators is sediment. However, comparable reductions are observed for zinc and total petroleum hydrocarbons-diesel, presumably as a result of binding to trapped sediments. The filter also demonstrates minimal nitrate removal. This treatment does not have a storage volume and therefore has no peak flow or volume reduction. Influent and effluent hydrographs are the same. These devices must receive frequent inspection and cleaning to maintain effectiveness.

AquaShield™ STORMWATER TREATMENT SOLUTIONS www.AquaShieldInc.com



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VortSentry™ Hydrodynamic Separator (VS40)

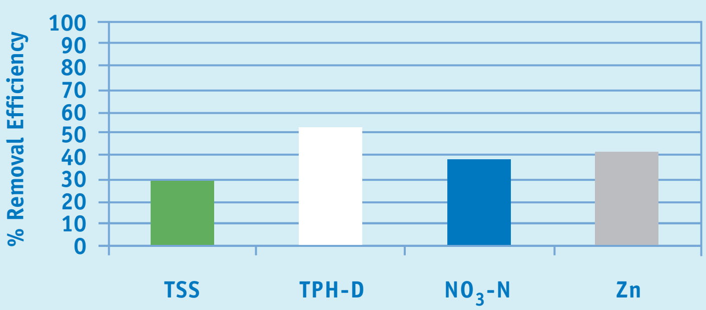
The VortSentry hydrodynamic separator is composed of a weir and baffle [above] encased in a concrete storm drain [insert]. It primarily addresses sediment, but also exhibits comparable reduction of zinc and total petroleum hydrocarbons-diesel.

The VortSentry is a hydrodynamic separator that uses vortex settling to remove sediment, trap debris and trash, and separate floatable oil and grease. Its compact design is well suited for space constrained and urban sites, where the installation of a larger stormwater treatment is impractical. Depending on state regulations, these devices are either used by themselves, or as a pretreatment system in conjunction with other stormwater treatments.

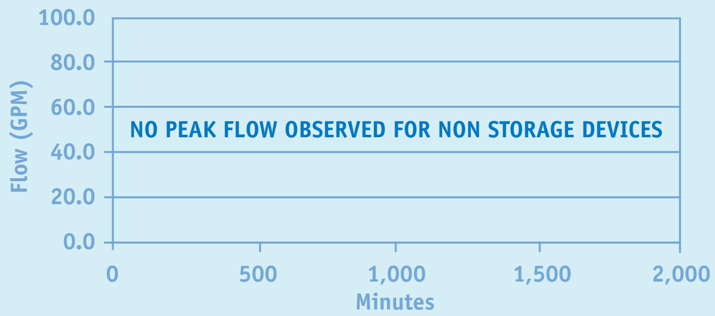
This prefabricated system is on-line with an internal bypass. It is composed of a weir and a baffle mounted internally in a four-foot diameter concrete storm drain.

This treatment's unobstructed access and lack of moving parts enables easy maintenance. Maintenance requirements are similar to other hydrodynamic separators, and include the periodic removal of solids by a vacuum truck.

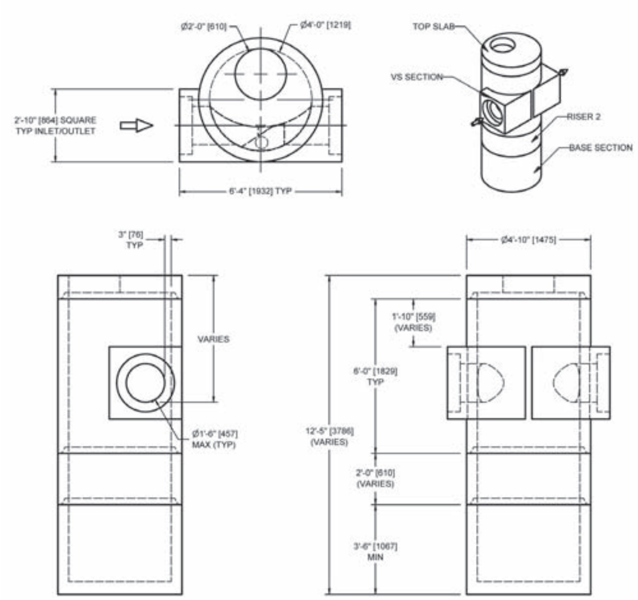
WATER QUALITY PERFORMANCE



PEAK FLOW REDUCTION



Water Quality Treatment Process



VortSentry treats water quality through the hydrodynamic separation of solids from liquids. It is configured for tangential flow, which creates a hydraulic vortex that settles out particles. It contains a flow partition, designed to minimize sediment resuspension for flow rates that exceed the targeted design.

The primary contaminant addressed by hydrodynamic separators is sediment. However, comparable reductions are observed for zinc and total petroleum hydrocarbons-diesel, presumably as a result of binding to trapped sediments. This treatment does not have a storage volume and therefore has no peak flow or volume reduction. Influent and effluent hydrographs are the same. These devices must receive frequent inspection and cleaning to maintain effectiveness.

Category Type
Manhole Retrofit

BMP Type
Manufactured Device

Design Source
Vortechnics, Inc.

Basic Dimensions
Diameter: 4 ft
Depth Below Invert: 6.5 ft

Specifications
Catchment Area: 1/3 acre
Peak Flow: 1/3 cfs
Volume: 327 cf

Treatment Function
Physical, Hydrodynamic Separation

Cost Per Acre
$18,000

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

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V2B1 Structural Stormwater Treatment System

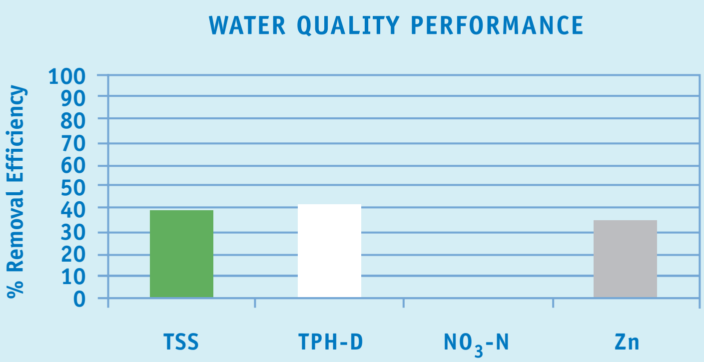
The V2B1's compact design is well-suited for space constrained and urban sites, where the installation of a larger stormwater treatment is impractical. Depending on state regulations, these devices are used by themselves, or as a pretreatment system in conjunction with other stormwater treatments.

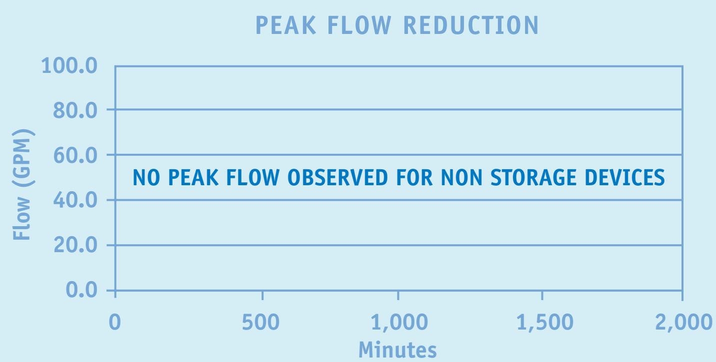
The V2B1 is a two-chambered system encased in two, shallow, pre-cast concrete storm drains in series. Each drain measures four feet in diameter. Stormwater enters the first drain, where a tangential inlet pipe creates a vortex and hydrodynamic separation for sediment removal. A four- to five-foot deep sump provides sediment storage.

Stormwater then enters the second drain, where a floatables chamber containing a baffle wall traps floating oil and organic debris. An underflow opening beneath the baffle wall directs water to the outlet pipe.

Maintenance requirements are similar to other hydrodynamic separators and include the periodic removal of solids by a vacuum truck. The unobstructed access and lack of moving parts enables easy maintenance.

The V2B1's first chamber [right] uses a hydraulic vortex to settle out particles, and then allows clarified water to exit through a central drain into the second chamber [left], where a baffle traps oil and organic debris.





Category Type
Manhole Retrofit

BMP Type
Manufactured Device

Design Source
Environment 21, LLC

Basic Dimensions
2 Manholes, Each 4 ft in Diameter
Depth Below Invert: 5.1 ft

Specifications
Catchment Area: 1/3 acre
Peak Flow: 1/3 cfs
Volume: 577 cf

Treatment Function
Physical

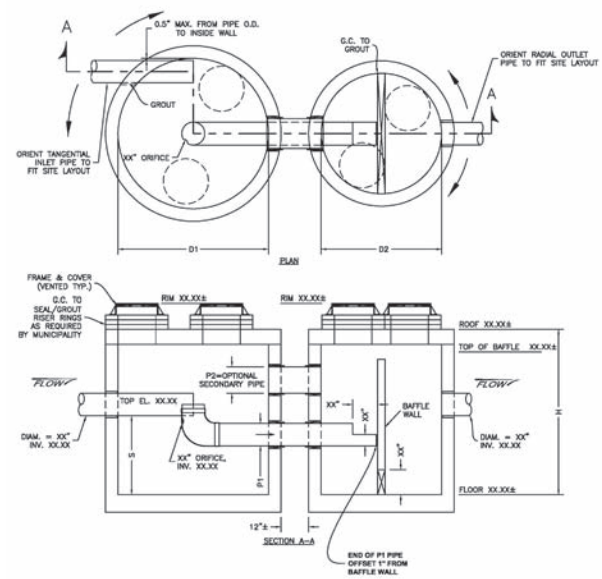
Cost Per Acre
$20,000

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

Water Quality Treatment Process

The V2B1 treats stormwater through the hydrodynamic removal of sediment, followed by the skimming of floatables such as oil, grease, trash, and debris. In the first chamber, a hydraulic vortex settles out particles, and clarified stormwater exits through a central drain. In the second chamber, a baffle wall traps floatables such as trash and organic debris. (It can capture small volumes of oil or fuel spills when outfitted with a top-mounted baffle.)

The primary contaminant addressed by hydrodynamic separators is sediment. However, comparable reductions are observed for zinc and total petroleum hydrocarbons-diesel, presumably as a result of binding to trapped sediments. This treatment does not have a storage volume and therefore has no peak flow or volume reduction. Influent and effluent hydrographs are the same. These devices must receive frequent inspection and cleaning to maintain effectiveness.



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Continuous Deflective Separation Unit (Models 20–15)

The CDS unit has a filter screen that can be sized by the vendor to accommodate a range of particle sizes.

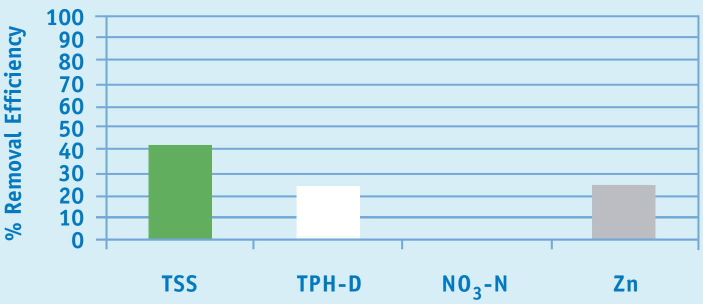
The Continuous Deflective Separation (CDS) units are mainly used to manage stormwater, but they also have wastewater, water supply, and industrial applications. The compact design is well suited for space constrained and urban sites, where the installation of a larger stormwater treatment is impractical. Depending on state regulations, these devices are either used by themselves, or as a pretreatment system in conjunction with other stormwater treatments.

The CDS unit is a hydrodynamic separator that uses vortex settling to remove sediment, trap debris and trash, and separate floatables such as oil and grease.

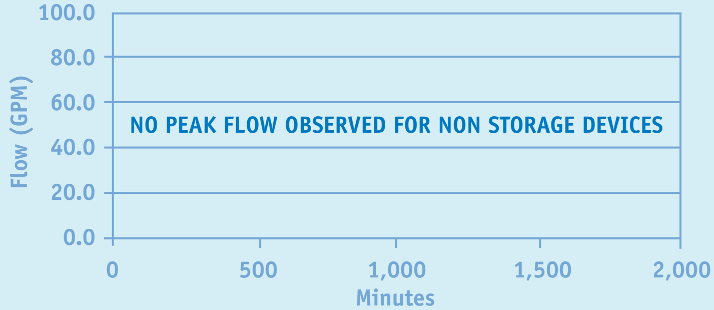
A CDS unit can be made from precast or *in situ* cast concrete, stainless steel, or fiberglass. It is composed of a sophisticated insert with a filter screen with openings that can be sized during manufacture. The insert is mounted internally in a four-foot diameter concrete manhole. This prefabricated system is on-line with an internal bypass.

This treatment's insert can obstruct cleaning. Maintenance requirements are similar to other hydrodynamic separators, and include periodic removal of solids by a vacuum truck.

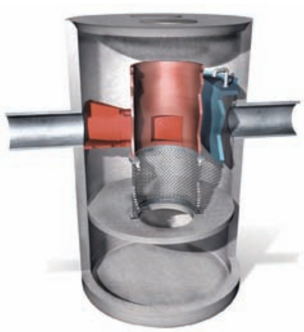
WATER QUALITY PERFORMANCE



PEAK FLOW REDUCTION



Water Quality Treatment Process



The CDS unit has a cylindrical fine screen that separates solids by indirect filtration. Strong tangential velocity around the screen keeps it free of debris, while a small secondary hydraulic head across the screen surface promotes a weak flow through it. Buoyant solids float to the surface. Suspended particles deflect from the screen, move to the stagnant core of the screen chamber, and settle into the sump. The sump has a narrow opening to separate trapped solids from flow and prevent re-suspension. The baffle captures oil and grease in a storage chamber between the inlet invert and baffle bottom.

The primary contaminant addressed by hydrodynamic separators is sediment. However, comparable reductions are observed for zinc and total petroleum hydrocarbons-diesel, presumably as a result of binding to trapped sediments. This treatment does not have a storage volume and therefore no peak flow or volume reduction. Influent and effluent hydrographs are the same. These devices need frequent inspection and cleaning to maintain effectiveness.

Category Type
Manhole Retrofit and Filtration

BMP Type
Manufactured Device

Design Source
CDS Technologies

Basic Dimensions
Diameter: 6 ft, Height: 9 ft

Specifications
Catchment Area: 1/3 acre
Peak Flow: 1/3 cfs
Volume: 327 cf

Treatment Function
Physical: Settling and Filtration

Cost Per Acre
$20,000

Maintenance Data
Maintenance Sensitivity: High
Inspections: High
Sediment Removal: High

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Gravel Wetland

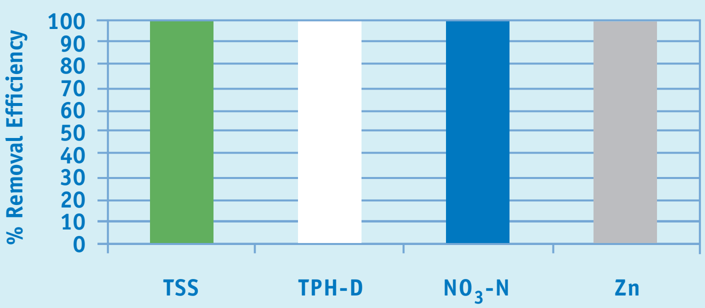
The gravel wetland is a recent innovation in Low Impact Development (LID) designs that treat stormwater. Like other infiltration/filtration systems, it has a tremendous capacity to reduce peak flow and stormwater volume in general. It also has limited use as a replacement for septic systems.

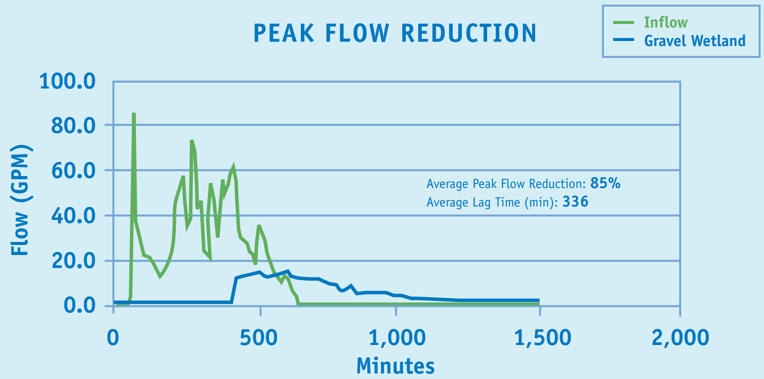
This gravel wetland is designed as a series of horizontal, flow-through treatment cells, preceded by a sedimentation forebay. The device is designed to retain and filter the entire water quality volume (WQV)—10 percent in the forebay and 45 percent in each treatment cell.

For small, frequent storms, each treatment cell filters 100 percent of its WQV. Additionally, the wetland can detain a channel protection volume (CPV) of 4,600 cubic feet, and release it over 24 to 48 hours. WQV is filtered and drains offsite. Any storm volume exceeding WQV overflows into the adjacent swale. Since standing water of significant depth is not expected (except during heavy rains), swale side slopes are graded at 3:1 or flatter for maintenance.

Maintenance involves the periodic mowing and replacement of vegetation, as needed.

The fully vegetated gravel wetland [left top & bottom] exhibits excellent pollutant removal, provides subsurface anaerobic treatment, attenuates peak flow, and reduces flow volume. [Right] The gravel wetland's forebay and retention cells just after installation.





Category Type
Stormwater Wetland

BMP Type
Low Impact Development Design

Design Source
Not Available

Basic Dimensions
Filter Beds: 15 ft L X 32 ft W
Forebay Top Width: 37 ft L X 56 ft W
Total Area: 5,450 sf

Specifications
Catchment Area: 1 acre
Peak Flow: 1 cfs
Treatment Volume: 3,264 cf

Treatment Function
Physical, Chemical, Biological

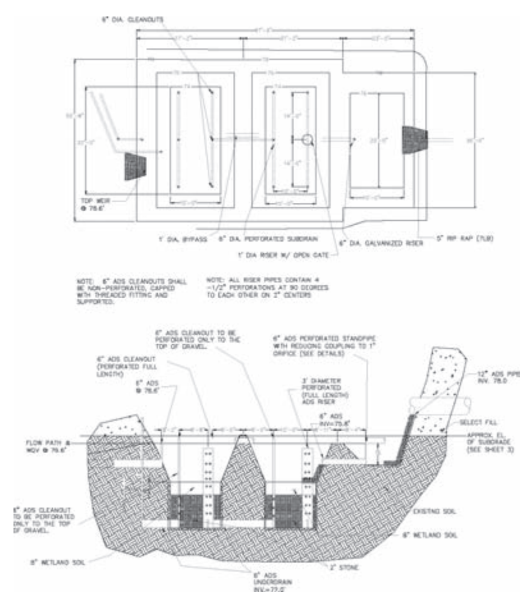
Cost Per Acre
$22,327

Maintenance Data
Maintenance Sensitivity: Low
Inspections: Low
Sediment Removal: High

Water Quality Treatment Process

This treatment removes pollutants, provides subsurface anaerobic treatment, attenuates peak flow, and reduces flow volume through evapotranspiration and infiltration. Biological treatment of water quality occurs through plant uptake and soil microorganism activity. Physical and chemical treatment happens in the soil through filtering and adsorption with organic matter and mineral complexes.

During lighter rains, each cell filters 100 percent of its water quality volume. The cells allow stormwater to pass horizontally through the microbe-rich, gravel substrate and drain into a sump basin. The wetland is designed to continuously saturate at a depth that begins four inches beneath the treatment's surface. This promotes water quality treatment and vegetation growth. To generate this condition, the system outlet pipe has an invert 4 inches below the wetland surface.



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The stone swale [right] is designed to mimic a natural stream channel. Its combination of rock and fabric [left] helps trap sediment and promote vegetation. This treatment performed poorly for most evaluation criteria.

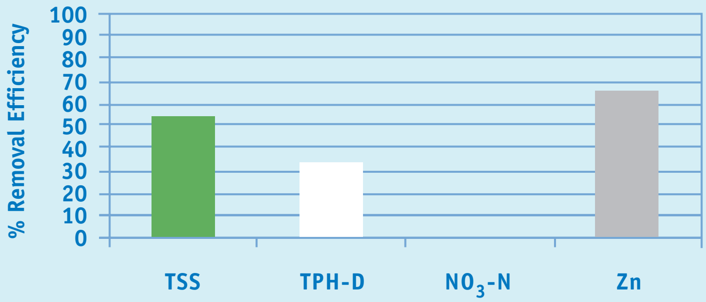
The most common stormwater treatment, swales range from irrigation ditches to engineered systems. Similar in form to a natural stream channel, swales are commonly protected from erosion by a layer of riprap (stone), and underlain with a geotextile filter fabric.

The swale tested here is not to be confused with engineered systems known as water quality swales, which are designed with internal drainage or check dams. State design criteria specify slopes of typically less than one percent, and flow velocities of less than one foot per second for a 10-year storm.

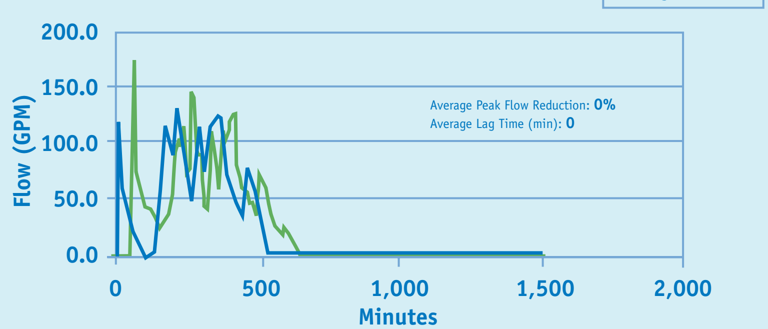
Maintenance demands involve standard landscaping, primarily periodic mowing. Many swales are designed to function as dry systems. Often, however, they collect water due to vegetation and lack of proper maintenance.

Our first year of testing this approach focused on a stone-lined swale; in year two we will examine a vegetated swale; and in year three, a vegetated swale retrofitted with engineered filter berms.

WATER QUALITY PERFORMANCE



PEAK FLOW REDUCTION



Water Quality Treatment Process

Stormwater enters the swale and experiences limited filtration through the spaces between the large stones lining the pathway. If the swale is composed of an appropriate subbase and flow is of low velocity, infiltration can be expected. Slower, non-erosive, flow velocities allow pollutants to fall out of suspension and into the spaces in the riprap.

The combination of rock and fabric help trap additional sediment and develop vegetation over time. In some cases, vegetation is planted during or after the swale's installation. Commonly, swales are left to passively re-vegetate.

Because of demanding staging requirements in adjacent construction areas, stormwater is commonly directed into swales prior to robust root growth of vegetation. The reported water quality treatment effectiveness of vegetated swales and engineered water quality swales is higher than non-vegetated treatments.

Category Type
Open Channel System

BMP Type
Conventional Structural

Design Source
New York State Stormwater Management Design Manual

Basic Dimensions
Length: 280 ft Width: ~10 ft

Specifications
Catchment Area: 2 acres
Peak Flow: 2 cfs

Treatment Function
Physical

Cost Per Acre
$11,951.31

Maintenance Data
Maintenance Sensitivity: Low
Inspections: Low
Sediment Removal: Low

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