FINAL REPORT
Catch Basin Inserts for Ohio Roadways

SEPTEMBER 2018

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16. Abstract

Detailed evaluation of roadside catch basin inserts (CBIs) for the removal of TSS. Study consisted of both field and laboratory testing. Field testing evaluated the installation, maintenance and removal needs for CBIs during a year-long installation period. The Lab testing evaluated the sediment retention associated with each CBI. Since none of the units met both the sediment removal and installation requirements, and due to the high effort and cost to maintain, the CBIs tested do not appear to be a viable option to be added as post-construction stormwater BMPs for ODOT.

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Catch Basin Inserts for Ohio Roadways

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In collaboration with:

AUBURN UNIVERSITY

DAVEY RESOURCE GROUP

September 2018

Prepared for and in cooperation with the Ohio Department of Transportation

The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation. This report does not constitute a standard, specification, or regulation

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EXECUTIVE SUMMARY

The Ohio Department of Transportation (ODOT) is required to comply with Ohio Environmental Protection Agency (EPA) permit requirements in order to discharge stormwater runoff from roadway right of ways. ODOT has been working with the Ohio EPA to research, identify, implement, operate, and maintain sustainable stormwater best management practices (BMPs) that meet the post-construction water quality requirements. This research is assessing the viability of catch basin inserts (CBIs) as acceptable BMPs which ODOT could incorporate into its Location and Design Manual Volume 2 (L&Dv2).

From a water quality perspective, permit compliance is primarily focused on the removal of total suspended solids (TSS). Eight vendor CBI post-construction water quality products were chosen to be evaluated within the study using two primary selection criteria: (1) meeting 80% TSS removal per manufacturer's claims or independent testing and (2) the capability to be installed in an ODOT Catch Basin Type 3A (CB-3A). This research focused on collecting field and laboratory data that documents the performance of each CBI. The field testing evaluated each CBI's installation, maintenance, removal requirements and procedures over a twelve month period. The lab testing evaluated the solids removal associated with each CBI.

Field data results show that, except for the Triton™ CBI, all the other units do not comply with ODOT's design criteria for the CB-3A because the curb opening had to be obstructed for the CBI to function. However, the Triton™ installation and removal was the most labor intensive and time consuming. Installation was also difficult for the rigid frame type CBIs, including the DrainPac™ and FlexStorm®, due to inconsistent construction of the existing CB-3A's. All the CBIs required maintenance within the first three months after installation. Five CBI products became clogged (i.e., contained standing water) and were removed prior to the completion of the twelve month field study period. Three CBI products remained in the field for the entire duration of the study.

Lab data results for the performance evaluation testing showed that only two CBIs, DrainPac™ and Adsorb-It™, achieved 80% sediment retention. Longevity testing was also performed for all CBIs to determine the unit's ability to maintain performance and structural integrity over a more strenuous testing cycle. During longevity testing, the DrainPac™ and Adsorb-It™ fell below the cumulative sediment retention at approximately 80% for up to four tests for the OK110 silica sand before falling below the 80% threshold.

Although the research selection criteria were met individually by some of the CBIs evaluated, none of the CBIs met both of two primary selection criteria. Since none of the units met both the sediment removal and installation requirements, and due to the high level of effort and cost to maintain, the CBIs tested do not appear to be a viable option as a post-construction stormwater BMP within ODOT's L&Dv2 manual.

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ACRONYMS AND ABBREVIATIONS

The listing of acronyms and abbreviations.

ac	Acres
ADT	Average Daily Traffic
AU-ESCTF	Auburn University Erosion and Sediment Control Test Facility
BMP	Best Management Practice
CB	Catch Basin
CBI	Catch Basin Insert
CB-3A	Catch Basin Type 3A
CGP	Construction General Permit
DOT	Department of Transportation
F	Fahrenheit
FHWA	Federal Highway Administration
ft	Feet
ft^3	Cubic feet
ft^3/s	Cubic feet per second
ID#	Identification Number
lb	Pounds
lb/ft^3	Pounds per cubic foot
L&Dv2	Location and Design Manual Volume 2
min	Minutes
mg/L	Milligrams per liter
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination Systems
NRCS	National Resources Conservation Service
ODOT	Ohio Department of Transportation
Ohio EPA	Ohio Environmental Protection Agency
PVC	Polyvinyl Chloride
SR	State Route
SRD	Sediment retention device
SS995	Supplemental Specification 995
TARP	Technology Acceptance Reciprocity Partnership
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
WQf	Water Quality Flow

1 INTRODUCTION

The Ohio Department of Transportation (ODOT) is required to comply with the Ohio Environmental Protection Agency (Ohio EPA) National Pollutant Discharge Elimination Systems (NPDES) Construction General Permit (CGP) and the Municipal Separate Storm Sewer System (MS4) Permit in order to discharge stormwater runoff from roadway right of ways. From a water quality perspective, compliance with the post-construction stormwater requirements of the CGP is primarily focused on total suspended solids (TSS). Compliance with the NPDES regulations also allows ODOT to meet their Federal Highway Administration (FHWA) required environmental commitments for projects that require post-construction water quality controls per the CGP.

ODOT has been working with Ohio EPA since 2009 to identify, implement, operate, and maintain sustainable post-construction stormwater best management practices (BMPs) that address Ohio EPA's CGP requirements. ODOT has unique challenges as a non-traditional MS4 entity that include limited right-of-way space to design and construct stormwater BMPs. ODOT also has a responsibility to understand individual BMPs' maintenance requirements and likely performance. This research is intended to assess the viability of catch basin inserts (CBIs) as potential alternative stormwater BMPs to meet the post-construction water quality requirements. CBIs have the potential to reduce the TSS loads and are accepted by other state DOTs (e.g., Virginia, Oregon, and New York). ODOT continues to receive requests from vendors to consider and accept CBIs as post-construction water quality products for use on ODOT projects.

While CBIs have shown potential to remove TSS, whether or not the extent of the TSS removal meets Ohio EPA requirements remains unclear. If it is demonstrated that the performance of CBIs met Ohio EPA's requirements and that the levels of maintenance are reasonable and economical, Ohio EPA could approve the CBIs to become an acceptable alternative BMP, which ODOT could incorporate into its Location and Design Manual Volume 2 (L&Dv2).

This research will provide a third party evaluation of eight vendor CBI post-construction water quality products. The research is focused on collecting laboratory and field data that documents the lab performance of each CBI to remove sediment as the CGP requires and also documents the field performance based on each CBI's maintenance requirements.

2 LITERATURE REVIEW

The research planned for this study was built upon existing documentation of CBI performance and maintenance, with special attention to reports associated with roadside catch basins. Several documents, studies and reports were identified and used as reference for selecting the CBIs for lab and field testing. Appendix A lists the documents used to identify the types and characteristics of CBIs to be included in the study.

Many of these documents served as the basis for determining the types and characteristics of each of the CBIs. The CBIs fell into three distinct types: basket, bag, and cartridge. The basket type has a rigid structure with internal media providing the treatment. The bag type does not have a rigid structure, the bag itself provides the treatment. The cartridge systems are contained within a rigid frame with the treatment provided within a manufacturer provided cylinder.

BASKET TYPE

The basket type consists of a rigid frame containing a fabric liner or media packet. The basket is supported by the frame of the catch basin and the grate is placed on top holding the basket in place. The basket usually has large orifice holes that would not facilitate the capture of fine materials. The basket fabric liner or internal media provide the majority of the TSS removal.

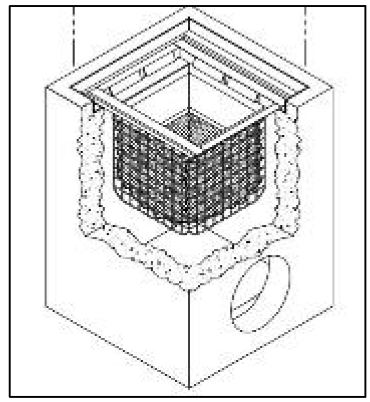


Figure 2-1: Basket Type CBI
(Source: Old Castle)

BAG TYPE

The bag type CBI is similar to the basket type. The bag CBI is constructed of fabric bag material attached to a frame. The frame is supported within the catch basin underneath the grate. Treatment is provided by the fabric bag or media packets located within the fabric bag. There is no rigid support structure around the fabric bag, the bag provides all the needed support to contain the accumulation of debris. The bag fabric or media provide the TSS removal.

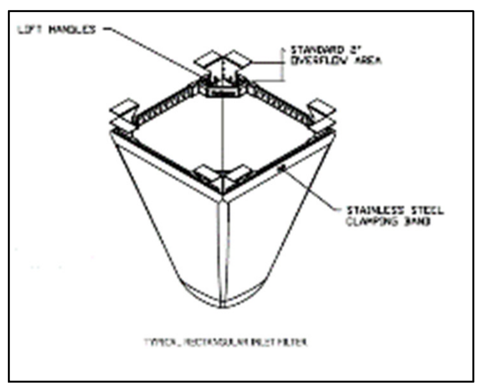


Figure 2-2: Bag CBI
(Source: Advanced Drainage Systems)

CARTRIDGE TYPE

The cartridge type CBI contains a tray with filter media contained within a cartridge. The tray is installed within the catch basin below both the grate and curb openings. The cartridge can sit above or below the tray. The tray will contain any collected gross solids, with the cartridge providing the TSS removal.

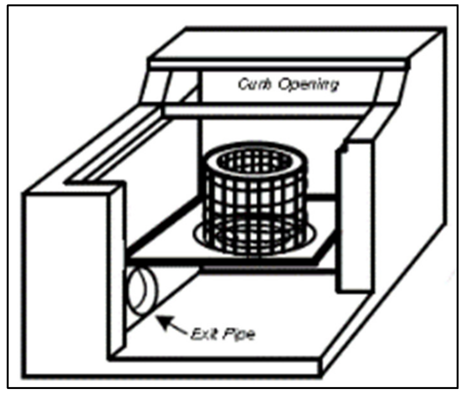


Figure 2-3: Cartridge Type
(Source: REM Filtration)

TABLE 2-1 provides a summary of advantages and disadvantages of the three primary CBI types.

Table 2-1 Primary Advantages and Disadvantages of CBI Types

CBI Type	Advantages	Disadvantages
Cartridge	Disposable cartridges allow for easy maintenance.	Most are too large for smaller, single grate catch basins.
Bag	Ponding of water inside bag allows for some settling of finer particles.	Material can often be easily clogged with sediment or ripped, requiring maintenance or replacement.
Basket	Baskets are often durable and long-lasting.	Structural frames can add weight to CBI, making installation and removal more difficult.

The literature review was also used to document characteristic categories for the CBIs. The main characteristic categories were identified as: (1) general, (2) installation, (3) maintenance, and (4) performance. Within each category several criteria were identified as differentiators between the CBIs. A matrix was developed using the categories and criteria to assess and gather information on each CBI's characteristics. Although these characteristics were not used in the selection of the CBIs for testing, the information may be useful to end users of the products. Table 2-2 summarizes the characteristics documented through the literature search.

Table 2-2 CBI Characteristic Categories

General	Installation	Maintenance	Performance
Vendor location Warehouse location Cost of CBI # of media units needed per CB-3A Cost of media replacement Specifications/ standard drawings available CBIs approved for use by other DOT's CBI used in other industries	Size: Base fits within CB-3A Size: Frame/Grate with no corrections to frame/grate Size: CBI Depth Size: CBI available for other ODOT standard inlets/catch basins Vendor supplied installation instructions Vendor to supply installation support Number of personnel needed to install (not including MOT) Time Required to install	Vendor maintenance guide available Frequency of inspection Frequency of media replacement Frequency of cleaning Cleaning methods Cleaning procedures # of personnel needed to inspect/maintain unit Time required to clean/replace filter Does the outlet pipe require plugging to clean CBI Specialized equipment needed to maintain or clean	80% TSS removal performance, of TARP or OK110 soil types Maximum flow rate before overflow/bypass Maximum bypass/overflow rate. Testing available Tested by outside agency

3 CATCH BASIN INSERT SELECTION

The first step in the process was to identify potential CBIs for inclusion in the study. A review of the information compiled from documents, internet searches, and discussions with industry personnel was completed to identify possible CBIs for the study.

CRITERIA

The research was limited to testing up to 10 units, with the purpose of studying a variety of types to determine the applicably of using CBIs as post-construction water quality BMPs to meet regulatory performance requirements, as well as the potential operational and maintenance needs. **Although the CBIs were tested on an individual basis, this study is not intended to represent approval or acceptance by ODOT or Ohio EPA**.

There are two primary criteria a CBI unit needed to satisfy for inclusion into the study:

1.) The unit must be able to meet the 80% sediment retention[1], and;
2.) The unit needs to be able to be installed in a standard ODOT CB-3A.

SELECTION

A total of 16 CBIs were initially identified as having the potential to satisfy the 80% sediment retention criteria. Seven of the 16 CBIs did not have a standard size available that could be installed in ODOTs CB-3A, therefore these units were removed from further consideration. One other potential CBI was removed due to the unit's very low flow rate. The flow rate for this unit was an order of magnitude lower than others reviewed. The remaining eight CBI vendor products were selected for the field and laboratory testing part of the study. The testing included eight CBI products (Table 3-1) that provided three different types of inserts: basket, bag, and cartridge, which were evaluated in the field at two different sites (i.e., Site 1 and Site 2 – described further in Section 4), as well as in a controlled testing setting at the Auburn University's-Erosion and Sediment Control Test Facility (AU-ESCTF).

From the vendor perspective, the Gullywasher© had a bag and basket version of the same product, only the bag type was included in the study in an attempt to balance the study between insert types. Only one cartridge type CBI was identified to be included.

[1] From testing data or manufacturer's claim.

Table 3-1 CBI Product List

CBI Name	CBI Manufacturer	CBI Type	Site 1	Site 2
Adsorb-It™	Stormwater BMP Products, LLC	Basket	114	205
DrainPac™	United Storm Water, Inc.	Basket	104	n/a
Flo-Gard Plus®	KriStar / Oldcastle Stormwater Solutions	Basket	110	208
WQS	Water Quality Solutions, LLC	Basket	111	209
FlexStorm® Inlet Filters	Advanced Drainage Systems(ADS), Inc,	Bag	105	210
Gullywasher©	Gullywasher, LLC	Bag	109	211
Storm Sentinel®	Enpac, LLC	Bag	101	213
Triton™	REM Filtration	Cartridge	113	207

All the CBIs were used in both the field and laboratory testing. The CBIs were installed in existing ODOT standard CB-3As constructed in 1977, 2013, and 2015. The following Table 3-2 includes a brief description and photographs for each CBI.

Table 3-2 CBI Descriptions

CBI Name **Profile view**	**General description** **Top view**
Adsorb-It™	Basket-type CBI consisting of a heavy-duty Polyvinyl Chloride (PVC) coated wire mesh steel basket supported by a rigid stainless steel frame. An internal filtration fabric material is supported by the PCV basket.
	
DrainPac™	Basket type CBI with a stainless steel metal basket lined with a filter fabric bag. The filter fabric is on the outside of the basket. A plastic netting attached to the metal frame provides support to the fabric.
	

Table 3-2 CBI Descriptions

CBI Name	**General description**
Profile view	**Top view**
Flo-Gard Plus®	Basket type CBI with a plastic, large-mesh basket structure. The plastic basket provides supports for a woven filter fabric liner that is attached to a stainless steel frame. The CBI contains two media packets.
	
WQS	Basket type CBI consisting of a hard-plastic outer shell with layers of filters stacked inside for a staged-treatment approach. The upper half of the CBI consists of four plastic mesh filters, each decreasing in mesh size deeper into the shell. The bottom half of the CBI consists of two fine mesh metal screens.
	

Table 3-2 CBI Descriptions

CBI Name Profile view	General description Top view
FlexStorm® Inlet Filters	Bag type CBI with a stainless steel frame and a woven geotextile filtration bag. The bag is lined with carpet fiber material to treat water exiting the bag. An additional more permeable fabric sits between the filtration bag and the stainless steel frame.
	
Gullywasher©	Bag type CBI with a non-woven geotextile filter fabric mounted on a rectangular metal frame. The bag is also supported by nylon straps that wrap under the bottom of the bag and support loads when the bag is full.
	

Table 3-2 CBI Descriptions

CBI Name	**General description**
Profile view	**Top view**
Storm Sentinel®	Bag-type CBI constructed of a nonwoven geotextile fabric that is supported by an adjustable steel wire frame.
	
Triton™	Cartridge type CBI with a filter cartridge consisting of a fine mesh medium, enclosed by a stainless steel housing that prevents debris from damaging the filter media. Filter sits on a base which fits down into the catch basin and is sealed against the catch basin structure, preventing water from exiting the catch basin without passing through the replaceable filter cartridge.
	

4 FIELD TESTING

LOCATION SELECTION

Two field testing locations of curbed roadway owned by ODOT were needed to provide replication to support valid test results and support the consistency of data at each site. The field testing areas needed to provide a relatively long stretch of roadway with consistent roadway characteristics, such as lane width, average daily traffic (ADT), drainage area, impervious area and weather patterns. Two field testing locations meeting these conditions were identified in Allen County, Ohio (refer to Figure 4-1). The field testing occurred on two state routes within the urbanized area around Lima, Ohio. Site 1 was located on SR 117 between Lost Creek Boulevard and Bowman Road. Site 2 was located on SR 81 between South Sugar Street and I-75. The two sites both provided a large number of catch basins for the installation of the CBIs. The site characteristics were similar enough between the two sites to provide an adequate basis of comparison.

Site 1 was located near the Allen County Fairgrounds on SR 117. The surrounding parcels are the County fairgrounds and agricultural land uses. SR 117 has two 12-foot lanes, a two-foot curb and gutter, with an ADT of 8,042. The drainage areas range from 0.10 to 0.16 acres of impervious surface.

Site 2 was located on SR 81 west of I-75. SR 81 has four 12-foot lanes with a two-foot curb and gutter. The surrounding parcels are mostly commercial and retail. The ADT is 11,366. The drainage areas range from 0.07 to 0.17 acres of impervious surface.

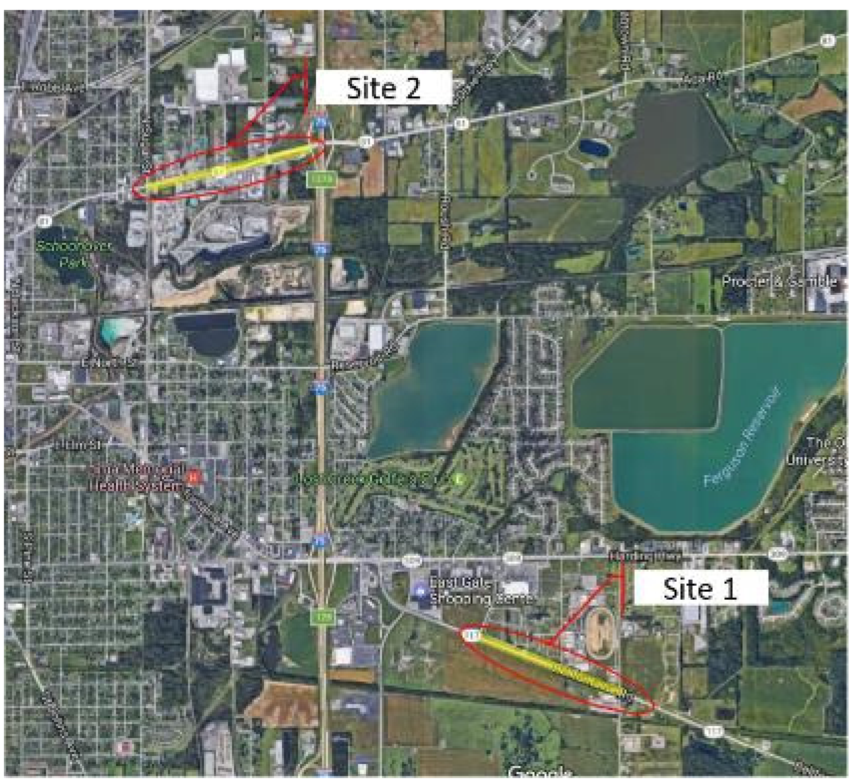


Figure 4-1: Field Testing Sites (Source: GoogleMaps, 2018)

CATCH BASIN MODIFICATIONS

The standard ODOT CB-3A is a single grated curb inlet with a grate and throat opening along the curb. See Figure 4-2 for an image of ODOT's Standard CB-3A. Stormwater flow in the gutter is captured by both the grate and curb throat opening. Most of the CBI units are designed to be installed within the grate, which provides treatment to only the stormwater flowing through the grate (refer to Figure 4-3). Stormwater flowing into the curb throat opening would bypass seven of the eight CBI units installed under the grate and the stormwater would not receive treatment. To prevent stormwater from entering the curb throat opening, the opening was blocked with a device called a "throat block". The throat block covers the entire curb opening, forcing stormwater into the grate. ODOTs design requirements for pavement spread and inlet spacing includes the stormwater flow to be captured in both the grate and curb throat opening. Blocking the curb inlet permanently would restrict flows below the design standard used for determining catch basin spacing. The design spacing is calculated assuming the curb throat opening is the only inlet, and the grate inlet is used as a safety factor. Intentionally blocking the curb opening was allowed by ODOT for this study only, but would not otherwise be considered an acceptable practice.

Figure 4-2: Standard CB-3A

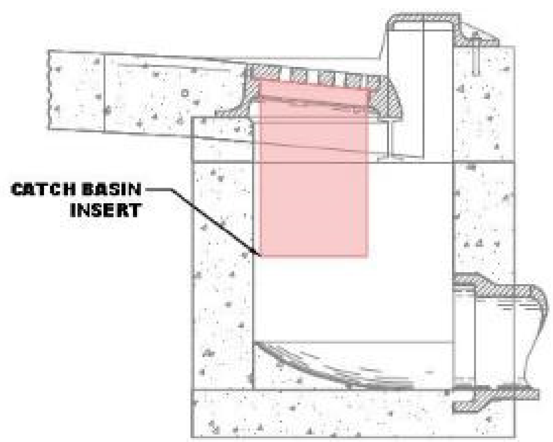


Figure 4-3: Cross section view of CB-3A

The throat block for the catch basins was accomplished by cutting 2"x6" treated dimensional lumber to fit the opening. Using slightly oversized pieces, the device was forced into the throat, which would affix the wood plug in place. Pliable sheet metal (26-gage) was cut to cover the wood plug and provide additional coverage over the catch basin throat. The sheet metal was fastened to the wood plug, protecting the wood and providing additional cover over the throat. The sheet metal was screwed into the wood and any gaps were sealed with caulk (See Figure 4-4, Figure 4-5, and Figure 4-6).

Figure 4-4: Throat block top view

Figure 4-5: Throat block front view

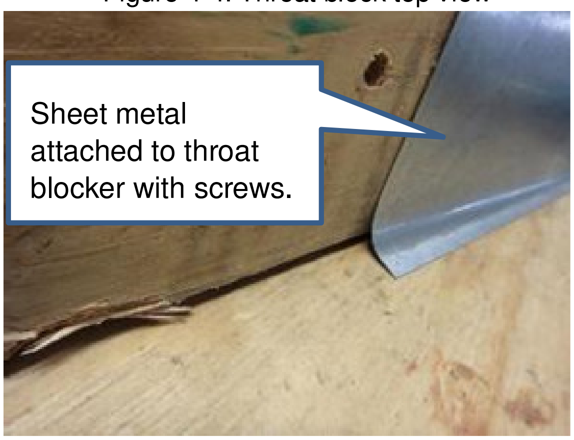


Figure 4-6: Sheet metal in front of throat block

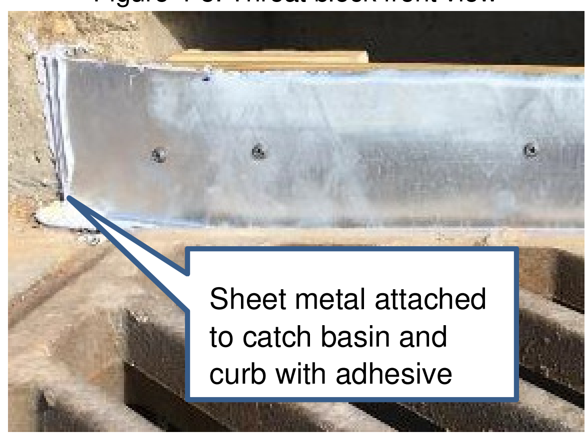


Figure 4-7: Throat block adhesive attachment

Installation

The CBIs were installed between March and June 2017, with the majority installed in March. The manufacturers provided installation guidelines and procedures for each CBI as part of the delivery. Each CBI was installed in accordance with the manufacturer's recommendations and guidelines. Deviations from the manufacturer's recommendations were recorded on the installation forms. See Appendix B for the completed installation forms.

At Site 1, eight CBIs were installed. Three bag types, four basket types, and one cartridge type. All the bags and three of the baskets were installed in March, 2017. The cartridge unit was installed in April, 2017. The final basket was installed in June, 2017. Figure 4-8 shows the distribution of the CBIs at Site 1 with their corresponding CBI ID numbers shown in Table 4-1.

Figure 4-8: Site 1 catch basin locations w/ corresponding ID no's. (Source: GoogleMaps, 2018)

At Site 2, seven CBIs were installed. Three bag types, three basket types and one cartridge. All the bags and two of the baskets were installed in March, 2017. The cartridge unit was installed in April, 2017. The final basket was installed in June, 2017. One CBI could not be installed at Site 2 because the basket unit had a very rigid housing which caused it to impact the connecting conduits or the rim of the concrete catch basin. Figure 4-9 shows the distribution of the CBIs at Site 2 with their corresponding CBI ID numbers shown in Table 4-1.

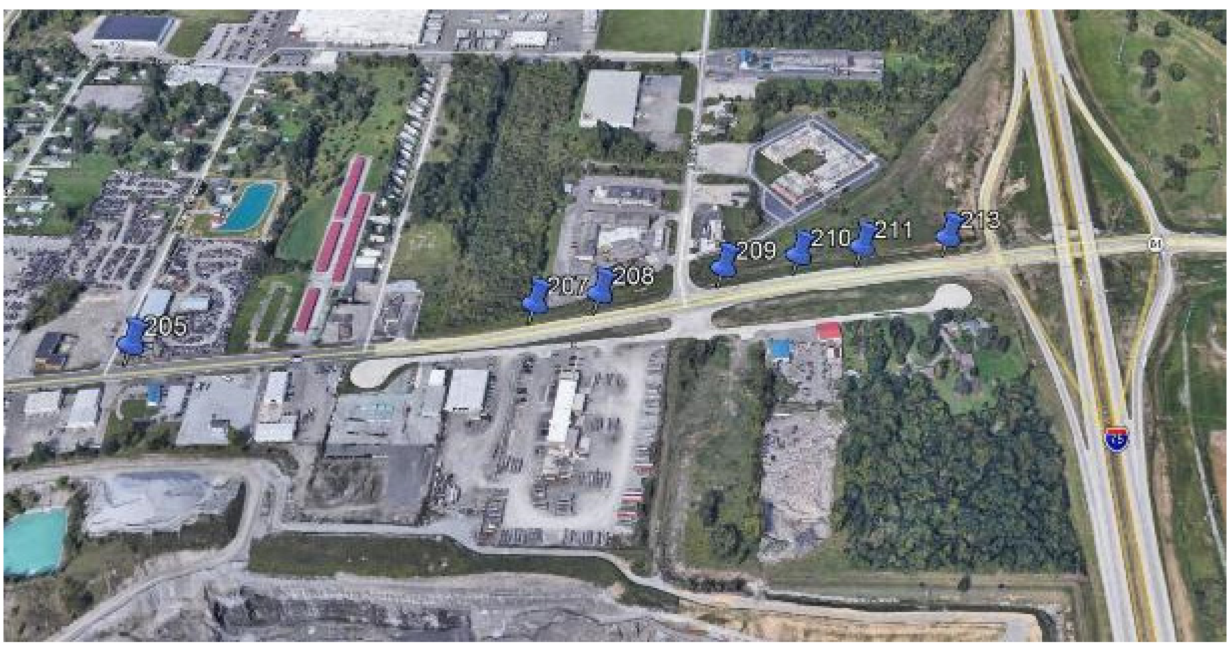


Figure 4-9: Site 2 catch basin locations w/ corresponding ID no's. (Source: GoogleMaps, 2018)

During the installation process, all of the units, excluding the Triton™, could be lifted and installed by one person. The time to install the CBI includes time associated with the following activities: removal of grate, clean debris, adjustments to CBIs, insert CBI, and reset grate. The standard equipment needed for installation included a grate lifter, brush, and scraper.

The time to install each unit and any additional observations are included in Table 4-1. The installation of the throat block required 10 minutes and was not included in the total unit installation times. Six of the CBI products were installed in 15-minutes or less. The remaining two CBIs required longer than 30-minutes, ranging from 37 to 83 minutes. As noted above, one of the basket units had a very rigid housing which limited the ability to install this CBI when connecting conduits created conflicts or the rim of the concrete catch basin was somewhat irregularly shaped. Installation of this CBI was possible in only one of the catch basins in the study area. Figure 4-10 shows an example of the potential issue for a CBI to impact a connecting conduit within the catch basin. Another CBI had a very rectangular frame which would not fit within the rounded corners of the catch basin frames. The corners of the CBI were ground down or cut off to allow for installation. Appendix B contains copies of all the installation logs.

Figure 4-10 Catch Basin Connecting Conduit

Table 4-1 Installation Summary

ID#	CBI Name	Type	Total time (min)	Installation Notes
101	Storm Sentinel®	bag	6	No issues
104	DrainPac™	basket	7	shape of the unit limited install locations. 10 catch basins were tried, site 104 was the only successful install location (other locations attempted 101, 105, 109, 110, 111, 205, 206, 209, and 210)
105	FlexStorm®	bag	37	Frame required trimming with circular saw to fit within the CB Required two people because of cutting.
109	Gullywasher©	bag	8	No issues
110	Flo-Gard Plus®	basket/bag	8	No issues
111	WQS	basket	11	Needed to adjust the handles to not impact the grate. The bolts on the handles were adjusted to let them sit lower into the CBI.
113	Triton™	cartridge	83	Installation of tray was difficult and required cutting of tray to fit within the CB, required two people.
114	Adsorb-It™	basket	15	No issues
205	Adsorb-It™	basket	10	Outlet pipe in CB prevented basket from fitting within CB. The basket was reshaped to avoid the outlet pipe allowing the insert to be installed.
207	Triton™	cartridge	75	Top hat location had to be moved closer to the front of the base to allow the unit to be installed within the catch basin. New holes were drilled and the vacated screw holes were filled with spray foam. required two people.
208	Flo-Gard Plus®	basket/bag	9	No issues
209	WQS	basket	10	Handles are higher than the basket, without modification the grate would sit on the handles. The handles were removed, bent slightly and reattached.
210	FlexStorm®	bag	65	Frame required trimming with saw to fit within the CB. Required two people because of cutting.
211	Gullywasher©	bag	12	No issues
213	Storm Sentinel®	bag	13	No issues

Storm Event and Rainfall Accumulation

Storm event and rainfall data was collected during the study to validate the conditions were representative of typical weather and precipitation events. The rainfall data was obtained from the weather station at the Lima Allen County Airport, three miles from Site 1 and seven miles from Site 2. Over the course of the study, 133 events occurred with measurable precipitation and seventeen rain events exceeded 0.75 inches per day (i.e., Ohio EPA's water quality storm depth). The total rainfall accumulation for the year was 39.39 inches. The largest rainfall event occurred in November with 2.27 inches measured. Gathering rainfall data also allowed the inspection team to conduct six monthly inspections during or within 24 hours of a storm event to visually monitor performance and potential impacts to traffic conditions. Figure 4-11 shows the rainfall accumulation and installation, maintenance and inspection activities at the two research locations.

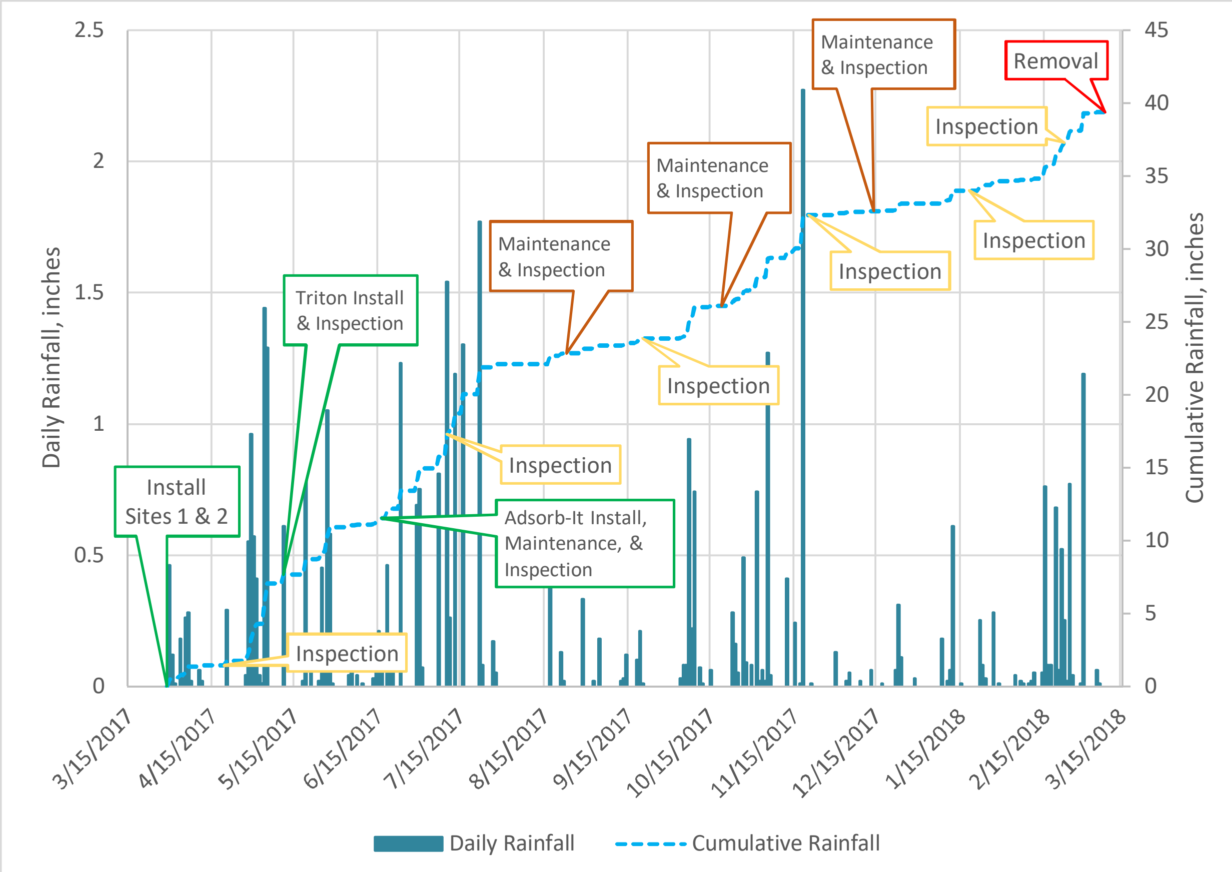


Figure 4-11: Rainfall Accumulation Data

Inspection

A monthly inspection was conducted for each CBI to monitor performance and condition in the field over the year testing period. Six of the inspections were performed during wet weather events or within 24 hours of measurable precipitation to evaluate the units' performance after a recent stormwater runoff collection event. Each inspection included an assessment of the CBI and throat blockage function and debris accumulation within and around each unit. Current roadway and weather conditions were also observed. Photos were taken to document each CBI's condition and surrounding conditions at the time of inspection. The CBI inspection, while monitoring performance, also aided in determination of maintenance needs for each individual unit. All inspection items were logged in a standard monthly inspection form, provided in Appendix B

Inspection of the CBIs were performed without the removal of the grate or removing the units from the catch basin. The observations were based solely on conditions visible through the catch basin grate and the observed accumulated debris contents of the CBIs. Several of the CBIs with filter media layers or external filter pieces proved difficult to inspect during the monthly visits due to lack of visibility through the grate openings to all sections of the unit. Specifically, for basket type units with a fabric lining, the outside of the unit only allowed a partial visual inspection. The external fabric liner was not visible through the catch basin and only the internal basket could be inspected. Any accumulation of debris within that portion of the filter fabric could not be determined. Any basket types with internal layered filter media also posed a problem in obtaining a complete visual inspection. The top layer of the media could only be viewed while any debris or water accumulation within the unit below that top layer was not visible. Figure 4-12 provides an example of the typical visual inspection view of a CBI unit showing standing water.

Figure 4-12: Typical Visual Inspection

An analysis of the inspection details was completed each month to determine the current condition of the CBIs and if the condition of the CBI could pose a potential safety risk to the traveling public. This analysis was used to determine the nature of the next month’s activities. The activity could be an inspection, maintenance, or removal of the CBI.

Maintenance

The original maintenance schedule and activities for each CBI was set based on review of the vendor information provided with the unit. The amount of maintenance and replacement information included varied between CBI units. Most included recommendations as to how often to maintain the unit, however the details on the exact type of maintenance to perform was often excluded. Two of the vendors did not provide any maintenance information, with one of the two only including details for removal of the unit. The field research team recommended frequency of maintenance based on inspection of the CBI and its performance in the field. If the unit had accumulated a certain volume of solids or water, then maintenance would be required.

For consistency between all CBIs, if a unit was observed with standing water or half full of debris during the monthly inspection, then maintenance would be performed the following month. This maintenance schedule follows most vendor recommendations and provided a maintenance plan approach for other units that did not provide details pertaining to maintenance. The schedule did not decrease recommended maintenance frequency for any CBI units. All units were provided the same, and in some cases more, maintenance than detailed by the vendor.

Units that were shipped without maintenance instructions or guidance were maintained based on a similar CBI vendor-provided maintenance recommendations. It was determined, if a CBI required maintenance, that all units would have removal of debris by a shop vacuum on site. After the removal and disposal of debris, every bag and most basket type CBIs were removed and taken to a nearby facility to back flushed with water. Each unit was back flushed until water ran clear and positive flow through the filter was achieved. While most bag type CBIs were not recommended to be back flushed, this extra step in maintenance was added to ensure all bag types were cleaned as well as possible and equal to the other CBI types. Cartridge type CBIs were only vacuumed to remove debris, but were not flushed with water. These units were difficult to remove to perform back flushing maintenance due to the seal and fastening of the units to the CB. Table 4-2 provides a comparison of vendor recommended maintenance to maintenance performed in the field.

Table 4-2 Manufacturer Recommended Maintenance

	ID#							
	Storm Sentinel®	**DrainPac™**	**FlexStorm®**	**Gullywasher©**	**Flo-Gard Plus®**	**WQS**	**Triton™**	**Adsorb-It™**
	101, **213**	**104**	**105**, **210**	**109**, **211**	**110**, **208**	**111**, **209**	**113**, **207**	**114**, **205**
	bag	basket	bag	bag	basket	basket	cartridge	basket
Vendor Recommended Maintenance Schedule	None	Clean 3-4 times per year	If unit is 50% full.	If solids accumulate or standing water. every 3-4 weeks.	Clean 3 times per year	Annual cleaning	Clean 3 times per year	Remove accumulated debris monthly. Every 6 months, wash
Vendor Recommended Maintenance Type	None	None	Vacuum and flush with medium spray.	Dump out solids and wash with pressure hose.	None	None	None	Vacuum and flush with water
Vendor Recommended Replacement	If 50% full or every 6 months	None	If torn or punctured >1/2" diameter on lower half of bag.	None	Replace filter medium annually	None	None	Filter media to be replaced every 6-12 months
Actual Maintenance	Back flushed after three months	Debris removed twice, back flushed in Oct	Back flushed after three months	Back flushed after three months	Debris removed twice, back flushed in Oct	Debris removed Aug, Oct, Dec	Debris removed Aug, Oct, Dec	Debris removed twice, back flushed in Oct

While performing the maintenance, the amount and type of debris collected was documented. Site 1 and Site 2, while being relatively close in proximity, varied in the type and amount of debris collected in each CBI. Site 2 units collected larger amounts of debris, mainly fine road grit and trash. Site 1 units collected more organic materials, such as grass clippings, as well as some larger road grit. While the type of debris collected varied between sites, both field study sites required the same number of maintenance visits.

By the end of the second month several CBIs were clogged and contained standing water. During the third month maintenance was performed on the clogged units. The maintenance consisted of removing debris from the CBI, removing the CBI from the catch basin, back flushing the CBI to achieve positive drainage, and reinstalling the CBI in the original catch basin. The volume of debris removed was measured and disposed of at ODOT's Allen County Garage. See Table 4-3 for a summary of the June 2017 Maintenance.

Table 4-3 CBI June 2017 Maintenance Summary

Product Name	ID#	Type	Maintenance activity	Volume of Debris Removed
Storm Sentinel®	101	bag	Debris removed and back flushed	< 1 gallon
FlexStorm®	105	bag	Debris removed and back flushed	< 1 gallon
Gullywasher©	109	bag	Debris removed and back flushed	< 1 gallon
FlexStorm®	210	bag	Debris removed and back flushed	< 1 gallon
Gullywasher©	211	bag	Debris removed and back flushed	< 1 gallon
Storm Sentinel®	213	bag	Debris removed and back flushed	< 1 gallon

In the fifth month all the units received maintenance based on the amount of debris accumulation noted in the July 2017 monthly inspection. The maintenance consisted of removing debris from the CBI. The volume of debris removed was measured and disposed of at ODOT's Allen County Garage. See Table 4-4 for a summary of the August 2017 maintenance activities.

Table 4-4 CBI August 2017 Maintenance Summary

Product Name	ID#	Type	Maintenance activity	Volume of Debris Removed
Storm Sentinel®	101	bag	Vacuum debris	< 1 gallon
DrainPac™	104	basket	Vacuum debris	1.5 gallons
FlexStorm®	105	bag	Vacuum debris	1.5 gallons
Gullywasher©	109	bag	Vacuum debris	< 1 gallon
Flo-Gard Plus®	110	basket	Vacuum debris	< 1 gallon
WQS	111	basket	Vacuum debris	1 gallon
Triton™	113	cartridge	Vacuum debris	1 gallon
Adsorb-It™	114	basket	Vacuum debris	< 1 gallon
Adsorb-It™	205	basket	Vacuum debris	3.5 gallons
Triton™	207	cartridge	Vacuum debris	4 gallons

Table 4-4 CBI August 2017 Maintenance Summary

Product Name	ID#	Type	Maintenance activity	Volume of Debris Removed
Flo-Gard Plus®	208	basket	Vacuum debris	8 gallons
WQS	209	basket	Vacuum debris	3 gallons
FlexStorm®	210	bag	Vacuum debris	< 1 gallon

During the sixth month several CBIs were observed to be clogged and contained standing water. During the seventh month maintenance was performed on the clogged units. The maintenance consisted of removing debris from the CBI, removing the CBI from the catch basin, back flushing the CBI to achieve positive drainage, and reinstalling in the original catch basin. The cartridge and two of the basket types were not back flushed, only the debris was removed. For all CBIs, the volume of debris removed was measured and disposed of at ODOT's Allen County Garage. See Table 4-5 for summary of October 2017 maintenance activities.

Table 4-5 CBI October 2017 Maintenance Summary

Product Name	ID#	Type	Maintenance activity	Volume of Debris Removed
DrainPac™	104	basket	Debris removed and back flushed	< 1 gallon
Flo-Gard Plus®	110	basket	Debris removed and back flushed	< 1 gallon
WQS	111	basket	Vacuum debris	< 1 gallon
Triton™	113	cartridge	Vacuum debris	1 gallon
Adsorb-It™	114	basket	Debris removed and back flushed	< 1 gallon
Adsorb-It™	205	basket	Debris removed and back flushed	1 gallon
Triton™	207	cartridge	Vacuum debris	2 gallons
Flo-Gard Plus®	208	basket	Debris removed and back flushed	1 gallon
WQS	209	basket	Vacuum debris	< 1 gallon

During the eighth month two of the CBIs were observed to have accumulated debris between the grate and the CBI. The maintenance consisted of removing debris from the CBI. The volume of debris removed was measured and disposed of at ODOT's Allen County Garage. See Table 4-6 for a summary of the December 2017 maintenance activities.

Table 4-6 CBI December 2017 Maintenance Summary

Product Name	ID#	Type	Maintenance activity	Volume of Debris Removed
WQS	111	basket	Vacuum debris	< 1 gallon
WQS	209	basket	Vacuum debris	4 gallons

For all maintenance performed, debris removed was measured and photos taken to document conditions before and after maintenance. Any additional tools or steps needed to clean each CBI or deviations from vendor recommendations were also noted in the maintenance forms. All completed field maintenance forms are provided in Appendix B.

CBI Removal

Over the duration of the study, decisions were made to remove specific CBIs based on observed field performance. The units were removed from further field testing after the second observation of standing water within the CBI, which indicated the unit required replacement. A summary of the CBI removal is provided in Table 4-7

Table 4-7 CBI Removal Summary

Product Name	ID#	Month Installed	Month Removed	Reason for removal	Length of time installed	Time required to remove
Storm Sentinel®	101	March	October 2017	Clogged	7 months	2 minutes
DrainPac™	104	March	March 2018	End of study/fabric damaged	12 months	6 minutes
FlexStorm®	105	March	October 2017	Clogged	7 months	2 minutes
Gullywasher©	109	March	October 2017	Clogged	7 months	3 minutes
Flo-Gard Plus®	110	March	March 2018	End of study	12 months	13 minutes
WQS	111	March	March 2018	End of study	12 months	18 minutes
Triton™	113	May	December 2017	Clogged	7 months	48 minutes
Adsorb-It™	114	June	December 2017	Clogged	6 months	4 minutes
Adsorb-It™	205	June	December 2017	Clogged	6 months	7 minutes
Triton™	207	May	March 2018	Clogged	8 months	70 minutes
Flo-Gard Plus®	208	March	March 2018	End of study	12 months	12 minutes
WQS	209	March	March 2018	End of study/frozen	12 months	8 minutes
FlexStorm®	210	March	October 2017	Clogged	7 months	2 minutes
Gullywasher©	211	March	August 2017	Clogged	5 months	3 minutes
Storm Sentinel®	213	March	August 2017	Clogged	5 months	4 minutes

Field Testing Summary

The conditions of each CBI observed in the field were broadened to five status categories: installed (I), functional (F), clogged (C), maintenance completed (M), and removed (R). The status of a unit provided insight into their performance as well if activities such as maintenance or removal would be required in the following month. Table 4-8 outlines these monthly inspection statuses of each unit over the year timeframe and give a generalized view of performance.

Table 4-8 CBI Inspection Log

Product Name	ID#	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
			1	2	3	4	5	6	7	8	9	10	11	12
Wet Weather Inspection			X	X	X	X	X			snow	snow			
Product Name	**ID#**	**Condition Status**												
Adsorb-It™	114				I	F	M	C	M	C	R			
Adsorb-It™	205				I	F	M	C	M	C	R			
DrainPac™	104	I	F	F	F	F	M	F	M	F	F	F	F	R
FlexStorm®	105	I	F	C	M	F	M	C	R					
FlexStorm®	210	I	F	C	M	F	M	C	R					
Flo-Gard Plus®	110	I	F	F	F	F	M	F	M	F	F	F	F	R
Flo-Gard Plus®	208	I	F	F	F	F	M	F	M	F	F	F	C	R
Gullywasher©	109	I	F	C	M	F	M	C	R					
Gullywasher©	211	I	F	C	M	C	R							
Storm Sentinel®	101	I	F	C	M	F	M	C	R					
Storm Sentinel®	213	I	F	C	M	C	R							
Triton™	113			I	F	F	M	F	M	F	R			
Triton™	207			I	F	F	M	F	M	F	F	F	C	R
WQS	111	I	F	F	F	F	M	F	M	F	M	F	C	R
WQS	209	I	F	F	F	F	M	F	M	F	M	F	C	R

GENERAL FIELD TESTING CONCLUSIONS

Installation

- Except for the Triton™ CBI, all the other units do not comply with ODOT's design criteria for the CB-3A because the curb opening had to be obstructed for the CBI to be effective.
- All units, excluding the Triton™, during the installation process could be lifted by one person and could have been installed by one person.
- The Storm Sentinel®, DrainPac™, FlexStorm®, Gullywasher©, Flo-Gard Plus®, and WQS CBIs were installed in 15 minutes or less.
- The Triton™ and FlexStorm® required longer than 30-minutes for installation, ranging from 37 to 87 minutes. Also, additional tools were needed that were not listed with manufacturer's installation instructions.
- The DrainPac™ had a very rigid housing, which caused it to impact the connecting conduits or the rim of the concrete catch basin. Installation was possible in only one of the catch basins in the study area.
- The FlexStorm® had a very rectangular frame, which would not fit within the rounded corners of the catch basin frames. The corners of the CBI were ground down or cut off to allow for installation.

- Catch basins themselves are not always constructed exactly per the ODOT CB-3A standards. The catch basin frame is not always set directly over the concrete casting causing a slight offset. Also, the connecting conduits and underdrains create additional obstructions if they are not cut off flush with the concrete casting. Proper installation of the more rigid-framed CBIs can be impacted by the non-flush construction and conduit intrusions.

Inspection

- Inspection was completed without removing the CBIs from the catch basins. Observations were limited to what could be seen through the grate opening, including the presence of debris and standing water.
- Any internal or external parts of the CBIs could not be inspected without removing the CBI from the catch basin.

Maintenance

- In general, the manufacturer recommended maintenance to be performed three to four times per year. The study confirmed this requirement. All of the units required maintenance at least three times during the study.
- Back flushing was conducted on the bags and three of the basket units. Back flushing was not recommended for all the CBIs in the manufacturers' requirements.
- During maintenance, a shop vacuum was used in place of vacuum truck to remove accumulated debris. The volume of debris collected by the shop vac were measured for each unit.

Rainfall

- Most of the CBIs manufacturers did not provide information on the volume or number of storm water events the unit could treat. This is likely due to potential variability in site conditions, including sediment concentrations and loads.
- During the study period 133 events occurred with measurable precipitation, with seventeen rain events exceeding 0.75 inches per day. The total rainfall accumulation for the year was 39.39 inches.

Removal

- Nine of the 15 CBIs were removed within the first seven months of the study due to clogging failure. Failure was determined by standing water observed in the CBI.
- Most of the units were easy to remove and required only one person.
- All of the CBIs needed a grate lifter. Only the Triton™ CBI required additional equipment.
- The Triton™ CBI required extended removal times to remove the tray constructed within the catch basin. Two personnel were required to remove this CBI.
- Five CBI units (two WQS, two Flo-Gard Plus®, and one DrainPac™) remained installed for the entire 12-month study.
- The time to remove the curb throat block and measuring the final volume of material collected was included in the removal times.

5 LAB TESTING

LITERATURE REVIEW

A literature review was conducted to study common methods of evaluating CBIs from a lab testing procedure.

Methods of Evaluating CBIs

To properly evaluate CBIs as a post-construction stormwater BMP, many different criteria can be considered. The lab testing for this research focused on sediment retention and long term performance. The CBI sediment removal rate were compared to the water quality standards and regulations set forth by the Ohio EPA. Evaluation of long term performance and maintenance requirements should also be considered. Other studies have shown that over time, CBIs can become clogged with sediment or saturated with oils, causing the CBIs to lose their ability to effectively treat influent stormwater (Kostaleros et al. 2010). A thorough literature review was conducted to evaluate existing procedures used for testing of CBIs through other studies.

Standard Test Methods

ASTM International (ASTM) D7351, titled *Standard Test Method for Determination of Sediment Retention Device (SRD) Effectiveness in Sheet Flow Applications*, establishes the standardized procedures for evaluating the effectiveness of a SRD in retaining sediment when exposed to sediment-laden sheet flow conditions. While modifications were made to this testing standard to make the testing methodology more applicable to ODOT conditions, the general design of the AU-ESCTF testing apparatus was developed around this model.

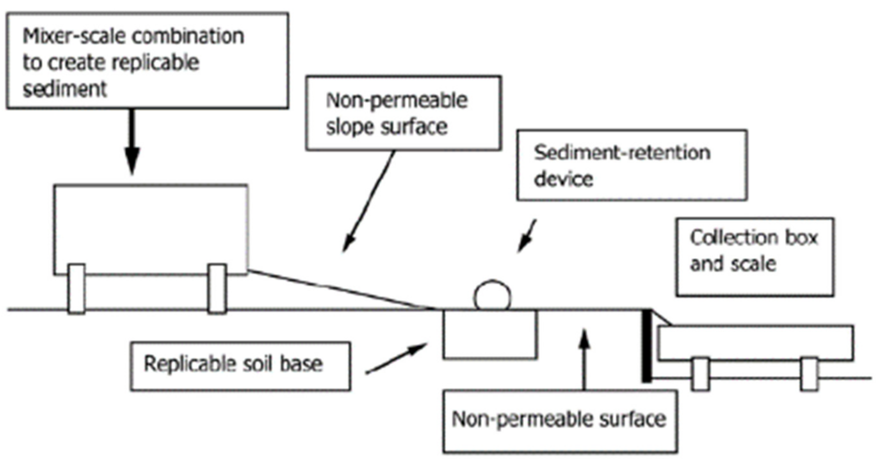


Figure 5-1: ASTM D7351 channel schematic (ASTM D7351 2013).

ASTM D5141, titled *Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device*, details a standard testing procedure used to determine filtering efficiency and flow rate of the filtration component of a SRD. In this testing method, the filtration component of a SRD is placed vertically or over a horizontal opening at the end of a flume and sediment-laden water is allowed to pass through the filter. The amount of time for the mixture to pass through the filter and the amount of suspended sediment passing through the filter are measured. From this data, the amount of soil retained, filtering efficiency, and flow rate of the SRD are then calculated (ASTM D5141, 2011). This standard is not as detailed as ASTM D7351 and doesn't specify a particular storm event or flow rate, meaning the test method can be modified to simulate different flow and sediment conditions. However, this standard does include measuring for sediment retention of the SRD, which AU-ESCTF used for evaluation of CBI products.

CBI Studies from Controlled Testing Environments

AU-ESCTF reviewed the following references from previously conducted studies on CBIs in controlled testing environments. Review of these studies helped inform our lab testing methods and research plan.

A study performed by *Water Environment Research* (Remley et al. 2005) conducted bench-scale testing of four CBIs (AbTech Ultra Urban Filter®, AquaShield™ I, DrainPac™, Hydro-Cartridge®) using an average flow rate for the 6-month, 30-minute, National Resource Conservation Service (NRCS) Type II storm at typical pollutant loads for a transportation facility. The products were subjected to similar flow rates of 207 to 213 gpm (0.46 to 0.47 ft^3/s) and TSS concentrations of 0.027 oz/gal (225 mg/L) for a total of 30 minutes. Influent samples were taken at the 2, 15, 17, and 30-minute marks during each test to ensure consistency. Effluent samples were taken at the 5, 10, 20, and 25 minute marks. Each product underwent 10 tests, with clean CBIs being used for each test, and the samples were averaged for a single effluent value. Analysis for TSS was conducted in accordance with the American Public Health Association (APHA) 2540D standard test method (APHA 2540D 1997) with TSS removal efficiencies ranging between 10 to 42%.

University of Arkansas also conducted lab testing on four products (AbTech Ultra Urban Filter, AquaShield™ II, Hydro-Cartridge, Suntree Technologies™) using similar testing methods. The AquaShield filters used in this study and the last were different CBIs from the same manufacturer. However, the AbTech and Hydro-Cartridge were used in both studies. Each different CBI type was tested five times for a total of 20 tests at influent rates of 0.007 ft^3/s and SSC concentrations of 0.022 oz/gal (180 mg/L), with clean CBIs being used for each test. Average SSC removal efficiency ranged from 25 to 62% for the four products (Remley et al. 2005).

Analytical Industrial Research Laboratories tested the sediment removal efficiency of the Aqua-Filter™ Cartridge at a target influent rate of 0.045 ft^3/s and target sediment concentrations of 0.013, 0.020, 0.026, 0.040 oz/gal. Prior to testing, 800 gallons of sediment free water was run through the cartridge, removing any possible residual dust from the media and simulating wet operating conditions. Ten simulation tests were performed at each target influent TSS concentration. Tests were run for four minutes for a total of 80 gallons of water per test. It was found that average sediment removal rates were calculated between 78 to 83% for all tests and therefore, influent concentrations had little effect on sediment removal efficiency based upon this test method (NJCAT 2005).

A study from California Polytechnic State University (MacLure 2009) performed bench testing using a DrainPac™ Filter. The product was inserted in a flume intended to simulate a large-scale catch basin. Pond water was fed to the flume with sediment concentration measured to range between 0.004 and 0.007 oz/gal. Suspended solids removal efficiency was tested at flow rates of 0.045, 0.134, 0.334, and 0.446 ft^3/s. For each test, roughly 200 gallons of pond water was conveyed through the filter before sampling was performed to build up solids in the bottom of the filter, simulating preloading. Three influent and three effluent samples were collected using clean 0.13 gal plastic sample bottles. Influent and effluent samples were taken simultaneously at the spillway prior to the filter and at the concrete channel located after the flume. Average sediment removal efficiency for the different flowrates ranged from 82.9% to 90.9%.

Table 5-1 provides an overview of results obtained from lab testing of CBI TSS removal efficiency for several studies that were reviewed. TSS removal efficiencies varied greatly in some of these studies because of the differences in influent flow rates and concentrations.

Table 5-1 Summary of Previous CBI Lab Testing

Study	# of Products	Influent Flow Rate [ft^3/s]	Influent Concentration [oz/gal (mg/L)]	TSS Removal Efficiency Ranges (Average)
Morgan et al. 2003	4	0.46-0.48	0.030 (225)	10-42% (29.5%)
Remley et al. 2005	4	0.46	0.024 (180)	25-62% (48.3%)
NJCAT 2005 (AIRL)	1	0.04	0.013-0.040 (100-300)	78-83% (80.5%)
MacLure 2009	1	0.045-0.45	0.004-0.007 (30-50)	83-91% (86.6%)

Overview of Lab Testing Plan

The Auburn University Erosion and Sediment Control Test Facility (AU-ESCTF) tested the performance of CBI products with influent flow rates and volumes based upon design requirements specified in ODOT's L&Dv2 (ODOT, 2017). The lab testing plan used to accomplish this was two-phased: (1) performance evaluation testing and (2) longevity testing.

During performance evaluation testing, each CBI was tested at a low, medium, and high flow rates for a period of 70 minutes using two different soil types. The performance of each CBI was evaluated to determine whether the product captured 80% of the sediment introduced. Each test was performed using a new CBI unit. The first soil type was an OK110 silica sand, used in accordance with ODOT Supplemental Specification 995 (SS995) "Precast Water Quality Structure" (ODOT, 2012), and the second soil type was a United States Department of Agriculture (USDA) classified sandy loam soil that corresponds to standards specified in the "Technology Acceptance Reciprocity Partnership: Protocol for Stormwater Best Management Practices Demonstrations" (TARP) (TARP, 2003). Sediment retention was measured to determine each CBI's performance.

The purpose of longevity testing was to determine the CBI's ability to maintain structural integrity and sediment removal performance over a more strenuous testing cycle. Longevity testing consisted of multiple consecutive tests on a single installed CBI. The flow rates for the tests were at the maximum flow rate that the CBI was capable of providing 80% sediment retention determined from the performance evaluation test. Sediment retention percentage was calculated for each individual test, as well as cumulatively across all longevity tests. The longevity testing cycle continued until it was determined that the CBI would not be able to provide 80% sediment retention or until the CBI failed structurally. The longevity testing methodology provides a representative understanding of how many storm events the CBI can withstand without maintenance or removal in the field, while still satisfying water quality standards. Similar to the methods used in performance evaluation testing, sediment retention was measured to determine each CBI's longevity performance.

Determination of Flow Characteristics

L&Dv2 Section 1115 specifies that pre-manufactured, post-construction BMPs should be designed according to the runoff flow rate resulting from a 0.65 in/hr storm event over the drainage area associated with the catch basin under consideration. Water quality flow (WQ_f) is calculated by the rational equation, found in L&Dv2 Section 1101.2.2, which specifies:

$$WQ_f = kCiA \quad (5\text{-}1)$$

WQ_f	=	Water Quality Flow (ft^3/s)
k	=	unit conversion factor (1.0)
C	=	Coefficient of Runoff (0.9 for impervious)
i	=	Rainfall Intensity (in/hr)
A	=	Contributing Drainage Area (acre)

"k" is a unit conversion factor, usually taken as 1.0 for standard units. While the coefficient of runoff (i.e., 0.9 for impervious areas) and rainfall intensity, 0.65 in/hr, are specified by L&Dv2, an appropriate drainage area must be selected to determine the flow rate that CBI products are expected to treat based upon ODOT typical conditions (Equation 5-1). An examination of ODOT field installation sites concluded that typical drainage areas contributing runoff to catch basins ranged from approximately 0.10 to 0.25 acres. As a result, it was determined that each CBI would be evaluated at three different flow rates, representative of a small drainage area of 0.1 acre, medium drainage area of 0.2 acre, and large drainage area of 0.3 acre. Flow rates associated with the small, medium, and large drainage area according to the rational equation can be found in Table 5-2Table 5-3.

While L&Dv2 does not specify that pre-manufactured, post-construction BMPs be designed to manage a water quality volume (WQ_v), Ohio EPA's CGP specifies that "Alternative Post-Construction BMPs" could be used in place of BMPs typically used to treat stormwater runoff volumes with the requirement that the BMPs be able to treat the water quality volume (WQ_v) discharge rate (OHIO EPA, 2013). Therefore, the water quality volume calculation method (Equation 5-2) was used to determine the total volume of water and flow durations for each test. WQ_v was calculated according to the following equation as specified in L&Dv2:

$$\mathrm{WQ_V} = \frac{\mathrm{PAC_q}}{12} \quad (5\text{-}2)$$

WQ_V	=	Water Quality Volume (acre-feet)
P	=	Precipitation (0.75 in.)
A	=	Contributing Drainage Area (acre)
C_q	=	coefficient of runoff (0.9 for Impervious Drainage Areas)

WQ_v can be divided by WQ_f to determine the duration for each test. This will ensure that each practice is exposed to an adequate amount of runoff volume to determine overall performance. Table 5-2 summarizes the water quality flow rate, water quality volume, and duration of testing for each of the proposed drainage areas.

Table 5-2 Summary of Drainage Areas and Corresponding Testing Flow Rates and Volumes

Drainage Area Size	Drainage Area [ac. (ha)]	Flow Rate [ft^3/s]	Volume		Duration
			[acre-ft (m^3)]	[ft^3 (m^3)]	[min]
Small	0.1 (0.04)	0.06	0.00579 (7.14)	252 (7.14)	70
Medium	0.2 (0.08)	0.12	0.01157 (14.27)	504 (14.27)	70
Large	0.3 (0.12)	0.18	0.01736 (21.41)	756 (21.41)	70

Sediment Introduction

CBIs were tested using two different soil types. First, CBIs were tested in accordance with ODOT Supplemental Specification 995 (SS995) "Precast Water Quality Structure", which specifies a laboratory test influent concentration of 0.028 lb/ft^3 (450 mg/L) while using an OK110 particle distribution with a specific gravity of 2.65 or less (ODOT, 2012). This influent concentration can be multiplied by the volume of water used during each test for the small, medium, and large drainage areas resulting in total sediment loads of 7.08, 14.16, and 21.24 lb., respectively.

CBIs were also tested using a United States Department of Agriculture (USDA) classified sandy loam soil type that corresponds to standards specified in the "Technology Acceptance Reciprocity Partnership: Protocol for Stormwater Best Management Practices Demonstrations" (TARP) (TARP, 2003). TARP specifies that the sandy loam soil be introduced at a target concentration of 0.012 lb/ft^3 (185 mg/L). Over the duration of a test, this concentration results in target loads of 2.91, 5.82, and 8.73 lb, respectively. To obtain the required particle size distribution to meet the TARP standards, soil was taken from an onsite stock pile at the AU-ESCTF. The soil was sifted to separate larger sand particles from finer silt and clay particles, and then mixed together at the appropriate ratio to create a particle size distribution which met the sandy loam classification. The soil sifting and mixing process is illustrated in Figures 5-2(a-d) below.

(a) stockpile soil (b) mechanical shaker (c) sandy loam soil

(d) seperated soils

Figure 5-2: Soil mixing process.

To determine the gradation of the mixed soil, a wet sieve analysis was conducted to determine the ratio of sands to fines. A sample of the fines were then collected and used to perform a hydrometer analysis, further determining the ratio of silt to clay particles. The final distribution of the mixed soil was determined to be 64% sand, 27% silt, and 9% clay. Using the USDA soil classification triangular chart, seen in Figure 5-3, we can verify that this distribution does meet the required classification of a sandy loam.

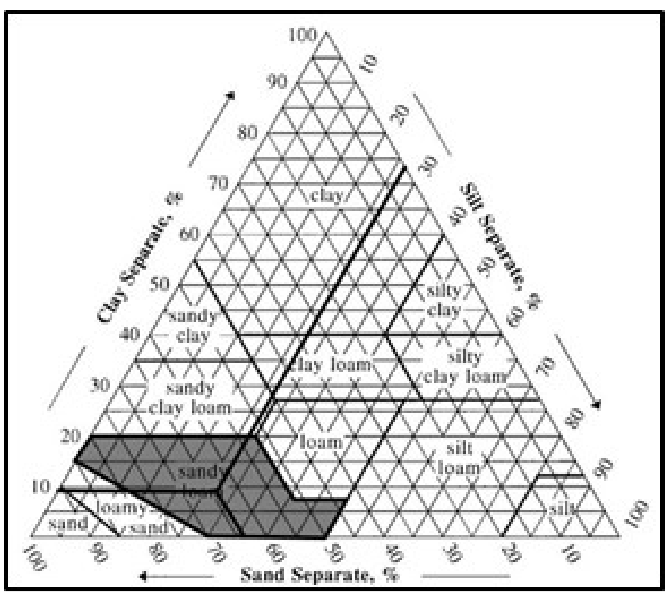
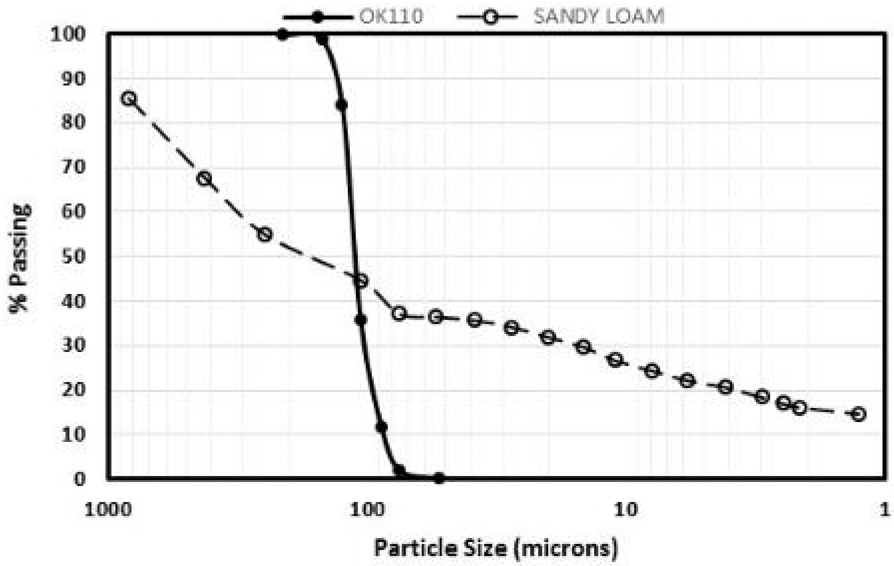
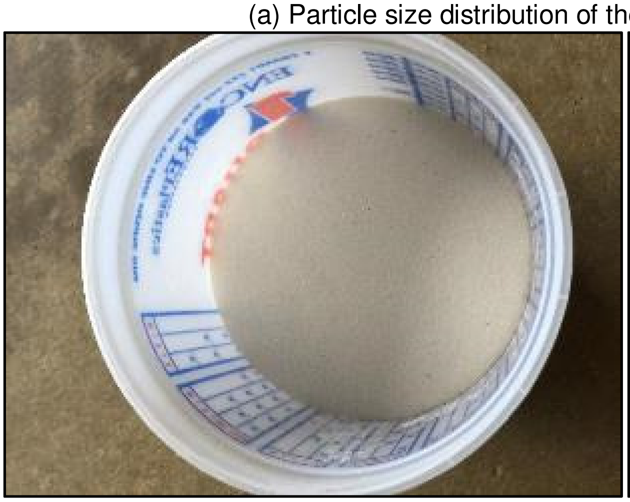


Figure 5-3: USDA soil classification triangular chart. (NRCS Soils, 2018)

To compare the two soil types, the opposing particle size distribution curves for each soil can be seen in Figure 5-4(a). While the OK110 silica sand is primarily composed of sand particles ranging in diameter from 100-200 microns, the sandy loam soil is much more diverse, and contains clay particles, which can cause filtration materials to become clogged, or blinded, affecting sediment removal performance. This also is supported by Figure 5-4(b) and Figure 5-4(c). Particle sizes range greatly in the sandy loam soil, whereas there is little difference in particle size in the OK110 silica sand. By testing CBIs with both soil types, we gained a greater understanding of how the products will perform under different sediment loading conditions.



(a) Particle size distribution of the OK110 and Sandy Loam soils



(b) OK110 silica sand (c) sandy loam

Figure 5-4: Comparison of soil types used for testing.

Equipment and Methodology

The construction of the CBI testing apparatus consisted of three primary components that included the water and sediment introduction system, flow conveyance system, and the discharge platform. Figure 5-5 provides the schematic design of the testing apparatus and major components. Figure 5-6 provides photographs of individual components of the testing apparatus.

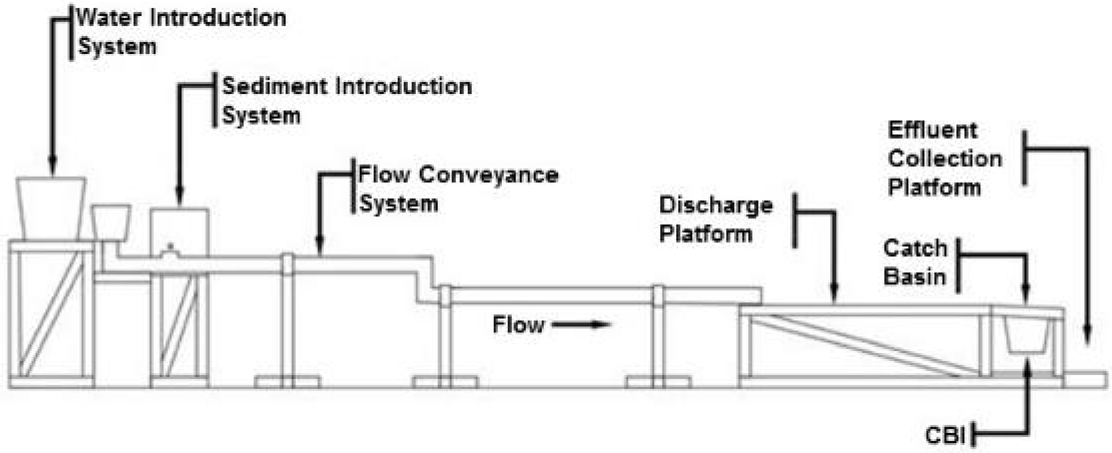


Figure 5-5: Schematic of CBI testing apparatus.

(a) water and sediment introduction system

(b) sediment introduction zone

(c) Schenck Process Model 106M Material Feeder

(d) flow conveyance and transition point

(e) discharge and test platform

(f) catch basin grate

(g) effluent collection platform

Figure 5-6: Catch Basin Insert (CBI) testing apparatus.

Water and Sediment Introduction System

Water is pumped from an on-site supply pond into a water equalization tank located at the upstream end of the apparatus, shown in Figure 5-6(a). To ensure that the water provided by the on-site supply pond had no impact on the lab testing process, water quality samples were taken from the pond at different times throughout each test. This allowed the research group to remove any test in which the supply water was deemed higher than the acceptable standard. However, this was also avoided through careful planning of when to run tests based upon the visual quality of the supply pond. Average concentrations from pond samples were below 0.001 lb/ft^3 (20 mg/L). The water equalization tank is equipped with a calibrated, 90-degree, V-notch weir that allows for controlled discharge into the flow conveyance system by adjusting drainage valves to maintain the water level in the tank at a desired depth. Effective head, or depth according to the weir, can be calculated according to Equation 5-3.

$$h_e = \frac{Q}{4.27997C}^{2/5} \times 12 \quad (5\text{-}3)$$

h_e = effective head, in.
Q = flow rate, ft^3/s
C = discharge constant (0.578)

Using Equation 5-3, the calculated effective heads for each of the three flow rates are 2.71, 3.58, and 4.21 in., respectively. These effective heads were verified using timed flow capture to further calibrate and validate the desired discharges.

The V-notch weir discharges into a 6-inch polyvinyl chloride (PVC) flow conveyance system. Just downstream of the water introduction point, a vertical tee is placed in the flow conveyance system that allows for the introduction of sediment into the flow, shown in Figure 5-6(b).

A Schenck AccuRate® series auger type volumetric feeder with a 0.75 in. diameter helix and a 0.25 ft^3 hopper was used for sediment introduction, which is shown in Figure 5-6(c). This system is equipped with a three-digit thumbwheel speed potentiometer for enhanced repeatability that provides a consistent and accurate means of sediment introduction. The auger discharges into the flow conveyance system through a pre-drilled hole placed on the vertical tee end cap that was used to protect falling sediment from being disrupted by wind.

Flow Conveyance System

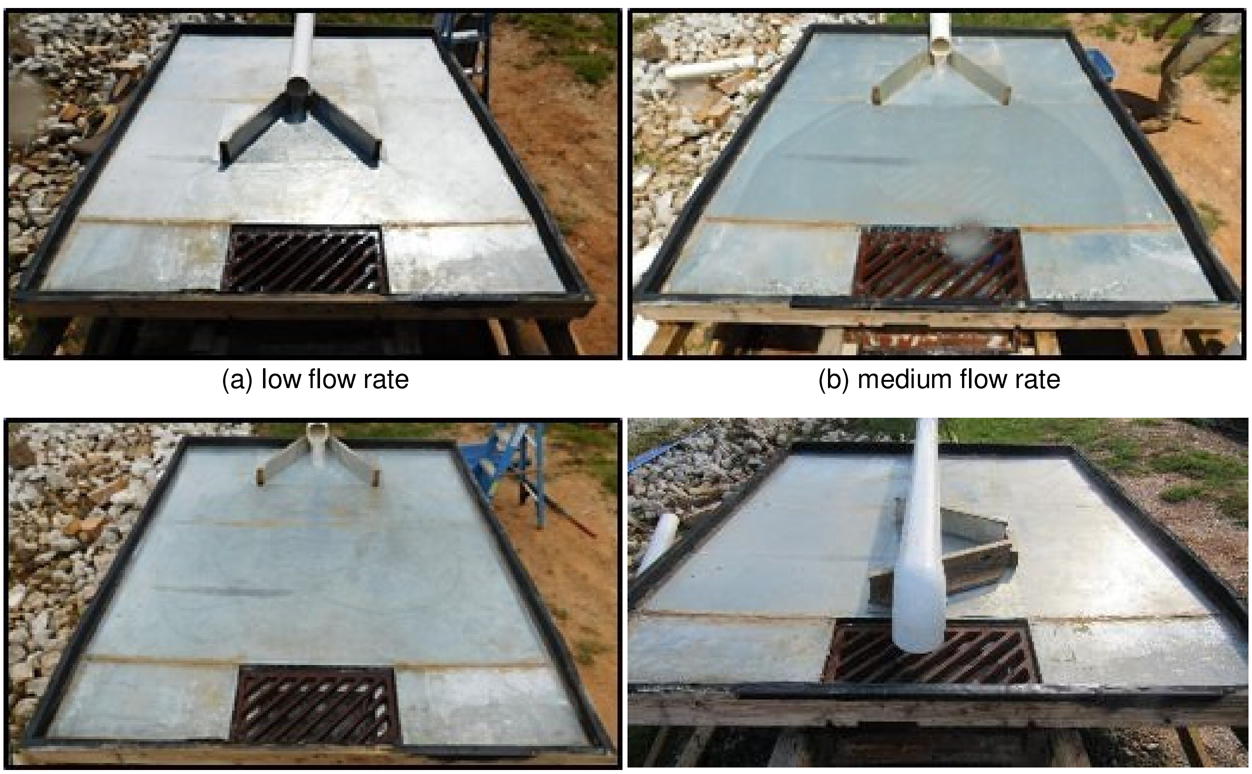
The flow conveyance system consists of 20 ft in length by 6 in. inside diameter PVC pipe laid at a 2% slope that conveys sediment-laden water from the upstream introduction point to the drainage platform, as shown in Figure 5-6(d). A transition point was constructed in the middle of the flow conveyance system to produce turbulent flow for the sediment-laden water and cause soil particles to mix more evenly.

Discharge Platform

The discharge platform was constructed on a stable and level area so that influent would spread evenly across the platform. The lower support frame was then constructed using treated 4 x 4 lumber with treated 2 x 4 lumber as cross-bracing. The manufactured ODOT CB-3A frame was then placed on top of the lower support frame, and the upper platform was constructed around the catch basin frame. The upper platform consists of two 4 ft x 8 ft x 0.75 in. plywood sheets to create an 8-foot by 8-foot surface. The plywood was installed at a 2% slope both in the downstream direction and toward the middle of the platform to direct sheet flow into the catch basin from the discharge point of the flow conveyance system. The 2% slope was selected to be representative of a typical roadway cross-sectional slope. Additional plywood was installed at a location similar to the slope of the catch basin frame to simulate the curb.

The platform was then sealed with silicon caulking and covered with a rubber sealant material. The platform was sprayed with a LINE-X® coating to provide a watertight seal. Finally, 14-gauge sheet metal was placed on top of the platform as a finished surface that would allow influent to flow as sheet flow into the catch basin without causing disturbances that could result in sediment falling out of suspension prematurely. Edges and corners were again sealed with silicone caulking to prevent leaking. The completed drainage platform is pictured in Figure 5-6(e).

A 6 in. PVC coupling was placed at the upstream side of the drainage platform. This allows the operator to change the length of pipe based upon the flow rate that the test is being performed at, as seen in Figure 5-7. For low flow rate tests, the flow conveyance pipe is extended closer to the catch basin, and for high flow rate tests, the conveyance system ends at the coupling, and no additional piping is used. The purpose of this adjustment is to ensure flow enters the catch basin grate at a consistent velocity across all three flow rates and prevent particles from falling out of suspension on the platform prematurely due to slowed velocity. Modifications were also made to the system to allow water to be directly discharged into the inlet opposed to influent sheet flow. Direct discharge modifications can be seen in Figure 5-7(d).



(a) low flow rate (b) medium flow rate

(c) high flow rate (d) direct discharge

Figure 5-7: Modifications to flow conveyance system based on flow rate.

PERFORMANCE EVALUATION OF CBIs

The primary focus of the CBI testing was to characterize performance by quantifying sediment removal efficiency by measuring the percentage of sediment captured in the CBI (Equation 5-4). Prior to installation, the CBI's pre-test weight was determined to compare to the post-test weight of the CBI and captured sediment. Each product was installed based upon manufacturer installation protocols. Upon completion of the test, the saturated CBI is placed in an industrial oven at approximately 217°F for at least 12 hours to ensure that all moisture was removed from the sediment or the filter media. The weight of the sediment introduction system was also recorded before and after the test so that the amount of sediment introduced could be determined. Any lost sediment that may have fallen out of suspension on the platform during sheet flow testing prior to entering the inlet was also collected and allowed to dry in the oven for at least 12 hours before being weighed and accounted for as lost sediment.

$$SRE = \frac{(A-B)}{(C-D-E)} \qquad (5\text{-}4)$$

SRE = sediment removal efficiency, %
A = weight of CBI, post-test, lb
B = weight of CBI, pre-test, lb
C = weight of sediment introduction system, pre-test, lb
D = weight of sediment introduction system, post-test, lb
E = weight of lost sediment, lb

During each test, photo and video documentation was also performed to capture important flow characteristics. Photo documentation was performed from predetermined and ad hoc locations to visually show pre- and post-test conditions.

LAB RESULTS

Performance Evaluation Testing

The following section discusses the installation, testing, and performance of each CBI based upon performance testing. Each product was tested at the low, medium, and high flow rates of 0.06, 0.12, and 0.18 ft^3/s. Target sediment introductions for the low, medium, and high tests were 7.08, 14.16, and 21.24 lb for OK110 tests and 2.91, 5.82, and 8.73 lb for sandy loam tests.

A common issue observed during many of the tests was that a majority of the products allowed water to bypass the treatment material. Many of the products did not fit tightly to the catch basin frame, allowing some influent to bypass the entire product, and hindering treatment potential. Because of this, the testing was modified to the direct discharge method, which forced the influent directly into the CBI, eliminating potential for bypass. Figure 5-8 provides an example of the bypass allowed during sheet flow testing compared to that allowed during direct discharge testing. Figure 5-8(a) shows the water bypassing the CBI by flowing down the outside of the device during sheet flow testing. Figure 5-8(b) shows only water flowing out of the bottom of the device during direct discharge testing. While the WQS is shown as an example, all CBI products except the Triton™ experienced similar issues and had some volume of water bypassing due to the lack of a watertight seal between the CBI frame and the catch basin frame. The bypass volume varied between these units, depending on the CBI's frame and fit, but was not quantified.

(a) sheet flow (b) direct discharge

Figure 5-8: Bypass allowed between discharge methods.

Summary of Performance Evaluation Testing

Table 5-3 summarizes all sediment retention percentage data for all performance evaluation tests. It can be seen that the Adsorb-It™ exceeded the 80% target removal rate multiple times, while other products failed to exceed the threshold. However, the FlexStorm®, Storm Sentinel®, Gullywasher©, and DrainPac™ nearly met the target threshold, with sediment retention values reaching above 70% for one of the low flow tests.

Table 5-3 Summary of Sediment Retention Percentage of Performance Evaluation Testing

Product Name	Sheet Flow OK110			Direct Discharge OK110			Direct Discharge Sandy Loam		
	0.06 ft³/s	**0.12** ft³/s	**0.18** ft³/s	**0.06** ft³/s	**0.12** ft³/s	**0.18** ft³/s	**0.06** ft³/s	**0.12** ft³/s	**0.18** ft³/s
Adsorb-It™	77.2	64.4	48.7	96.2	82.5	64.3	85.4	64.2	50.5
DrainPac™	36.0	46.1	47.1	79.8	64.8	62.7	68.1	46.8	38.4
FlexStorm®	51.2	56.8	46.5	71.3	50.2	36.3	65.4	58.3	43.9
Flo-Gard Plus®	7.3	1.0	0.7	10.4	0.8	2.2	24.7	19.8	22.0
Gullywasher©	75.8	58.8	41.0	67.1	47.8	35.7	51.7	38.1	33.4
Storm Sentinel®	59.2	41.0	21.7	71.3	38.5	26.0	41.6	30.1	20.3
Triton™	59.4	49.0	45.2	68.5	59.7	44.9	40.4	38.4	36.4
WQS	2.7	27.3	26.8	27.1	51.4	53.9	42.7	49.4	50.5

A multiple linear regression was conducted to determine the relative impact that each of the four variables (e.g., product, discharge method, soil type, flow rate) has on sediment retention, independent of other factors. This analysis helped to isolate the impacts influencing factors (i.e., independent variables) had on sediment retention and to explain the relationship between the dependent variable and independent variables. The dependent variable selected for the analysis was the sediment retention value associated with each test.

The detailed discussion and results of the statistical analysis of the sediment retention data are provided in Appendix C. In summary, the following conclusions can be drawn from these analyses.

1. The Adsorb-It™ retained sediment at a statistically significant higher rate than any of the other CBI products, while the Flo-Gard Plus® retained sediment at a statistically significant lower rate than any of the other CBI products.
2. CBIs exhibited a statistically significant decrease in sediment retention as flow rates increased, suggesting that CBIs are more effective in smaller drainage areas, which tend to contribute lower flows. Higher flow rates also led to more overflow conditions of the CBIs, thus bypassing treatment.
3. The direct discharge test method showed a statistically significant increase in sediment retention over the sheet flow method. This supports the observation that most of the CBIs did not create a water tight seal between the CBI frame and the catch basin frame. During testing, runoff leaked through this space and was not filtered (or treated) through the CBI.
4. While the data do show that there was a small decrease in sediment retention between tests with sandy loam compared to tests with the OK110 silica sand, there was not a statistically significant difference.

Longevity Testing

Longevity testing was performed to better understand the performance characteristics of the products over time. Based upon performance testing it was determined that the low flow rate of 0.06 ft^3/s would be used to test the products for longevity because, with the exception of the Adsorb-It™, no CBI successfully captured 80% of the introduced sediment at the 0.12 ft^3/s or 0.18 ft^3/s flow rates. Therefore, target sediment introductions for the tests were 7.08 lb. for OK110 tests and 2.91 lb. for sandy loam tests. As with the performance testing, sediment capture was determined by pre- and post-test weight of the dried CBI. However, since the purpose of longevity testing is to determine temporal performance, pre- and post-test weights were determined for each longevity test, providing both an individual and a cumulative sediment retention for each CBI tested. Table 5-4 and Figure 5-9 are presented to show the overall performance of each CBI product. Furthermore, figures with graphs showing the trends in the weight of sediment introduced, captured, and bypassed during the longevity tests are included in Appendix C. For example, when evaluating the graphs, the difference between the sediment introduction line and the sediment captured line will determine sediment capture performance over time. This is determined by the difference in the lines increasing or decreasing over time. If the difference increases, sediment retention decreases over time and vice versa. This distance is also equivalent to the value of the sediment bypassed line shown on each graph, which shows the amount of sediment bypassing, or not being captured, by the products. Appendix C contains additional detailed testing results for each CBI.

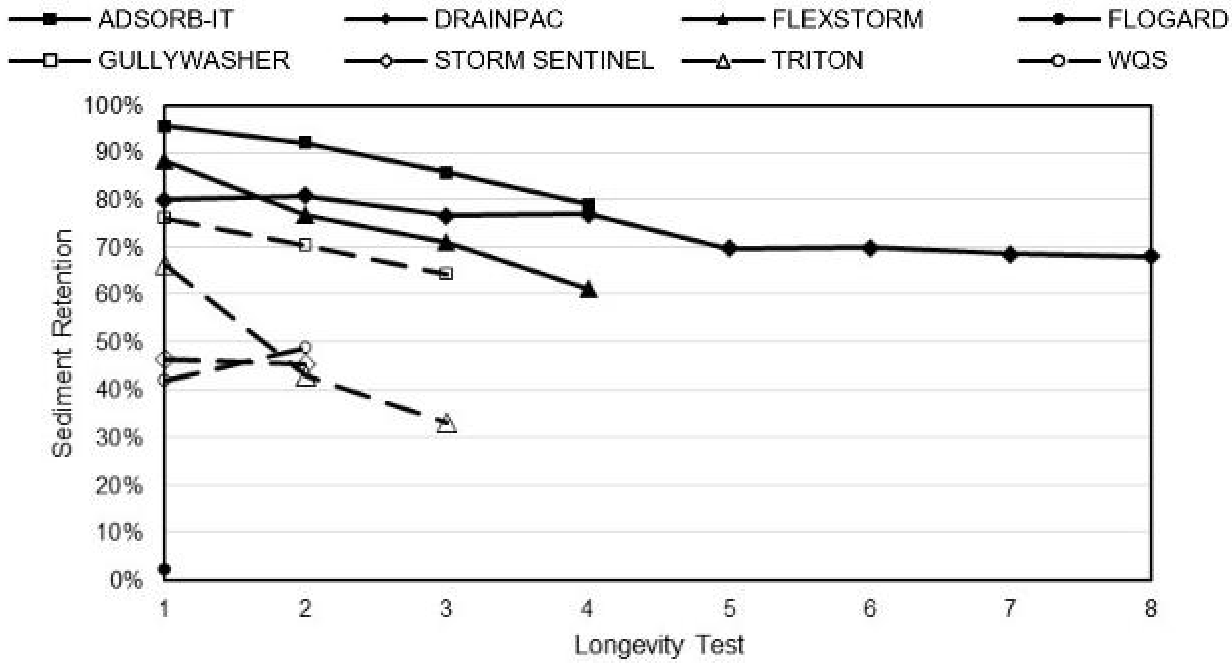
Summary of Longevity Testing

Table 5-4 summarizes all sediment retention percentage data for all longevity tests. The DrainPac™ was tested eight consecutive times with OK110 silica sand. While individual tests values varied, it can be seen that there was a gradual decrease in cumulative retention rate from test to test. Despite this performance, the DrainPac™ was only tested twice with the sandy loam due to low retention rates. The Adsorb-It™ performed similarly to the performance evaluation testing, having the highest retention values of all CBIs. While most products were tested at least twice to ensure that they were not meeting the 80% target rate, the Flo-Gard Plus® was only tested once per soil type due to its low performance, both during the first longevity test (i.e., L1) tests and the performance evaluation testing.

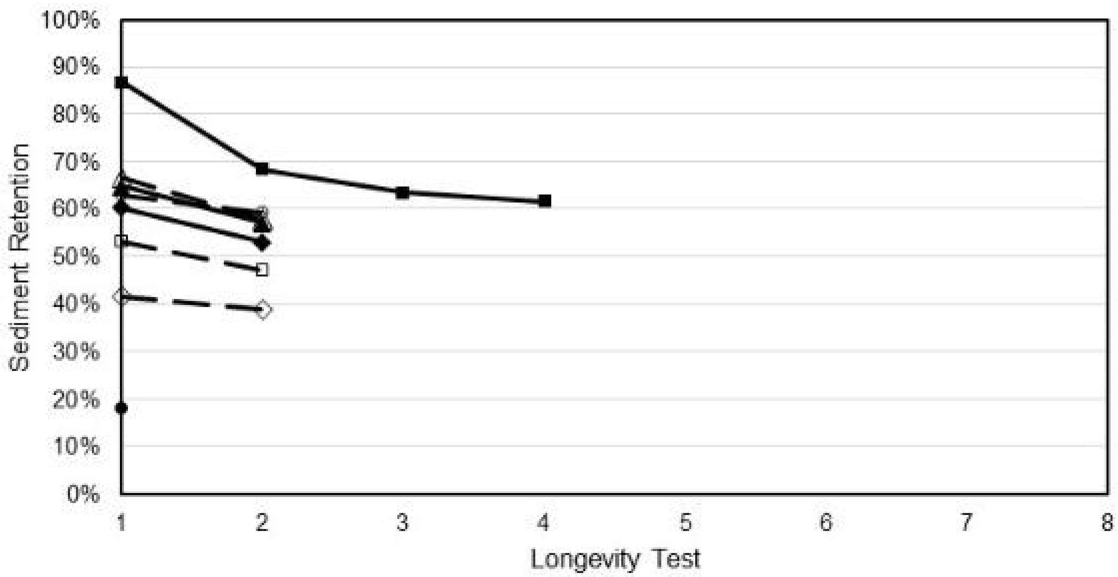
Table 5-4 Summary of Sediment Retention Percentage of Longevity Tests

(a) Longevity Tests with OK110 Silica Sand									
		L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**
Adsorb-It™	Indiv.	95.6%	88.4%	72.4%	55.7%	-	-	-	-
	Cumul.	-	*92.0%*	*85.7%*	*78.9%*	-	-	-	-
DrainPac™	Indiv.	80.0%	81.7%	68.4%	78.1%	40.6%	70.5%	60.7%	64.3%
	Cumul.	-	*80.9%*	*76.7%*	*77.0%*	*69.7%*	*69.8%*	*68.5%*	*68.0%*
FlexStorm®	Indiv.	88.3%	64.5%	58.8%	31.2%	-	-	-	-
	Cumul.	-	*76.8%*	*71.1%*	*61.3%*	-	-	-	-
Flo-Gard Plus®	Indiv.	2.3%	-	-	-	-	-	-	-
	Cumul.	-	-	-	-	-	-	-	-
Gullywasher©	Indiv.	75.9%	64.9%	50.8%					
	Cumul.	-	*70.4%*	*64.2%*					
Storm Sentinel®	Indiv.	46.2%	44.1%	-					
	Cumul.	-	*45.2%*	-					
Triton™	Indiv.	66.2%	20.8%	14.2%					
	Cumul.	-	*42.8%*	*33.2%*					
WQS	Indiv.	41.9%	55.3%						
	Cumul.	-	*48.7%*						
(b) Longevity Tests with Sandy Loam Soil									
		L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**
Adsorb-It™	Indiv.	86.8%	49.8%	53.6%	53.8%	-	-	-	-
	Cumul.	-	*68.4%*	*63.5%*	*61.6%*	-	-	-	-
DrainPac™	Indiv.	60.3%	45.5%	-	-	-	-	-	-
	Cumul.	-	*53.0%*	-	-	-	-	-	-
FlexStorm®	Indiv.	64.8%	49.7%	-	-	-	-	-	-
	Cumul.	-	*57.0%*	-	-	-	-	-	-
Flo-Gard Plus®	Indiv.	18.0%	-	-	-	-	-	-	-
	Cumul.	-	-	-	-	-	-	-	-
Gullywasher©	Indiv.	53.1%	39.8%	-	-	-	-	-	-
	Cumul.	-	*46.9%*	-	-	-	-	-	-
Storm Sentinel®	Indiv.	41.6%	36.0%	-	-	-	-	-	-
	Cumul.	-	*38.8%*	-	-	-	-	-	-
Triton™	Indiv.	66.7%	48.8%	-	-	-	-	-	-
	Cumul.	-	*57.7%*	-	-	-	-	-	-
WQS	Indiv.	62.7%	55.7%	-	-	-	-	-	-
	Cumul.	-	*59.2%*	-	-	-	-	-	-

Figure 5-9 plots cumulative retention percentages for each CBI throughout their respective longevity testing tenure. It can be seen that, on average, CBIs were able to endure more longevity tests when using the OK110 silica sand than when using the sandy loam soil, despite the fact that the OK110 silica sand was introduced at higher concentrations. This would suggest that CBIs subjected to sandy soils might require less maintenance in the field since performance capabilities were sustained longer than with loamy soils. This is most likely due to the higher clay content in the sandy loam soil causing the filter material to become blinded, hindering flow-through ability and performance by clogging the pore passages of the CBI media. For most CBIs, sediment retention percentage was also higher through the first few tests with OK110 silica sand than with sandy loam soil, indicating that the larger sized sand particles in the OK110 silica sand were easier to capture than the smaller silt and clay particles in the sandy loam soil.



(a) OK110 silica sand



(b) sandy loam soil

Figure 5-9: Longevity Testing Summary of Cumulative Retention Data

The lab testing conducted provides an in-depth analysis of how the selected CBIs will perform in terms of both sediment removal and need for maintenance over time. The results provided in this section, paired with the data collected during the field testing phase of the project, can be combined to make final recommendations on the performance on each of the products.

6 GENERAL LABORATORY CONCLUSIONS

Lab Testing Methodology

- The overall design of the lab testing was conducted in accordance with the ODOT L&Dv2 flow rate and volume requirements.
- During performance evaluation tests, CBIs were tested at three different influent flow rates of 0.06, 0.12, and 0.18 ft^3/s for 70 minutes, representative of drainage areas of 0.1, 0.2, and 0.3 acres.
- CBIs were also tested using two different soil types, an OK110 silica sand gradation introduced at a target concentration of 0.028 lb/ft^3 (450 mg/L), and a sandy loam introduced at a target concentration of 0.012 lb/ft^3 (185 mg/L).
- Sediment retention within the CBIs was measured to determine each CBIs performance.
- Longevity testing consisted of multiple consecutive tests on a single installed CBI and were conducted using each soil type at the low flow rate. Sediment retention percentage was calculated for each individual test, as well as cumulatively across all longevity tests.
- The longevity testing cycle continued until it was determined that the CBI was no longer capable of reaching the 80% sediment retention percentage during an individual test event or until the CBI failed structurally.
- Originally, CBIs were tested with the OK110 silica sand under sheet flow conditions. Most CBIs exhibited a leak between the CBI frame and the catch basin frame. So, flow introduction methods were adapted to directly discharge the sediment-laden influent into the catch basin to minimize flow bypass potential. CBIs were then tested with both soil types under the direct discharge testing method.

Lab Performance Evaluation Testing Results

- Most products failed to meet the 80% sediment retention criterion. However, the Adsorb-It™ did capture above 80% sediment for both soil types and at multiple flow rates. The DrainPac™ reached 80% retention when tested with OK110 sand at the low flow rate under direct discharge conditions, but did not reach the target for other tests.
- The Adsorb-It™ retained sediment at a statistically significant higher rate than any of the other CBI products, while the Flo-Gard Plus® retained sediment at a statistically significant lower rate than any of the other CBI products.
- CBIs exhibited a statistically significant decrease in sediment retention as flow rates increased, suggesting that CBIs are more effective in smaller drainage areas, which tend to contribute lower flows. Higher flow rates also led to more overflow conditions of the CBIs, thus leading to bypassing treatment.
- The direct discharge test method showed a statistically significant increase in sediment retention over the sheet flow method. This supports the observation that most of the CBIs did not create a water tight seal between the CBI frame and the catch basin frame. During testing, runoff leaked through this space and was not filtered (or treated) through the CBI.
- While the data do show that there was a small decrease in sediment retention between tests with sandy loam compared to tests with the OK110 silica sand, there was not a statistically significant difference.

- Analysis of performance evaluation tests concluded that, for most products, long periods of overflow were likely to result in reduced retention efficiencies of CBIs.

Longevity Testing Results

- Six of the eight CBIs did not perform well enough during the first and second longevity tests to justify further longevity testing, suggesting that these products are incapable of providing the sediment retention needed to meet standard requirements.
- Sediment retention performance degraded with multiple simulated storm events. The cumulative sediment retention was less than 80% by the fourth test for the Adsorb-It™, by the third test for the DrainPac™, and by the second test for the FlexStorm®.
- Most products performed better during longevity testing with OK110 silica sand than with sandy loam soil. It is expected that the higher clay content in the sandy loam caused filter media to blind after repeated tests.

7 CONCLUSION

The goal of this research was to test the performance and maintenance requirements of a variety of CBIs available on the market in order to assess the viability of CBIs as acceptable alternative BMPs which ODOT could incorporate into the L&Dv2 BMP toolbox. To meet the research criteria, each CBI was required to achieve 80% sediment retention and be able to be installed in a standard ODOT CB-3A. None of the CBIs tested met both conditions.

Eight CBI products were evaluated in lab and field settings to accomplish this research goal. The field testing assessed the installation, maintenance, and removal needs of the CBIs during the 12-month monitoring period. The laboratory testing measured the CBIs sediment retention for two soil types (i.e., silica sand and sandy loam).

The field testing installed the CBIs in existing ODOT CB-3As at two locations. Fifteen CBI products were installed in the field at two site locations. One CBI product could not be installed at both locations, it was only installed at Site 1. The CBIs were assessed on installation, maintenance, and removal over a one year duration.

Of the eight CBIs evaluated, only the Triton™ could be installed in the CB-3A without requiring modifications to the curb inlet of the standard catch basin. All stormwater that entered into the standard catch basin could be treated by the Triton™. All other CBIs require installation within the grate of the catch basin, allowing any water captured by the curb "throat" opening to bypass the CBI. The catch basins required a throat block to divert the stormwater into the grate and allow it to be collected entirely. Intentionally blocking the curb throat opening was allowed by ODOT for this study only, but would not otherwise be considered an acceptable practice. All of the units required maintenance over the duration of the study with the first occurring within one to three months of installation. Five CBI units (two WQS, two Flo-Gard Plus®, and one DrainPac™) remained installed for the entire 12-month study. Nine of the 15 units were removed within the first seven months.

Laboratory testing exposed the CBI products to influent flow rates and durations to properly simulate field-like conditions during large-scale lab testing. Under these conditions, the CBIs performance in capturing 80% of the sediment introduced was analyzed. Both sandy loam and OK110 soil types were evaluated in the testing.

For the sediment retention criteria, the DrainPac™ and Adsorb-It™ both met 80% sediment retention at one or more flow variations within the lab testing. However, the remaining units fell below this threshold. During longevity testing, sediment retention rates decreased with repeated back-to-back simulated storms, falling below 80% within as many as four tests and as few as two tests.

The lab and field testing allowed for a comparable basis between each CBI, as well as an individual evaluation of each unit's performance. Key factors in evaluating performance in the field were the installation process, maintenance needs, and duration in the field before failure. Lab testing was evaluated on the unit's ability to meet the 80% sediment retention requirement for the two soil types. Table 7-1 below summarizes the results from the field and lab testing to allow for a complete summary of each CBI's performance.

Table 7-1 CBI Overall Results Summary

Product Name	Installed in CB Without Modification	Duration in Field Before Maintenance (Months)	Duration in Field Before Failure (Months)	80% Sediment Retention OK110 Silica Sand	80% Sediment Retention Sandy Loam Soil
Adsorb-It™	No	2	6	Yes [1]	Yes[2]
DrainPac™	No	5	12	Yes[2]	No
FlexStorm®	No	2	7	No	No
Flo-Gard Plus®	No	5	12	No	No
Gullywasher©	No	1.5	6	No	No
Storm Sentinel	No	1.5	6	No	No
Triton™	Yes	2	8.5	No	No
WQS	No	5	12	No	No

[1] 80% sediment retention met for direct discharge, low flow rate (0.06 ft^3/s) and medium flow rate (0.12 ft^3/s) only.
[2] 80% sediment retention met for direct discharge, low flow rate (0.06 ft^3/s) only.

Although the research selection criteria were met individually by some of the CBIs evaluated, none of the CBIs met both of the requirements. The two CBIs that met the sediment retention targets for any of the flow rates (i.e., Adsorb-It™ and DrainPac™) showed that within as many as four simulated storm events, the CBIs fell below the 80% threshold. This relatively quick drop in performance suggest the units would require frequent maintenance or replacement to continue meeting the sediment retention requirement. The field testing supported these longevity testing results, requiring frequent maintenance— the Adsorb-It™ in as little as two months and the DrainPac™ an average of quarterly—based on the CBIs showing clogging with standing water. As demonstrated in the longevity testing, actual maintenance is likely needed even more frequently than conducted in the field testing to keep CBIs performing at or above 80% sediment retention (i.e., every two to four precipitation events). With the potentially large number of CBIs that would be required to address post-construction stormwater BMPs, this represents a significant maintenance burden from a practical standpoint.

Seven of the eight CBIs required the curb inlet of the standard catch basin CB-3A to be blocked. This modification does not align with ODOT's drainage design standards due to the significant reduction in flow capacity and increased risk of roadway flooding.

Based on the criteria established for this study, none of the units tested appear to be a viable option as a post-construction stormwater BMP within ODOT's L&Dv2 manual.

Appendix A Literature Review

APPENDIX A

Title:	*On the Efficiency of Catch Basin Inserts for Stormwater Runoff Treatment*
Publisher/Sponsor:	11th International Conference on Urban Drainage
Author(s):	Berretta, C., Gnecco, I., Molini, A., Palla, A., Lanza, L. G., and La Barbera, P.
Publication Date:	2008
Content and Focus:	Studied two industrial sites with CBIs. Using the data collected, they extrapolated future performance to determine how long these practices will be adequately functional. At the time of the publication, the study was still ongoing and little data was presented on reductions and performance longevity.
Url:	https://www.researchgate.net/publication/228506754_On_the_efficiency_of_catch_basin_inserts_for_storm_water_runoff_treatment

Title:	*An Evaluation of Storm Drainage Inlet Devices for Stormwater Quality Treatment*
Publisher/Sponsor:	Water Environment Federation Technical Exposition and Conference
Author(s):	Field, R. and Pitt, R.
Publication Date:	1998
Content and Focus:	Evaluated two CBIs and one conventional catch basin inlet with a sump. Their findings showed some significant improvements in water quality using the conventional sump, but limited water quality improvements from the CBIs The median removal rates were about 30% for suspended solids, about 40% for turbidity, about 15% for color, and about 20% for total solids. No other pollutants were found to be significantly reduced. However, the coarse screened inlet device was found to significantly reduce the discharges of trash and other large debris. Unfortunately, flows passing through trapped material caught on the screen had increased concentrations of suspended solids and volatile solids, probably due to washing of decomposing large organic material through the screen.
Url:	https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=100340

Title:	*Catch Basins and Inserts for the Control of Gross Solids and Conventional Stormwater Pollutants*
Publisher/Sponsor:	Critical Transitions in Water and Environmental Resource Management, American Society of Civil Engineers
Author(s):	Field, R. and Pitt, R.
Publication Date:	2004
Content and Focus:	This presentation summarizes the results from past and recent studies of catch basin inlet devices, and recommend important features to optimize their performance. Case studies are also presented, summarizing two EPA-funded projects that examined catch basins and insert performance. While many types of inlet devices may capture some stormwater debris, care must be taken in their design. Catch basins with sumps may remove up to about 30% of suspended loads that enter the inlet, but much of this material is relatively coarse and in many cases would not have moved to the outfall.
Url:	http://ascelibrary.org/doi/abs/10.1061/40737%282004%2957

Title:	*Catch Basins and Inserts for the Control of Gross Solids and Conventional Stormwater Pollutants*
Publisher/Sponsor:	Critical Transitions in Water and Environmental Resource Management, American Society of Civil Engineers
Author(s):	Field, R. and Pitt, R.
Publication Date:	2004
Content and Focus:	Reported 30% removal of suspended loads; however, they noted much of these loads were coarser material that likely would accumulate in the sewer system and actually reach the outfalls. They provided recommendations on desirable characteristics for CBIs, including: • Does not cause flooding when it clogs with debris; • Does not force stormwater through the captured material; • Does not have adverse hydraulic head loss properties; • Maximizes pollutant reductions; and • Requires inexpensive and infrequent maintenance.
Url:	http://ascelibrary.org/doi/abs/10.1061/40737(2004)57

Title:	*Mass Loading of First Flush Pollutants with Treatment Strategy Simulations*
Publisher/Sponsor:	TRR – Journal of the Transportation Research Board
Author(s):	Kayhanian, M. and Stenstrom, M. K.
Publication Date:	2005
Content and Focus:	Evaluated theoretical pollutant load reductions through simulations of CBI performance. The research results showed that treating the initial (first flush) pollutant loads was more beneficial than treating 20% of the entire runoff form the precipitation event.
Url:	http://trrjournalonline.trb.org/doi/10.3141/1904-14

Title:	*Field Study of Catch Basin Inserts for the Removal of Pollutants from Urban Runoff*
Publisher/Sponsor:	Water Resources Management (WATER RESOUR MANAG)
Author(s):	Kostarelos, K., Khan, E., Callipo, N., Velasquez, J., and Graves, D.
Publication Date:	2010
Content and Focus:	The study evaluated six CBIs in field but produced little quantifiable data. It included discussion of types of captured pollutants and maintenance activities
Url:	https://www.researchgate.net/publication/227153221_Field_Study_of_Catch_Basin_Inserts_for_the_Removal_of_Pollutants_from_Urban_Runoff

Title:	*Stormwater Management Practices (Closed Drainage) Study C-01-74*
Publisher/Sponsor:	New York State DOT
Author(s):	Kostarelos, K. and Khan, E.
Publication Date:	December 2007
Content and Focus:	The study was to evaluate pollutant load reductions of stormwater runoff using catch basin inserts. NYDOT also recognized the opportunity to treat runoff without requiring land by using these inserts. However, NYDOT was not just concerned with TSS, but also fecal coliform bacteria, total phosphorus, total nitrogen, total petroleum hydrocarbons and biochemical oxygen demand. Of the six catch basin inserts evaluated, only the *Stream Guard Catch Basin Insert for Oil and Grease* was determined to remove at least 80% sediment.
Url:	https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-01-74%20Stormwater%20Management%20Practices%20(Closed%20Drainage.pdf

Title:	*Performance of a Catch Basin Filter and Leachate From Biocidal Media for Stormwater Treatment*
Publisher/Sponsor:	California Polytechnic State University-San Luis Obispo
Author(s):	MacLure, R.
Publication Date:	2009
Content and Focus:	This thesis covers the testing of a Drainpac™ filter for its sediment, oil and grease, and coliform bacteria removal efficiency in conjunction with bench-scale testing of biocidal polymer beads.
Url:	http://digitalcommons.calpoly.edu/theses/47/

Title:	*An Evaluation of the Urban Stormwater Pollutant Removal Efficiency of Catch Basin Inserts*
Publisher/Sponsor:	Water Environmental Research
Author(s):	Morgan, R.A., Edwards, F.G., Brye, K.R., and Burian, S.J.
Publication Date:	2005
Content and Focus:	Evaluated four different CBIs for TSS and other pollutant removals. These evaluations were performed using both lab and field testing. The lab testing used captures from local street sweeping operations as a representative pollutant sample. The test results showed average TSS removal range from 10 to 42%.
Url:	https://www.jstor.org/stable/25045905?seq=1#page_scan_tab_contents

Title	*Pollutant Removal Capacity of Stormwater Catch Basin Inserts*
Publisher/Sponsor:	World Water and Environmental Resources Congress
Author(s):	Remly, R., Morgan, R., Edwards, F., Brye, K.R. and Burain, S.
Publication Date:	2005
Content and Focus:	Transportation facilities such as parking lots or maintenance yards often do not have provisions to treat stormwater prior to discharge. Catch basin inserts can provide a retrofit alternative as a method to meet the new National Pollution Discharge Elimination System Phase II stormwater pollution prevention regulations. Six inserts manufactured by five manufacturers were evaluated for removal of suspended solids, petroleum hydrocarbons, and zinc using a pilot scale catch basin and a simulated stormwater.
Url:	http://ascelibrary.org/doi/pdf/10.1061/40792%28173%29217

Title:	*Environmental Technology Verification Report of the Low Cost Stormwater BMP Study*
Publisher/Sponsor:	Civil Engineering Research Foundation (CREF) - University of Arkansas
Author(s):	Staff, C. and Jiang, L.
Publication Date:	2003
Content and Focus:	This verification report describes the nature and scope of an environmental evaluation of catch basin inserts manufactured by four different companies: AbTech Industries, GeoTechnical Marine Corp., AquaShield, Inc., PacTec, Inc. The inserts are manufactured to be retrofitted into existing catch basins in order to remove sediment, hydrocarbons, metals, nutrients and debris from stormwater runoff.
Url:	http://faculty.cveg.uark.edu/edwards/papers%20etc/Low%20Cost%20BMP%20Final.pdf

Title:	*Evaluation of the Performance of Four Catch Basin Inserts in Delaware Urban Applications*
Publisher/Sponsor:	Delaware DOT
Author(s):	Walch, M., Cole, R. and Polasko, W Walters, D. and Frost, W. DiNicola, P. and Gneo, R.
Publication Date:	2004
Content and Focus:	The evaluation included comparing the performance of four CBIs with respect to their ability to remove sediment and hydrocarbons as well as maintenance requirements. The units were monitored for 3 years to capture seasonal and various rainfall conditions. The study concluded: Catch basin inserts are attractive retrofits because of the relative ease and low cost of installation. Ultimately, however, their cost effectiveness is determined by the frequency with which they must be maintained. Our study and others have demonstrated that for many applications a very high frequency of cleaning is necessary to keep the inserts from clogging and bypassing stormwater flows, as well as resuspending captured material. Inserts may not be practical for large drainage areas or for areas with high levels of leaves or debris that can plug them.
Url:	http://deldot.gov/stormwater/pdfs/StormCon04_Walch.pdf

Title:	*ASTM D5141 Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device (SRD)*
Publisher/Sponsor:	ASTM International
Author(s):	Individual authors not listed
Publication Date:	2018
Content and Focus:	This test method is used to determine the filtering efficiency and flow rate of the filtration component of a sediment retention device, such as a silt fence, a silt barrier, or a silt curtain, for specific soil tested.
Url:	https://compass.astm.org/CUSTOMERS/search/search.html?query=D5141&resStart=0&resLength=10&quicksearch=true&

Title:	*ASTM D7351 Standard Test Method for Determination of Sediment Retention Device (SRD)*
Publisher/Sponsor:	ASTM International
Author(s):	Individual authors not listed
Publication Date:	2013
Content and Focus:	This test method quantifies the ability of a sediment retention device (SRD) to retain eroded sediments caused by sheet flowing water under full-scale conditions. This test method may also assist in identifying physical attributes of SRDs that contribute to their erosion control performance.
Url:	https://compass.astm.org/CUSTOMERS/search/search.html?query=D7351&dltype=all&quicksearch=true

Title:	*NJCAT Technology Verification: Aqua-Swirl Concentrator and Aqua-Filter Stormwater Treatment Systems*
Publisher/Sponsor:	Tennessee Tech University/AIRL
Author(s):	Individual authors not listed
Publication Date:	2005
Content and Focus:	This report covers the NJCAT verification testing of Aqua-Swirl Concentrator.
Url:	http://www.state.nj.us/dep/dsr/bscit/AquaShield%20_Verification-Dec2005.pdf

Title:	*Treatment BMP Technology Report*
Publisher/Sponsor:	Caltrans
Author(s):	Individual authors not listed
Publication Date:	April 2008 and 2010
Content and Focus:	This report consolidates information about technologies in a standardized manner in a fact sheet format. This report also provides a comprehensive list of potential manufactures for possible consideration. Factsheets provide design, construction and cost information
Url:	http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-09-239-06.pdf

Appendix B CBI Field Testing Inspection, Maintenance and Removal Forms

101
Storm Sentinel®

Installation form			Weather Information
Date of Installation	3/30	**Location** ☒ Site 1 ☐ Site 2 101	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☒ Other: cloudy
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		

Local Depression Depth (inches)	Over 1”

CBI Name and Vendor	Installation Time		Number of personnel
	Start	**End**	
Storm Sentinel	10:34 10:39	10:40	2 Throat blocks install on 3/29

Observations

Describe contents of catch basin

CB has a sump in bottom. Standing water in bottom

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin Old concrete curbing in need of repair.  Throat	 Facing Left
Describe gutter condition and contents  Downstream Curb	 Upstream Curb

Depression

Special equipment required for installation no
Any deviation from manufacturer’s installation procedure no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☒ Site 1 ☐ Site 2 101	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	Time		Number of personnel
	Start	End	
Storm Sentinel	**10:09**	**10:13**	2

Observations	Photos
Describe contents and condition of catch basin insert: No standing water.	
Describe condition of throat block The block is working. Slightly bent, does not impact flow	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Debris removed from insert. Less than 1 gallon of material.

Equipment required for maintenance

Any deviation from manufacturer's recommendation

Maintenance Form			Weather Information
Date of Maintenance	6/15/17	**Location** ☒ Site 1 ☐ Site 2 101	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: rained in the morning. Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	Time		Number of personnel
	Start	End	
Storm Sentinel			3

Observations	Photos
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

Any deviation from manufacturer's recommendation
Manufacturer recommends remove and replace. Not backflushing

Removal form			**Weather Information**
Date of Removal	10/19/17	**Location** ☒ Site 1 ☐ Site 2 101	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	**Removal Time**		**Number of personnel**
	Start	**End**	
Gully Washer	**9:58**	**9:59**	2

Observations	**Photos**
Describe contents of catch basin insert Very little debris in CBI The insert contained standing water during September inspection	
Describe contents and condition of catch basin	Clean, no debris in CB

Special Equipment Required for Removal
No special equipment, removed by one person

Reason for removal
Clogged unit not functional




104
DrainPac™

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Installation form			Weather Information
Date of Installation	3/30	**Location** ☒ Site 1 ☐ Site 2 104	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		

Local Depression Depth (inches)	Over 1”

CBI Name and Vendor	Installation Time		Number of personnel
	Start	End	
Drainpac	10:24 10:30	10:31	2 Throat blocks install on 3/29

Observations

Describe contents of catch basin
CB has a sump in bottom. Standing water in bottom

Facing Curb

Side Right

Facing Roadway

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Describe condition of catch basin

Catch basin in good condition

Throat

Facing Left

Describe gutter condition and contents

Gutter around CB in poor condition

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

no

Any deviation from manufacturer's installation procedure

No

Other: this was the only location the Drain Pac could be installed. Attempted to install in (101, 104, 105, 109, 110, 111, 205, 206, 209, and 210)

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>8/23/17</td><td>Location
☒ Site 1 ☐ Site 2
104</td><td>Weather at time of this inspection?
☐ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver</td></tr>
</table>

<table>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>Drain Pac</td><td>10:01</td><td>10:07</td><td>2</td></tr>
</table>

<table>
<tr><th>Observations</th><th>Photos</th></tr>
<tr><td>Describe contents and condition of catch basin insert:
No standing water.
Debris is trapped between the wire mesh and outer fabric bag, the debris can’t be removed with the shop vac</td><td></td></tr>
<tr><td>Describe condition of throat block

The block is working.</td><td></td></tr>
<tr><td colspan="2">Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. 1.5 gallons of debris removed from insert.
Gutter around inlet was recently patched, the debris removed from the CBI is consistent with the patching material</td></tr>
<tr><td colspan="2">Equipment required for maintenance:
Shop vac</td></tr>
<tr><td colspan="2">Any deviation from manufacturer’s recommendation</td></tr>
</table>

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>10/19/17</td><td>Location
☒ Site 1 ☐ Site 2
104</td><td>Weather at time of this inspection?
☐ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

<table>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th>Number of personnel</th></tr>
<tr><th>Start</th><th>End</th><th></th></tr>
<tr><td>Drain Pac</td><td>10:47</td><td>10:54</td><td>2 – maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area</td></tr>
</table>

<table>
<tr><th>Observations</th><th>Photos</th></tr>
<tr><td>Describe contents and condition of catch basin insert:
No standing water.
Debris is trapped between the wire mesh and outer fabric bag, the debris can't be removed with the shop vac</td><td></td></tr>
<tr><td>Describe condition of unit

Debris is trapped between the wire mesh and outer fabric bag, the debris can't be removed with the shop vac</td><td></td></tr>
</table>

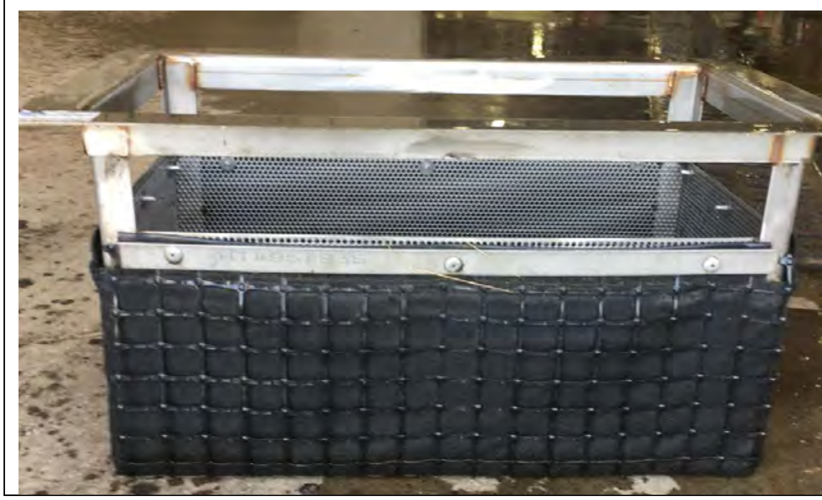
Describe maintenance activity (clean, replace filter,..)
Shop vac and back flushed at garage until positive flow was achieved.

CBI removed from catch basin. Less than 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac and hose from truck wash.

Any deviation from manufacturer's recommendation

Back flushing is not a recommended maintenance activity. Unit was clogged during September inspection. The other manufacturers allow back flushing to extend the life of the unit for consistency within the study all clogged units will be back flushed once.



<table>
<tr><th colspan="3">Removal form</th><th>Weather Information</th></tr>
<tr><td>Date of Removal</td><td>3/9/18</td><td>Location
☒ Site 1 ☐ Site 2
104</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

<table>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Removal Time</th><th rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>DrainPac</td><td>8:54</td><td>8:59</td><td>2</td></tr>
</table>

<table>
<tr><th>Observations</th><th>Photos</th></tr>
<tr><td>Describe contents of catch basin insert</td><td></td></tr>
<tr><td>Describe contents and condition of catch basin</td><td>A little less than one gallon of debris removed.
Outer mesh and fabric had detached from the basket. The fabric mesh was loose but not broken.</td></tr>
<tr><td colspan="2">Special Equipment Required for Removal
No special equipment, removed by one person</td></tr>
</table>

Reason for removal
End of study




105
FlexStorm®

Installation form			Weather Information
Date of Installation	3/30	**Location** ☒ Site 1 ☐ Site 2 105	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		
Local Depression Depth (inches)	Over 2”		

CBI Name and Vendor	Installation Time Start	Installation Time End	Number of personnel
FlexStorm	9:44 10:20	 10:21	302 Throat blocks install on 3/29

Observations

Describe contents of catch basin

CB has a sump in bottom. Standing water in bottom

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin

Good but old

Throat

Facing Left

Describe gutter condition and contents

Gutter is in poor condition with patching

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

Yes, Saw, file, circular saw

Any deviation from manufacturer's installation procedure

Needed to trim frame to install. Trimming frame not expected to impact performance in study.


BACK
FRONT

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☒ Site 1 ☐ Site 2 105	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	Time		Number of personnel
	Start	**End**	
Flex Storm	**9:49**	**9:59**	2

Observations	Photos
Describe contents and condition of catch basin insert: No standing water.	
Describe condition of throat block The block is working.	

Describe maintenance activity (clean, replace filter,..)

CBI not removed from catch basin. Used shop vac and brushes to remove debris. 1 gallon of debris removed from insert. Internal overflows cleaned

Equipment required for maintenance:
Shop vac

Any deviation from manufacturer's recommendation


5 Gal


Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	6/15/17	**Location** ☒ Site 1 ☐ Site 2 105	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: rained in the morning. Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Flexstorm			3

Observations	**Photos**
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

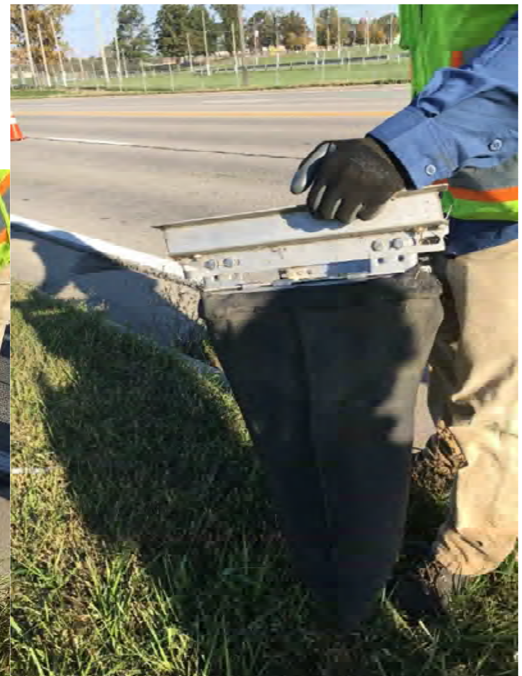
Any deviation from manufacturer's recommendation
Manufacturer recommends back flushing when bag is ½ full of debris.

Removal form			Weather Information
Date of Removal	10/19/17	**Location** ☒ Site 1 ☐ Site 2 105	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Removal Time		Number of personnel
	Start	End	
Gully Washer	**9:47**	**9:48**	2

Observations	Photos
Describe contents of catch basin insert Very little debris in CBI The insert contained standing water during September inspection	
Describe contents and condition of catch basin Clean, no debris in CB CB has a sump	
Special Equipment Required for Removal No special equipment, removed by two people	

Reason for removal
Clogged unit not functional

109
Gullywasher©

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Installation form			Weather Information
Date of Installation	3/30	**Location** ☒ Site 1 ☐ Site 2 109	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☒ Other: light mist
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		
Local Depression Depth (inches)			

CBI Name and Vendor	**Installation Time** Start	End	**Number of personnel**
Gullywasher	9:31 9:36	9:39	2 Throat blocks install on 3/29

Observations

Describe contents of catch basin

CB has a sump with standing water.

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin Good condition  Throat	 Facing Left
Describe gutter condition and contents  Downstream Curb	 Upstream Curb

Depression

Special equipment required for installation

no

Any deviation from manufacturer's installation procedure

no

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	8/23/17	**Location** ☒ Site 1 ☐ Site 2 109	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Gully Washer	**9:41**	**9:46**	2
Observations			**Photos**
Describe contents and condition of catch basin insert: No standing water. Small rips forming in bag at handles			
Describe condition of throat block The block is working.			
Describe maintenance activity (clean, replace filter,..) CBI removed from catch basin. Less than 1 gallon of debris removed from insert. Internal overflows cleaned.			
Equipment required for maintenance: **Removed CBI and poured contents into collection bucket**			
Any deviation from manufacturer's recommendation **no**			

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	6/15/17	**Location** ☒ Site 1 ☐ Site 2 109	**Weather at time of this inspection?** ☐ Clear ☒ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Gullywasher			3

Observations	**Photos**
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

Any deviation from manufacturer's recommendation
Manufacturer recommends back flushing every 3-4 weeks. Unit was installed 3/30/17

Removal form				Weather Information
Date of Removal	10/19/17	**Location** ☒ Site 1 ☐ Site 2 109		**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman			

CBI Name and Vendor	Removal Time		Number of personnel
	Start	End	
Gully Washer	**9:33**	**9:35**	2

Observations	Photos
Describe contents of catch basin insert Very little debris in CBI The insert contained standing water during September inspection	
Describe contents and condition of catch basin Clean, no debris in CB	

Special Equipment Required for Removal

No special equipment, removed by one person

Reason for removal
Clogged unit not functional

110
Flo-Gard Plus®

Installation form			Weather Information
Date of Installation	3/30	**Location** ☒ Site 1 ☐ Site 2 110	**Weather at time of this inspection?** ☐ Clear ☒ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		

Local Depression Depth (inches)	Over 1”

CBI Name and Vendor	Installation Time Start	Installation Time End	Number of personnel
Flo-Gard Plus	9:05 9:12	9:13	2 Throat blocks install on 3/29

Observations

Describe contents of catch basin

CB has a sump, standing water in bottom.

Facing Curb

Side Right

Facing Roadway

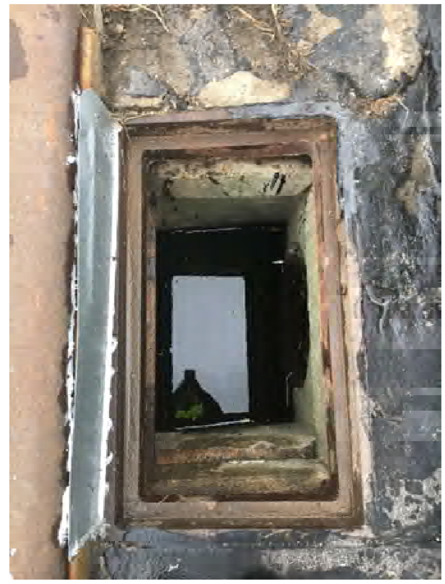
<table>
<tr>
<td>

Describe condition of catch basin

Old but good condition

Throat

</td>
<td>



Facing Left

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

Describe gutter condition and contents

Downstream Curb

</td>
<td>

Upstream Curb

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

Depression

Special equipment required for installation

no

Any deviation from manufacturer’s installation procedure

no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintena nce	8/23/17	**Location** ☒ Site 1 ☐ Site 2 110	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Flo Gard	**9:19**	**9:27**	2
Observations			**Photos**
Describe contents and condition of catch basin insert: No standing water. CBI looked full of debris, 1 gallon removed Media bags broken			
Describe condition of throat block The block is working.			
Describe maintenance activity (clean, replace filter,..) CBI removed from catch basin. Less than 1 gallon of debris removed from insert. Internal overflows cleaned.			
Equipment required for maintenance: **Shop vac**			
Any deviation from manufacturer's recommendation **no**			

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	10/19/17	**Location** ☒ Site 1 ☐ Site 2 110	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Time		Number of personnel
	Start	**End**	
Drain Pac	**10:45**	**10:47**	2 – maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	Photos
Describe contents and condition of catch basin insert: No standing water. Mouse nest in bag Some of netting chewed	

Describe maintenance activity (clean, replace filter,..)
Shop vac and back flushed at garage until positive flow was achieved.

CBI removed from catch basin. Less than 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac and hose from truck wash.

Any deviation from manufacturer's recommendation

Back flushing is not a recommended maintenance activity. Unit was clogged during September inspection. The other manufacturers allow back flushing to extend the life of the unit for consistency within the study all clogged units will be back flushed once.

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Removal form			Weather Information
Date of Removal	3/9/18	**Location** ☒ Site 1 ☐ Site 2 110	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	**Removal Time Start**	**Removal Time End**	**Number of personnel**
FloGard Plus	**8:34**	**8:47**	2

Observations	**Photos**
Describe contents of catch basin insert A little less than one gallon of debris removed. Outer mesh was damaged. Rodent nest was built in the outside mesh	
Describe contents and condition of catch basin Catch basin has a sump, very little debris	

Special Equipment Required for Removal
No special equipment, removed by one person

Reason for removal
End of study

111
WQS

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="4">Installation form</th><th>Weather Information</th></tr>
<tr><td>Date of Installation</td><td>3/30</td><td colspan="2">Location
☒ Site 1 ☐ Site 2
111</td><td>Weather at time of this inspection?
☐ Clear ☒ Rain ☐ Sleet ☐ Snowing
☐ Other:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver
Ariel Croasmun</td></tr>
<tr><td colspan="2">Local Depression Depth (inches)</td><td colspan="3">Over 2”</td></tr>
<tr><th colspan="2" rowspan="2">CBI Name and Vendor</th><th colspan="2">Installation Time</th><th rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td colspan="2">Water Quality Solutions
WQS</td><td>8:51
9:01</td><td>
9:02</td><td>2
Throat blocks install on 3/29</td></tr>
<tr><th colspan="5">Observations</th></tr>
<tr><td colspan="3">Describe contents of catch basin
CB has sump with standing water

Facing Curb</td><td colspan="2">Side Right
</td></tr>
<tr><td colspan="5">
Facing Roadway</td></tr>
</table>

Describe condition of catch basin

Old, but good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

no

Any deviation from manufacturer's installation procedure

Needed to adjust the handles to not impact the grate. The bolts on the handles were adjusted to let them sit lower into the CBI.

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>8/23/17</td><td>Location
☒ Site 1 ☐ Site 2
111</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th>Number of personnel</th></tr>
<tr><th>Start</th><th>End</th><th></th></tr>
<tr><td>WQS</td><td>9:01</td><td>9:16</td><td>2</td></tr>
<tr><th colspan="3">Observations</th><th>Photos</th></tr>
<tr><td colspan="3">Describe contents and condition of catch basin insert:
No standing water.
Each layer of filter material was removed and cleaned</td><td></td></tr>
<tr><td colspan="3">Describe condition of throat block

The block is working.</td><td></td></tr>
<tr><td colspan="4">Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Each layer of filter material removed. Metal screens were rinsed with water. 1 gallon of debris removed from insert.</td></tr>
<tr><td colspan="4">Equipment required for maintenance:

Shop vac</td></tr>
<tr><td colspan="4">Any deviation from manufacturer's recommendation

Manufacturer does not have recommended maintenance</td></tr>
</table>

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	10/19/17	**Location** ☒ Site 1 ☐ Site 2 111	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Drain Pac	**9:04**	**9:17**	2

Observations	**Photos**
Describe contents and condition of catch basin insert: No standing water.	

Describe maintenance activity (clean, replace filter,..)
Removed all layers of filter media and used shop vac to clean.

CBI removed from catch basin. Less than 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac

Any deviation from manufacturer's recommendation

Manufacture does not required in field cleaning. The product is to be removed and replaced with a fresh unit. The unit is then cleaned for later reuse.




Removal form			Weather Information
Date of Removal	3/9/18	**Location** ☒ Site 1 ☐ Site 2 111	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	**Removal Time**		**Number of personnel**
	Start	**End**	
WQS	**8:14**	**8:32**	2

Observations	Photos
Describe contents of catch basin insert A little less than one gallon of debris removed. Outer mesh was damaged. Rodent nest was built in the outside mesh	
Describe contents and condition of catch basin Catch basin has sump, very little debris	
Special Equipment Required for Removal No special equipment, removed by one person	

Reason for removal
Unit observed with standing water during February inspection and end of study

Bottom filter clogged

113
Triton™

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Installation form			Weather Information
Date of Installation	5/11	**Location** ☒ Site 1 ☐ Site 2 113	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☒ Other: misty
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		

Local Depression Depth (inches)	n/a, CBI does not impact grate		
CBI Name and Vendor	**Installation Time** Start	End	**Number of personnel**
Triton	9:22	10:45	2 CBI installed inside catch basin

Observations

Describe contents of catch basin

Standing water in sump

Facing Curb

Side Right

Facing Roadway

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

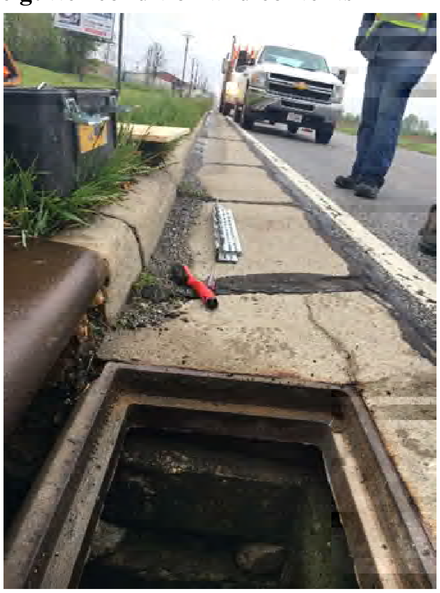
Describe condition of catch basin

Poor condition, concrete around throat is missing. Not expected to impact the flow or performance of unit

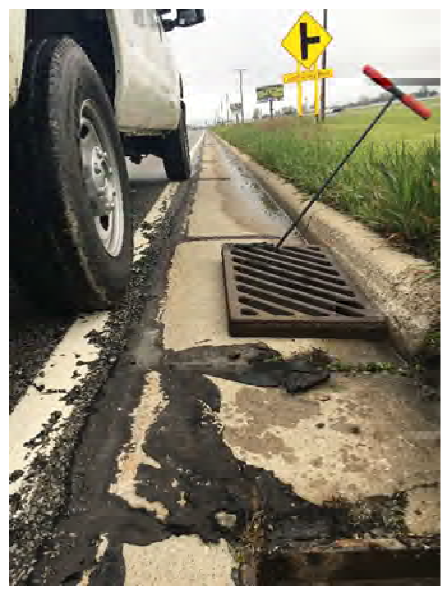
Throat

Facing Left

Describe gutter condition and contents



Downstream Curb



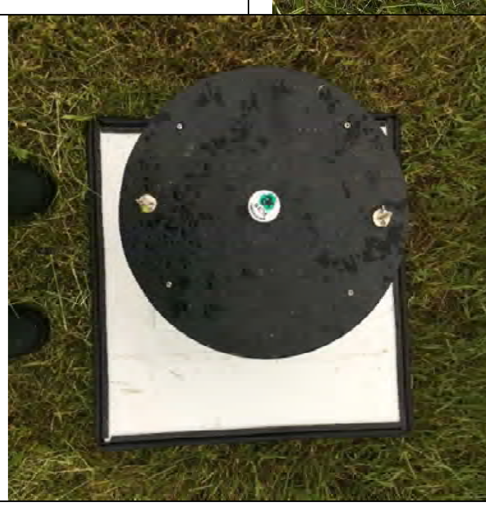
Upstream Curb

Depression

Special equipment required for installation

Circular saw, hammer, drill, screw driver

Any deviation from manufacturer's installation procedure



Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☒ Site 1 ☐ Site 2 113	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Triton	**8:30**	**8:45**	2

Observations	**Photos**
Describe contents and condition of catch basin insert: No standing water. Each layer of filter material was removed and cleaned	
Describe condition of throat block No throat block Picture taken from throat opening	

Describe maintenance activity (clean, replace filter,..)

Shop vac used to remove debris. Debris removed from overflows 1 gallon of debris removed

Equipment required for maintenance:

Shop vac and small shovel

Any deviation from manufacturer's recommendation

no


5 Gal
4 Gal
3 Gal

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>10/19/17</td><td>Location
☒ Site 1 ☐ Site 2
113</td><td>Weather at time of this inspection?
☐ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

CBI Name and Vendor	Time Start	End	Number of personnel
Drain Pac	**8:48**	**9:01**	2

Observations	Photos
Describe contents and condition of catch basin insert: 1" of debris on tray Some standing water	
	

Describe maintenance activity (clean, replace filter,..)
used shop vac to clean contents and removed debris from overflow.

2 gallons of debris and water removed. Without the water, 1 gallon of debris

Equipment required for maintenance: Shop vac
Any deviation from manufacturer's recommendation

Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="4">Removal form</th><th>Weather Information</th></tr>
<tr><td>Date of Removal</td><td>12/14/17</td><td colspan="2">Location
☒ Site 1 ☐ Site 2
113</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:
Temperature: 15</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver and Ariel Croasman</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Removal Time</th><th colspan="2" rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>Triton</td><td>9:05</td><td>9:53</td><td colspan="2">2</td></tr>
<tr><th colspan="2">Observations</th><th colspan="3">Photos</th></tr>
<tr><td colspan="2">Describe contents of catch basin insert
Very little debris in CBI,
Standing water</td><td colspan="3"></td></tr>
<tr><td colspan="2">Describe contents and condition of catch basin
Snow, grit and water.</td><td colspan="3"></td></tr>
<tr><td colspan="5">Special Equipment Required for Removal
Very time consuming to remove. Required 2 people.
Wrench, screw driver, saw.</td></tr>
</table>

Reason for removal
Standing water on tray. Unit clogged not functional




114
Adsorb-It™

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Installation form			Weather Information
Date of Installation	6/15	**Location** ☒ Site 1 ☐ Site 2 114	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☒ Other: misty
Inspector Name(s)	Kathryn Gruver Mark McCabe		
Local Depression Depth (inches)			

CBI Name and Vendor	**Installation Time** Start	End	**Number of personnel**
Adsorb-it	1:18 1:40	 1:43	2

Observations

Describe contents of catch basin

Standing water in sump

Facing Curb

Side Right

Facing Roadway

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Describe condition of catch basin
Poor condition, concrete around throat is missing. Not expected to impact the flow or performance of unit

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

Circular saw, hammer, drill, screw driver

Any deviation from manufacturer's installation procedure
No

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>8/23/17</td><td>Location
☒ Site 1 ☐ Site 2
114</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th>Number of personnel</th></tr>
<tr><th>Start</th><th>End</th><th></th></tr>
<tr><td>Adsorb-it</td><td>8:48</td><td>8:56</td><td>2</td></tr>
<tr><th colspan="3">Observations</th><th>Photos</th></tr>
<tr><td colspan="3">Describe contents and condition of catch basin insert:
No standing water, however the bag material was slightly damp.</td><td></td></tr>
<tr><td colspan="3">Describe condition of throat block

The block is working.</td><td></td></tr>
<tr><td colspan="4">Describe maintenance activity (clean, replace filter,..)

Shop vac to remove collected debris.</td></tr>
<tr><td colspan="4">Equipment required for maintenance:

Shop vac</td></tr>
<tr><td colspan="4">Any deviation from manufacturer's recommendation

Manufacturer does not have recommended maintenance</td></tr>
</table>

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	10/19/17	**Location** ☒ Site 1 ☐ Site 2 114	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Time		Number of personnel
	Start	**End**	
Drain Pac	**10:33**	**10:45**	2 – maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	Photos
Describe contents and condition of catch basin insert: No standing water at the time of the inspection/maintenance Minor debris	
	

Describe maintenance activity (clean, replace filter,..)
Shop vac and back flushed at garage until positive flow was achieved.

Less than 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac and hose from truck wash.

Any deviation from manufacturer's recommendation
Back flushing is not a recommended maintenance activity. Unit was clogged during September inspection. The other manufacturers allow back flushing to extend the life of the unit for consistency within the study all clogged units will be back flushed once.

<table>
<tr><th colspan="4">Removal form</th><th>Weather Information</th></tr>
<tr><td>Date of Removal</td><td>12/14/17</td><td colspan="2">Location
☒ Site 1 ☐ Site 2
114</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:
Temperature: 15</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver and Ariel Croasman</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Removal Time</th><th colspan="2" rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>Absorb-it</td><td>8:59</td><td>9:03</td><td colspan="2">2</td></tr>
<tr><th colspan="3">Observations</th><th colspan="2">Photos</th></tr>
<tr><td colspan="3">Describe contents of catch basin insert
Very little debris in CBI

Snow, grit and water.</td><td colspan="2"></td></tr>
<tr><td colspan="3">Describe contents and condition of catch basin

Grit and debris in catch basin.</td><td colspan="2"></td></tr>
</table>

Special Equipment Required for Removal
No special equipment, removed by one person

Reason for removal
Clogged unit not functional




205
Adsorb-It™

Installation form			Weather Information
Date of Installation	6/15	**Location** ☒ Site 1 ☐ Site 2 205	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Mark McCabe		
Local Depression Depth (inches)			

CBI Name and Vendor	Installation Time Start	Installation Time End	Number of personnel
Adsorb-it	10:24 10:43	 10:44	2

Observations

Describe contents of catch basin

Facing Curb

Side Right

Facing Roadway

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Describe condition of catch basin
Poor condition, concrete around throat is missing. Not expected to impact the flow or performance of unit

Throat

Facing Left

Describe gutter condition and contents

Upstream Curb

Depression

Special equipment required for installation

Circular saw, hammer, drill, screw driver

Any deviation from manufacturer's installation procedure
Yes, basket shape of basket was modified to within the catch basin

Basket was modified to fit within the catchbasin

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	8/23/17	**Location** ☐ Site 1 ☒ Site 2 205	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Adsorb-it	**12:00**	**12:10**	2

Observations	**Photos**
Describe contents and condition of catch basin insert: No standing water. Overflow clogged with debris. CBI fabric is discolored	
Describe condition of throat block The block is working.	

Describe maintenance activity (clean, replace filter,..)

Shop vac to remove collected debris. Removed 3.5 gallons of debris. Clean debris from overflows.

Equipment required for maintenance:

Shop vac and brush

Any deviation from manufacturer's recommendation

no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>10/19/17</td><td>Location
☐ Site 1 ☒ Site 2
205</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other: Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

CBI Name and Vendor	Time Start	Time End	Number of personnel
Drain Pac	**12:43**	**12:47**	2 – maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	Photos
Describe contents and condition of catch basin insert: No standing water at the time of the inspection/maintenance Minor debris	
	

Describe maintenance activity (clean, replace filter,..)
Shop vac and back flushed at garage until positive flow was achieved.

1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac and hose from truck wash.

Any deviation from manufacturer's recommendation

Back flushing is not a recommended maintenance activity. Unit was clogged during September inspection. The other manufacturers allow back flushing to extend the life of the unit for consistency within the study all clogged units will be back flushed once.

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

Removal form			Weather Information
Date of Removal	12/14/17	**Location** ☐ Site 1 ☒ Site 2 205	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature: 15
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Removal Time		Number of personnel
	Start	End	
Absorb-it	11:04	11:11	2

Observations	Photos
Describe contents of catch basin insert Very little debris in CBI	
Describe contents and condition of catch basin Snow, grit and water.	

Special Equipment Required for Removal
No special equipment, removed by one person

Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

Reason for removal
Clogged unit not functional




207
Triton™

Installation form			Weather Information
Date of Installation	5/11	**Location** ☐ Site 1 ☒ Site 2 207	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☒ Other: cloudy
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		

Local Depression Depth (inches)	n/a, CBI does not impact grate

CBI Name and Vendor	Installation Time		Number of personnel
	Start	End	
Triton	11:22	1:07	2 CBI installed inside catch basin

Observations

Describe contents of catch basin

CB clean no debris

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin

Very good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

Circular saw, hammer, drill, screw driver

Any deviation from manufacturer's installation procedure

Top hat location had to be moved closer to the front of the base to allow the unit to be installed within the catch basin. New holes were drilled and the vacated screw holes were filled with spray foam.

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☐ Site 1 ☒ Site 2 207	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Triton	**11:43**	**11:57**	2

Observations	**Photos**
Describe contents and condition of catch basin insert: No standing water. Overflow clogged with debris. CBI media is discolored	
Describe condition of throat block No throat block	

Describe maintenance activity (clean, replace filter,..)

Shop vac to remove collected debris. Removed almost 3 gallons of debris.

Equipment required for maintenance:

Shop vac and brush

Any deviation from manufacturer's recommendation

no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>10/19/17</td><td>Location
☐ Site 1 ☒ Site 2
207</td><td>Weather at time of this inspection?
☐ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

CBI Name and Vendor	Time Start	Time End	Number of personnel
Drain Pac	**12:14**	**12:21**	2

Observations	Photos
Describe contents and condition of catch basin insert: A few inches of debris on tray	
	

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Describe maintenance activity (clean, replace filter,..)
used shop vac to clean contents and removed debris from overflow.

2 gallons of debris removed.

Equipment required for maintenance:
Shop vac

Any deviation from manufacturer's recommendation
none


Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

Removal form			Weather Information
Date of Removal	3/9/18	**Location** ☐ Site 1 ☒ Site 2 207	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Removal Time		Number of personnel
	Start	End	
Triton	**9:49**	**10:51**	2

Observations	Photos
Describe contents of catch basin insert 15 gallons of debris removed.	
Describe contents and condition of catch basin	

Special Equipment Required for Removal
Very time consuming to remove. Required 2 people.
Wrench, screw driver, saw.

Reason for removal
Unit observed with standing water during February inspection and end of study

Outer filter

Inter filter

15 gallons of debris removed, collected in several buckets

208
Flo-Gard Plus®

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Installation form			**Weather Information**
Date of Installation	3/29	**Location** ☐ Site 1 ☒ Site 2 208	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		
Local Depression Depth (inches)	1”		

CBI Name and Vendor	**Installation Time**		**Number of personnel**
	Start	**End**	
Flo-Gard Plus	2:05 2:22	2:24	2

Observations

Describe contents of catch basin

Debris from removing the grate in basin

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin

Good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

No special equipment needed
Time to install includes construction of the throat blockage.

Any deviation from manufacturer's installation procedure

no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☐ Site 1 ☒ Site 2 208	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Flo-Gard	**11:30**	**11:41**	2

Observations	Photos
Describe contents and condition of catch basin insert: CBI very full of debris. No standing water.	
Describe condition of throat block The block is working.	

Describe maintenance activity (clean, replace filter,..)

Removed CBI from catch basin. Used small shovel and shop vac to remove collected debris. Removed 8 gallons of debris.

Equipment required for maintenance:

Small shovel, shop vac and brush

Any deviation from manufacturer's recommendation

no

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00


HOMER'S
BUCKET


THIS

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	10/19/17	**Location** ☐ Site 1 ☒ Site 2 208	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Time		Number of personnel
	Start	**End**	
Drain Pac	**12:47**	**12:50**	2 – maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	Photos
Describe contents and condition of catch basin insert: No standing water.	

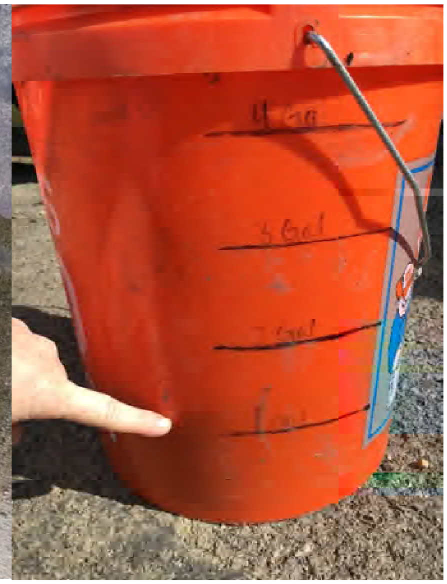
Describe maintenance activity (clean, replace filter,..)
Shop vac and back flushed at garage until positive flow was achieved.

CBI removed from catch basin. 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac and hose from truck wash.

Any deviation from manufacturer's recommendation

Back flushing is not a recommended maintenance activity. Unit was clogged during September inspection. The other manufacturers allow back flushing to extend the life of the unit for consistency within the study all clogged units will be back flushed once.



Removal form			Weather Information
Date of Removal	3/9/18	**Location** ☐ Site 1 ☒ Site 2 208	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Removal Time Start	Removal Time End	Number of personnel
FlowGard Plus	**9:36**	**9:48**	2

Observations	Photos
Describe contents of catch basin insert 1 gallon of debris removed. Standing water during last inspection	
Describe contents and condition of catch basin	
Special Equipment Required for Removal None	

Reason for removal: Standing water during last inspection

Media bag

209
WQS

Installation form			Weather Information
Date of Installation	3/29	**Location** ☐ Site 1 ☒ Site 2 209	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		
Local Depression Depth (inches)	½"		

CBI Name and Vendor	Installation Time Start	Installation Time End	Number of personnel
Water Quality Solutions WQS	11:48 12:07	12:08	2

Observations

Describe contents of catch basin

Basin clean

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin

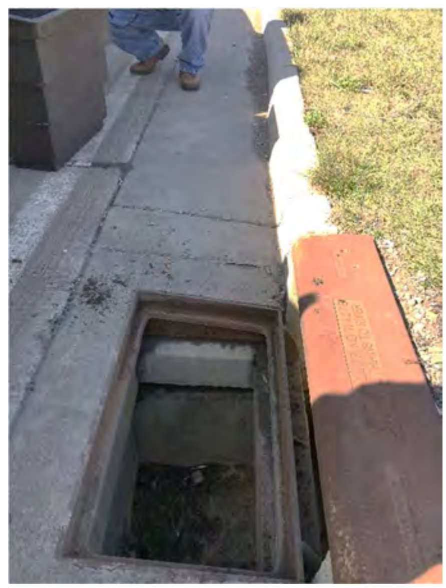
Good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb



Upstream Curb

Depression

Special equipment required for installation

No

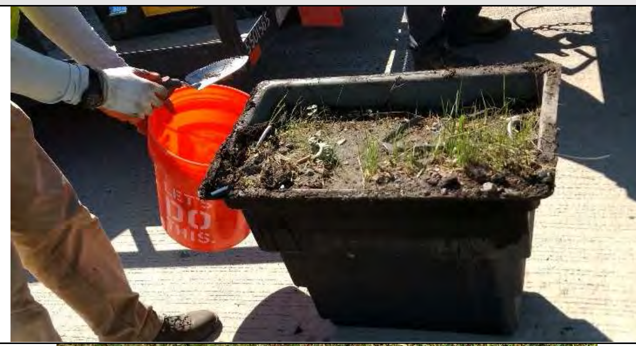
Time to install includes construction of the throat blockage.

Any deviation from manufacturer's installation procedure

Handles are higher than the basket, without modification the grate would sit on the handles. The handles were removed, bent slightly and reattached. The above modification is not expected to impact the performance of the unit.

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>8/23/17</td><td>Location
☐ Site 1 ☒ Site 2
209</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th>Number of personnel</th></tr>
<tr><th>Start</th><th>End</th><th></th></tr>
<tr><td>WQS</td><td>11:14</td><td>11:24</td><td>2</td></tr>
<tr><th colspan="3">Observations</th><th>Photos</th></tr>
<tr><td colspan="3">Describe contents and condition of catch basin insert:
Top layer of CBI covered with 3” of debris.
No standing water.</td><td></td></tr>
<tr><td colspan="3">Describe condition of throat block

The block is working.</td><td></td></tr>
<tr><td colspan="4">Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Each layer of filter material removed. Metal screens were rinsed with water. 3 gallon of debris removed from insert.</td></tr>
<tr><td colspan="4">Equipment required for maintenance:

Small shovel, shop vac and brush</td></tr>
<tr><td colspan="4">Any deviation from manufacturer’s recommendation

Manufacturer does not have recommended maintenance</td></tr>
</table>

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="3">Maintenance Form</th><th>Weather Information</th></tr>
<tr><td>Date of Maintenance</td><td>12/14/17</td><td>Location
☐ Site 1 ☒ Site 2
209</td><td>Weather at time of this inspection?
☐ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other: Sunny during maintenance
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="3">Kathryn Gruver and Ariel Croasman</td></tr>
</table>

<table>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Time</th><th rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>WQS</td><td>10:43</td><td>10:53</td><td>2</td></tr>
</table>

<table>
<tr><th>Observations</th><th>Photos</th></tr>
<tr><td>Describe contents and condition of catch basin insert:
Snow covered.
Debris on top filter layer

All filter layers removed and debris cleaned</td><td>
</td></tr>
</table>

Describe maintenance activity (clean, replace filter,..)
Removed all layers of filter media and used shop vac to clean.

CBI removed from catch basin. 4 gallon of wet debris removed from insert.

Equipment required for maintenance:
Shop vac

Any deviation from manufacturer's recommendation
Manufacture does not required in field cleaning. The product is to be removed and replaced with a fresh unit. The unit is then cleaned for later reuse.

Maintenance Form			Weather Information
Date of Maintenance	10/19/17	**Location** ☐ Site 1 ☒ Site 2 209	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
WQS	**11:56**	**12:08**	2

Observations	**Photos**
Describe contents and condition of catch basin insert: No standing water.	

Describe maintenance activity (clean, replace filter,..)
Removed all layers of filter media and used shop vac to clean.

CBI removed from catch basin. Less than 1 gallon of debris removed from insert.

Equipment required for maintenance:
Shop vac

Any deviation from manufacturer's recommendation

Manufacture does not required in field cleaning. The product is to be removed and replaced with a fresh unit. The unit is then cleaned for later reuse.

Removal form			Weather Information
Date of Removal	3/9/18	**Location** ☐ Site 1 ☒ Site 2 209	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver and Ariel Croasman		

CBI Name and Vendor	Removal Time		Number of personnel
	Start	End	
WQS	**9:25**	**9:33**	2

Observations	Photos
Describe contents of catch basin insert Standing water during last inspection Unit frozen, could not remove media layers to measure volume of debris collected	
Describe contents and condition of catch basin	

Special Equipment Required for Removal
None

Reason for removal: Standing water during last inspection

210
FlexStorm®

Installation form			Weather Information
Date of Installation	3/29	**Location** ☐ Site 1 ☒ Site 2 210	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:
Inspector Name(s)	Kathryn Gruver Ariel Croasmun		
Local Depression Depth (inches)	Over 1"		

CBI Name and Vendor	Installation Time Start	Installation Time End	Number of personnel
FlexStorm	11:00 12:10 12:39	11:48 12:40	2 Installation started at 11:00 and paused at 11:45 to get a tool, the unit at 209 installed. Then restarted install here at 12:10

Observations

Describe contents of catch basin

small amount of debris from removing grate

Facing Curb

Side Right

Facing Roadway

Describe condition of catch basin

good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			Weather Information
Date of Maintenance	8/23/17	**Location** ☐ Site 1 ☒ Site 2 210	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other:Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		
CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Flex Storm	**11:03**	**11:11**	2

Observations	Photos
Describe contents and condition of catch basin insert: No standing water.	
Describe condition of throat block The block is working.	

Describe maintenance activity (clean, replace filter,..)

Debris (less than 1 gallon) removed from CBI with shop vac. Overflows cleaned.

Equipment required for maintenance:

shop vac and brush

Any deviation from manufacturer's recommendation

Manufacturer does not have recommended maintenance

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	6/15/17	**Location** ☐ Site 1 ☒ Site 2 210	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: rained in the morning. Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Flexstorm	**11:40**	**12:03**	2-maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	**Photos**
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

Any deviation from manufacturer's recommendation
Manufacturer recommends back flushing when bag is ½ full of debris.

<table>
<tr><th colspan="4">Removal form</th><th>Weather Information</th></tr>
<tr><td>Date of Removal</td><td>10/19/17</td><td colspan="2">Location
☐ Site 1 ☒ Site 2
210</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver</td></tr>
<tr><td rowspan="2">CBI Name and Vendor</td><td colspan="2">Removal Time</td><td colspan="2" rowspan="2">Number of personnel</td></tr>
<tr><td>Start</td><td>End</td></tr>
<tr><td>Gully Washer</td><td>11:52</td><td>11:53</td><td colspan="2">2</td></tr>
<tr><td colspan="3">Observations</td><td colspan="2">Photos</td></tr>
<tr><td colspan="3">Describe contents of catch basin insert
Very little debris in CBI</td><td colspan="2"></td></tr>
<tr><td colspan="3">Describe contents and condition of catch basin
Clean, no debris in CB</td><td colspan="2"></td></tr>
<tr><td colspan="5">Special Equipment Required for Removal
No special equipment, removed by one person</td></tr>
</table>

Reason for removal
Clogged unit not functional




211
Gullywasher©

<table>
<tr><th colspan="4">Installation form</th><th>Weather Information</th></tr>
<tr><td>Date of Installation</td><td>3/29</td><td colspan="2">Location
☐ Site 1 ☒ Site 2
211</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver
Ariel Croasmun</td></tr>
<tr><td colspan="2">Local Depression Depth (inches)</td><td colspan="3">¼”</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Installation Time</th><th colspan="2" rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>Gullywasher</td><td>10:30
10:52</td><td>
10:52</td><td colspan="2">2 (one person could install it)</td></tr>
<tr><th colspan="5">Observations</th></tr>
<tr><td colspan="3">Describe contents of catch basin
Debris from removing grate

Facing Curb</td><td colspan="2">
Side Right</td></tr>
<tr><td colspan="5">
Facing Roadway</td></tr>
</table>

Catch Basin Inserts for Ohio Roadways
Installation Form
PID 103684
GS&P # 42299.00

Describe condition of catch basin

Good condition

Throat

Facing Left

Describe gutter condition and contents

Downstream Curb

Upstream Curb

Depression

Special equipment required for installation

No

Any deviation from manufacturer's installation procedure

No

Catch Basin Inserts for Ohio Roadways
Maintenance Form
PID 103684
GS&P # 42299.00

Maintenance Form			**Weather Information**
Date of Maintenance	6/15/17	**Location** ☒ Site 1 ☐ Site 2 211	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: rained in the morning. Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Gullywasher	**11:36**	**11:37**	2-maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	**Photos**
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

Any deviation from manufacturer's recommendation
Manufacturer recommends back flushing every 3-4 weeks. Unit was installed 3/30/17

Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

Removal form			Weather Information
Date of Removal	8/23/17	**Location** ☐ Site 1 ☒ Site 2 211	**Weather at time of this inspection?** ☒ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Removal Time**		**Number of personnel**
	Start	**End**	
Gully Washer	**10:58**	**11:01**	2

Observations	**Photos**
Describe contents of catch basin insert Standing water in CBI Very little debris in CBI	
The insert is clogged. Overflows clogged with debris	

Describe contents and condition of catch basin
Clean, no debris in CB

Special Equipment Required for Removal

No special equipment, removed by one person

Reason for removal
Clogged unit not functional

213
Storm Sentinel®

<table>
<tr><th colspan="4">Installation form</th><th colspan="2">Weather Information</th></tr>
<tr><td>Date of Installation</td><td>3/29</td><td colspan="2">Location
☐ Site 1 ☒ Site 2
213</td><td colspan="2">Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="5">Kathryn Gruver
Ariel Croasmun</td></tr>
<tr><td colspan="2">Local Depression Depth (inches)</td><td colspan="4">Over 1”</td></tr>
<tr><th colspan="2" rowspan="2">CBI Name and Vendor</th><th colspan="2">Installation Time</th><th colspan="2" rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td colspan="2">Storm Sentinel</td><td>10:05
10:27</td><td>
10:28</td><td colspan="2">2</td></tr>
<tr><th colspan="6">Observations</th></tr>
<tr><td colspan="3">Describe contents of catch basin
Debris from removing grate

Facing Curb</td><td colspan="3">
Side Right</td></tr>
<tr><td colspan="6">
Facing Roadway</td></tr>
</table>

Describe condition of catch basin Good  Throat	 Facing Left
Describe gutter condition and contents  Downstream Curb	 Upstream Curb

Depression

Special equipment required for installation

File, grinder, small circular saw.
Time to install includes construction of the throat blockage.

Any deviation from manufacturer's installation procedure

Needed to trim the corners of the CBI frame for the unit to fit within the catch basin grate. Trimming of the frame is not expected to impact the performance of the unit.

Depression

Special equipment required for installation

no

Any deviation from manufacturer's installation procedure

No

Maintenance Form			**Weather Information**
Date of Maintenance	6/15/17	**Location** ☐ Site 1 ☒ Site 2 213	**Weather at time of this inspection?** ☐ Clear ☐ Rain ☐ Sleet ☐ Snowing ☐ Other: rained in the morning. Sunny during maintenance Temperature:
Inspector Name(s)	Kathryn Gruver		

CBI Name and Vendor	**Time**		**Number of personnel**
	Start	**End**	
Storm Sentinel	**11:38**	**11:58**	2-maintenance time was measured only at the garage. It does not include time to remove unit and travel to maintenance area

Observations	**Photos**
Describe contents and condition of catch basin insert: Clogged, standing water. Debris partially blocking opening.	
Describe condition of throat block The block is working. Did not take a photo	

Describe maintenance activity (clean, replace filter,..)

CBI removed from catch basin. Water drained. Unit taken to Allen County Garage for back flushing.

Equipment required for maintenance
Truck wash hose at county garage

Any deviation from manufacturer's recommendation
Manufacturer recommends remove and replace. Not backflushing

Catch Basin Inserts for Ohio Roadways
Removal Form
PID 103684
GS&P # 42299.00

<table>
<tr><th colspan="4">Removal form</th><th>Weather Information</th></tr>
<tr><td>Date of Removal</td><td>8/23/17</td><td colspan="2">Location
☐ Site 1 ☒ Site 2
213</td><td>Weather at time of this inspection?
☒ Clear ☐ Rain ☐ Sleet ☐ Snowing
☐ Other:
Temperature:</td></tr>
<tr><td>Inspector Name(s)</td><td colspan="4">Kathryn Gruver</td></tr>
<tr><th rowspan="2">CBI Name and Vendor</th><th colspan="2">Removal Time</th><th colspan="2" rowspan="2">Number of personnel</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>Storm Sentinel</td><td>10:52</td><td>10:56</td><td colspan="2">2</td></tr>
<tr><th colspan="3">Observations</th><th colspan="2">Photos</th></tr>
<tr><td colspan="3">Describe contents of catch basin insert
Standing water in CBI
Very little debris in CBI</td><td colspan="2"></td></tr>
<tr><td colspan="3">Describe condition of catch basin insert
The insert is clogged.
Overflows clogged with debris</td><td colspan="2"></td></tr>
<tr><td colspan="3">Describe contents and condition of catch basin
Clean, no debris in CB</td><td colspan="2"></td></tr>
<tr><td colspan="5">Special Equipment Required for Removal

No special equipment, removed by one person</td></tr>
</table>

Reason for removal
Clogged unit not functional

Appendix C Laboratory CBI Performance Evaluation Testing

APPENDIX C:
LABORATORY CBI PERFORMANCE EVALUATION TESTING

ADSORB-IT™ - STORMWATER BMP PRODUCTS

The Adsorb-It™ is a basket-type catch basin insert consisting of a heavy-duty PVC coated wire mesh steel basket supported by a rigid stainless steel frame. The basket is also lined with a filtration fabric material. The basket has bypass openings on the two sides of the device and is equipped with heavy-duty wire lifting cables that are supported under the frame for easy removal. The Adsorb-It™ products that were shipped to AU-ESCTF for large-scale laboratory testing were undersized and did not fit appropriately into the ODOT Type 3A catch basin. Therefore, a plywood frame was constructed to fit inside the lip of the catch basin frame. The plywood frame was supported by 2x4's and was sealed to the existing catch basin frame using a silicon caulking to prevent water from passing between the two frames. This modification can be seen in Figure C-1(a).

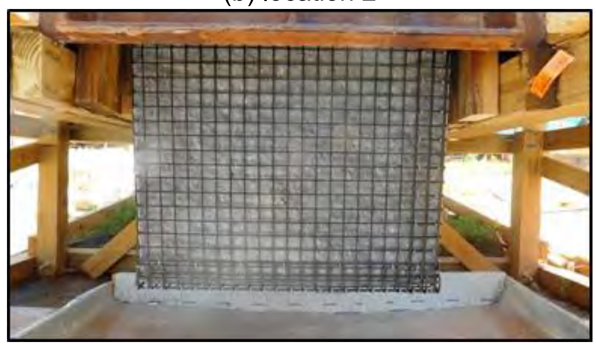
Photos of the Adsorb-It™ installed in the testing catch basin can be seen in Figure C-1.

Figure C-1: Pre-test installation for Adsorb-It™.

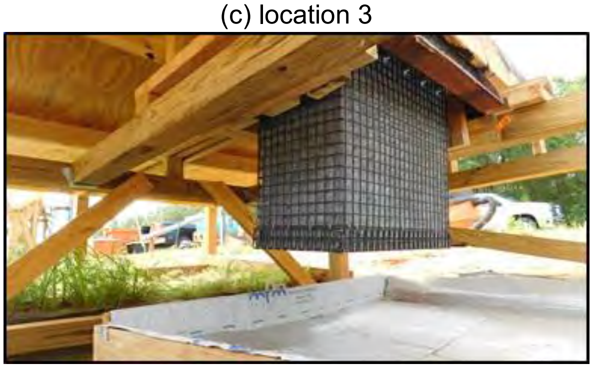
(a) location 1

(b) location 2

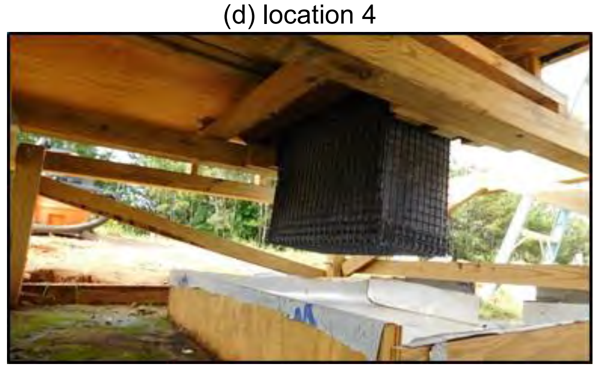
(c) location 3



(d) location 4



(e) location 5



(f) location 6

Figure C-2(a-c) shows images of the Adsorb-It™ during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. It was observed during the tests that a small amount of influent water was flowing into the catch basin and directly exiting through the bypass openings untreated, which could have had an effect on sediment removal efficiency.

Figure C-2: Adsorb-It™ during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Table C-1(a-c) summarizes performance evaluation data for the Adsorb-It™ when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. The 80% sediment removal target was exceeded at two of the three low flow tests, and also at the medium flow test when introducing OK110 silica sand under direct discharge conditions. However, performance did decrease as flow rate increased.

Table C-1: Summary of Performance Data for Adsorb-It™ for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.02 (-0.85%)	13.78 (-2.68%)	21.77 (2.50%)
Sediment Captured, lb	5.42	8.87	10.60
Sediment Retention, %	77.2	64.4	48.7
Time to Overflow, min	-	27	15

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.40 (4.52%)	14.43 (1.91%)	22.49 (5.89%)
Sediment Captured, lb	7.12	11.90	14.46
Sediment Retention, %	96.2	82.5	64.3
Time to Overflow, min	-	32	18

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.87 (-1.4%)	5.97 (2.6%)	8.68 (-0.6%)
Sediment Captured, lb	2.45	3.83	4.38
Sediment Retention, %	85.4	64.2	50.5
Time to Overflow, min	46	18	12

DRAINPAC™ - UNITED STORM WATER INC.

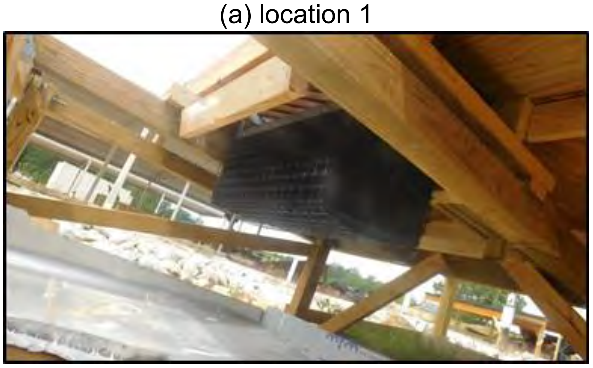
DrainPac™ consists of a metal basket lined with a filter fabric bag. A plastic netting attached to the metal frame also surrounds the fabric bag in order to provide structural support. The metal bag is equipped with large bypass openings on all four sides of the device. The DrainPac™ insert removes pollutants by both filtering the water through the mesh material and allowing particles to settle out while the influent accumulates in the bag prior to discharge. DrainPac™ insert variations include models for drop inlets, curb inlets, and round inlets, and can be made to specific sizes. The filter fabric material of the bag has been specified to have a maximum flow through rate of 0.31 cfs/ft^2, per manufacturer claims.

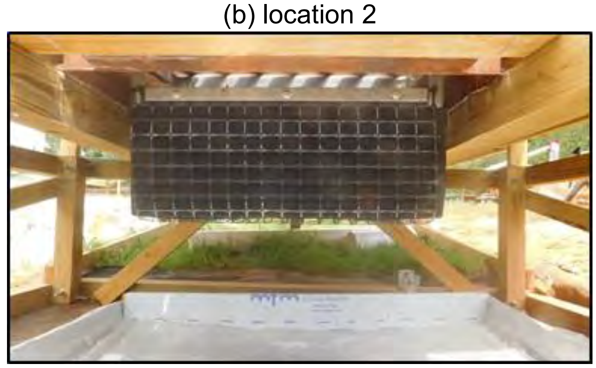
Photos of the DrainPac™ installed in the testing catch basin can be seen in Figure C-3.

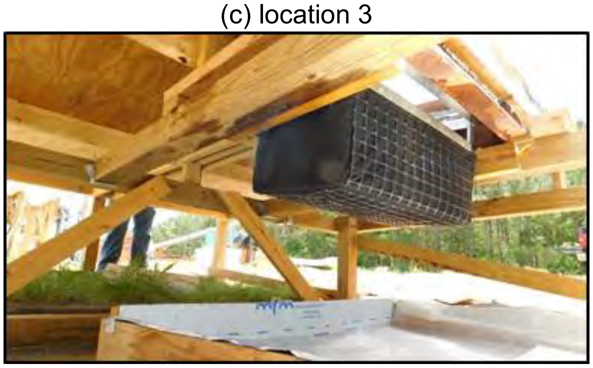
Figure C-3: Pre-test installation for DrainPac™.

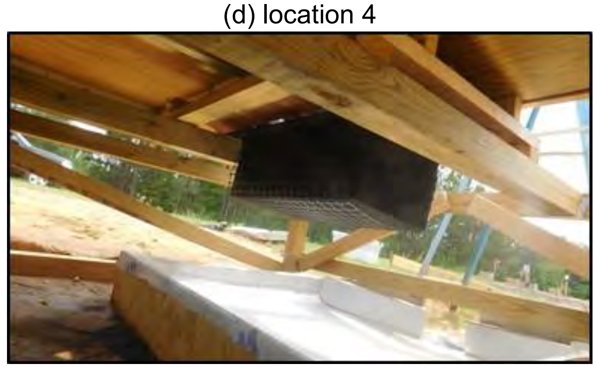

(a) location 1


(b) location 2


(c) location 3


(d) location 4


(e) location 5


(f) location 6

A common issue with the DrainPac™ was that many of the products were slightly damaged when shipped to AU-ESCT. When many of the products were removed from their respective shipping boxes, it was found that corners of the frame had been bent, as opposed to lying flat. These bent corners then create gaps between the CBI frame and the inlet frame which allow water to flow past the CBI untreated. Bent edges were attempted to be straightened before installation in order to mitigate the issue. Figure C-4 provides an example of two of the damaged CBIs. All damages are documented in the test reports included in Appendix C of this report.

Figure C-4: Bent edges of DrainPac™ frame.

(a) 0.06 ft^3/s with OK110 under sheet flow

(b) 0.18 ft^3/s with OK110 under sheet flow

Figure C-5(a-c) shows images of the DrainPac™ during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. It was observed during the tests that a small amount of influent water was flowing into the catch basin and directly exiting through the bypass openings untreated, which could have had an effect on sediment removal efficiency.

Figure C-5: DrainPac™ during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Table C-2(a-c) summarizes performance evaluation data for the DrainPac™ when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. The 80% sediment removal target was reached during the low flow test when introducing OK110 silica sand under direct discharge conditions. However, retention values were lower when introducing sandy loam and when using sheet flow conditions. This could possibly be accredited to the untreated flow bypassing the CBI due to the bent edges of the frame show in Figure C-4.

Table C-2: Summary of Performance Data for DrainPac™ for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.30 (3.11%)	14.67 (3.60%)	21.90 (3.11%)
Sediment Captured, lb	2.62	6.76	10.31
Sediment Retention, %	36.0	46.1	47.1
Time to Overflow, min	-	47	21

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.27 (2.68%)	14.04 (-0.85%)	21.62 (1.79%)
Sediment Captured, lb	5.80	9.10	13.56
Sediment Retention, %	79.8	64.8	62.7
Time to Overflow, min	67	25	20

(c): Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.98 (2.4%)	5.86 (0.7%)	8.48 (-2.86%)
Sediment Captured, lb	2.03	2.74	3.26
Sediment Retention, %	68.1	46.8	38.4
Time to Overflow, min	27	7	6

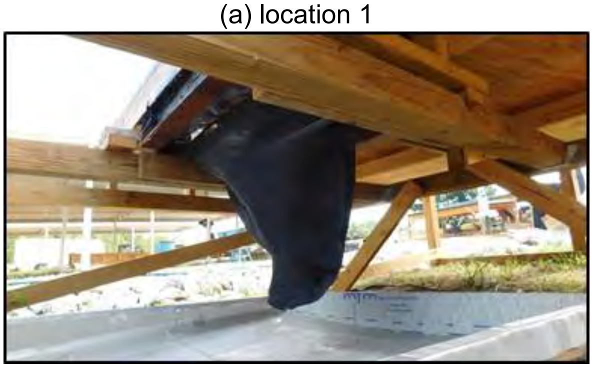
FLEXSTORM® - ADVANCED DRAINAGE SYSTEMS

The FlexStorm® has a stainless steel frame that can be custom configured to fit most drainage structures. The frame is equipped with supported handles for installation and removal. The frame also is constructed with large flow bypass openings on all four sides to allow water to bypass the CBI untreated in the event that the influent flow is too great for the CBI to treat effectively, herein referred to as untreated bypass. A clamping mechanism is used to secure replaceable filtration bags to the frame. Woven geotextile filtration bags are lined with carpet fiber material to treat water exiting the bag. The bag also has a more permeable fabric that sits between the filtration bag and the stainless steel frame that allows water to flow through at a higher rate than the filtration bag while still provided some treatment, herein referred to as treated bypass. The FlexStorm® has a manufacturer specified flow capacity of 0.45 ft^3/s, but it is not specified whether or not this capacity is based off of clean or sediment laden influent. Photos of the FlexStorm® installed in the testing catch basin can be seen in Figure C-6

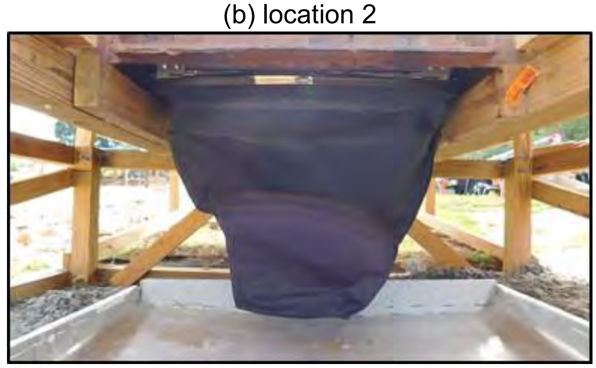
Figure C-6: Pre-test installation for FlexStorm®.

(a) location 1

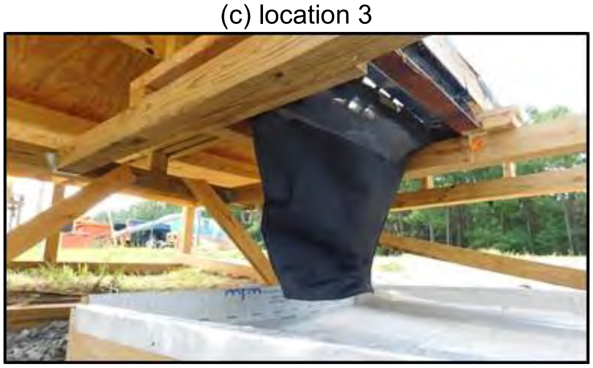
(b) location 2



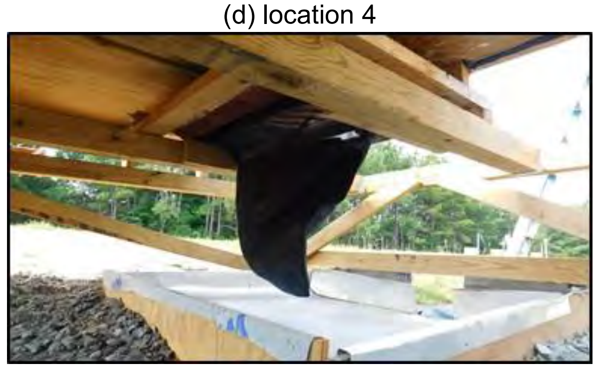
(c) location 3



(d) location 4



(e) location 5



(f) location 6

Figure C-7(a-c) shows images of the FlexStorm® during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. The water level inside the CBI reached the treated overflow level for all tests. However, the untreated overflow was only reached at the 44 minute mark of the high flow test using sandy loam soil under direct discharge conditions.

Figure C-7: FlexStorm® during testing using various test methods and soils

0.06 cfs 0.12 cfs 0.18 cfs

(a) FlexStorm® during sheet flow testing with OK110 silica sand.

0.06 cfs 0.12 cfs 0.18 cfs

(b) FlexStorm® during direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) FlexStorm® during direct discharge testing with sandy loam soil

Table C-3(a-c) summarizes performance evaluation data for the FlexStorm® when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. Sediment retention percentage was best at the low flow rate when directly discharging influent with OK110 silica sand but was still below the 80% target rate. With the exception of the low flow test under sheet flow conditions, sediment retention values decreased as flow rate increased.

Table C-3: Summary of Performance Data for FlexStorm® for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.52 (6.21%)	14.89 (5.16%)	21.51 (1.27%)
Sediment Captured, lb	3.85	8.46	10.01
Sediment Retention, %	51.2	56.8	46.5
Time to Overflow, min	46	24	9

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.29 (2.97%)	14.37 (1.48%)	22.70 (6.87%)
Sediment Captured, lb	5.20	7.21	8.25
Sediment Retention, %	71.3	50.2	36.3
Time to Overflow, min	33	10	7

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.95 (1.4%)	5.33 (-8.4%)	9.33 (6.9%)
Sediment Captured, lb	1.93	3.11	4.10
Sediment Retention, %	65.4	58.3	43.9
Time to Overflow, min	35	20	11

FLO-GARD® PLUS – OLD CASTLE

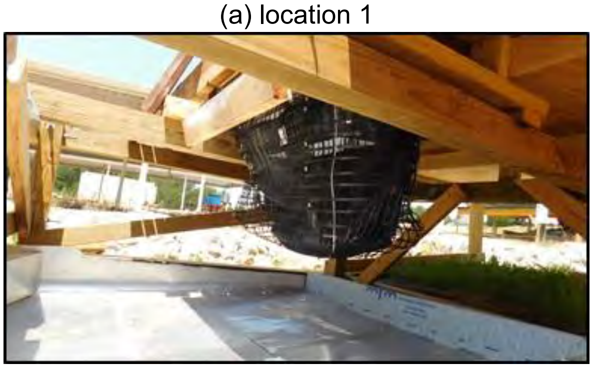
The Flo-Gard® Plus has characteristics of both a bag-type and basket-type catch basin insert. A plastic, large-mesh basket structure supports a woven filter fabric liner that is attached to a stainless steel frame. The frame is equipped with bypass openings on all four sides. The bypass openings also have a roof structure above them, preventing flow and contaminants from bypassing the device when entering the device from above, ensuring the only time flow exits through the bypass is when the CBI has become overloaded.

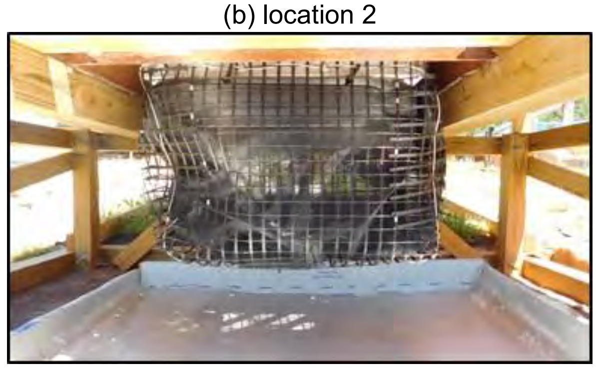
Photos of the Flo-Gard® Plus installed in the testing catch basin can be seen in Figure C-8.

Figure C-8: Pre-test installation for Flo-Gard® Plus.


(a) location 1


(b) location 2


(c) location 3


(d) location 4


(e) location 5

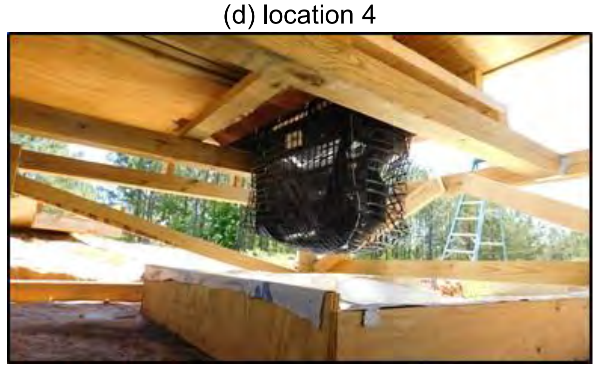

(f) location 6

Figure C-9(a-c) shows images of the Flo-Gard® during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. A reoccurring issue with the Flo-Gard® Plus was that there was never any impoundment of flow within the CBI. It appeared that the mesh opening size of the filter bag had a high flow through rate, inhibiting the CBI's ability to impound flow. The lack of impoundment greatly impaired the sediment removal efficiency of the product.

Figure C-9: Flo-Gard® during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Table C-4(a-c) summarizes performance evaluation data for the Flo-Gard® when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. Sediment retention values showed no potential for meeting the 80% target removal rate, which is most likely due to the high-flow through rate of the fabric.

Table C-4: Summary of Performance Data for Flo-Gard® for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	6.99 (-1.27%)	14.68 (3.67%)	23.36 (9.98%)
Sediment Captured, lb	0.51	0.15	0.16
Sediment Retention, %	7.3	1.0	0.7
Time to Overflow, min	-	-	-

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.40 (4.52%)	12.2 (-13.84%)	20.08 (-5.46%)
Sediment Captured, lb	0.77	0.10	0.44
Sediment Retention, %	10.4	0.8	2.2
Time to Overflow, min	-	-	-

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.91 (0.00%)	5.67 (-2.58%)	8.94 (2.41%)
Sediment Captured, lb	0.72	1.12	1.97
Sediment Retention, %	24.7	19.8	22.0
Time to Overflow, min	-	-	-

GULLYWASHER©

The Gullywasher© Commercial Duty Frame Mounted Insert consists of a nonwoven geotextile filter fabric mounted on a rectangular metal frame. The bag has sewn-in tabs that hold the frame into proper position, ensuring that the bag does not move around and become unsupported under heavy loading. The bag is also supported by nylon straps that wrap under the bottom of the bag and support loads when the bag is full. Nylon straps are also placed on the inside of the bag as removal handles. Finally, the bag is equipped with overflow openings on both the upstream and downstream side of the CBI.

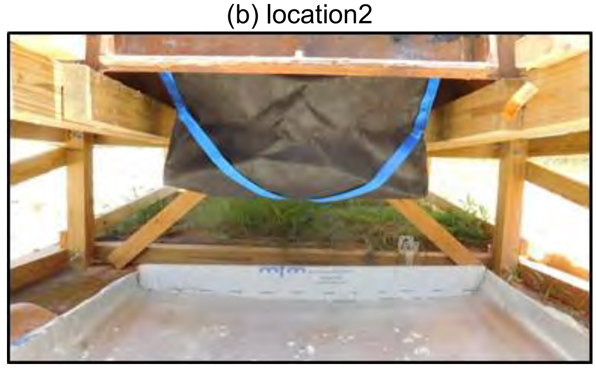
Photos of the Gullywasher© installed in the testing catch basin can be seen in Figure C-10.

Figure C-10: Pre-test installation for Gullywasher©.

(a) location 1

(b) location2

(c) location 3



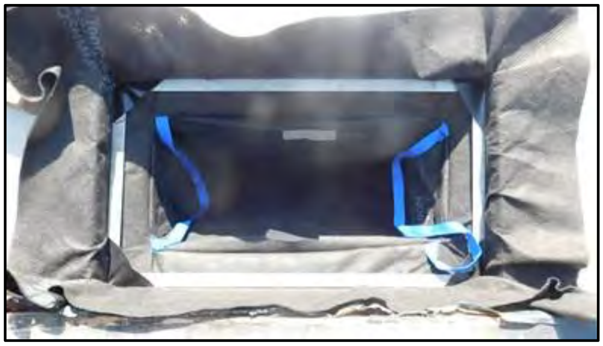
(d) location 4

(e) location 5

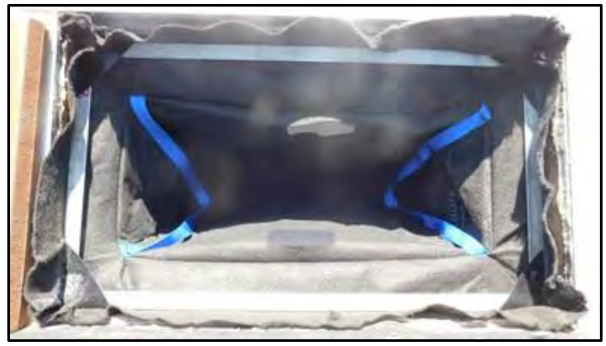
(f) location 6

Gullywasher© CBIs were shipped to AU-ESCTF with extra fabric around the frame, and installation instructions directed the installer to cut the fabric to fit as needed. The Gullywasher© before and after modifications can be seen in Figure C-11.

Figure C-11: Gullywasher© modifications.



(a) Gullywasher© before modifications



(b) Gullywasher© after modifications

It was observed during the low flow rate direct discharge test with OK110 silica sand that some influent water was flowing into the catch basin and directly exiting through the downstream bypass opening untreated, which could impact sediment removal performance. This was not an observed during other tests. Figure C-12(a-c) shows images of the Gullywasher© during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only.

Figure C-12: Gullywasher© during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Leaks were observed during the two high flow tests with OK110 silica sand that could have impacted sediment removal efficiency. The leaks can be seen in Figure C-13.

Figure C-13: Leaks in Gullywasher© at high flow rate tests

(a) sheet flow with OK110 silica sand

(b) direct discharge with OK110 silica sand

Table C-5(a-c) summarizes performance evaluation data for the Gullywasher© when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. During the testing with OK110 silica sand under sheet flow conditions, there was more sediment captured during the medium flow test than the high flow test, despite the fact that more sand was introduced during the high flow test. One possible explanation for this is that the leak shown in Figure C-13(a) impacted performance. Sediment retention decreased as flow rate increased for all test methods. The Gullywasher© was one of the few products that actually performed slightly better under sheet flow conditions than under direct discharge conditions. One possible explanation for this would be that overflow was reached quicker during direct discharge tests than with sheet flow tests, meaning that a larger volume of water was able to be treated under sheet flow than direct discharge before passing the CBI.

Table C-5: Summary of Performance Data for Gullywasher© for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.47 (5.51%)	14.45 (2.05%)	18.63 (-12.29%)
Sediment Captured, lb	5.66	8.49	7.64
Sediment Retention, %	75.8	58.8	41.0
Time to Overflow, min	42	11	6

(b) Direct Discharge with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.66 (8.19%)	14.68 (3.67%)	23.34 (9.89%)
Sediment Captured, lb	5.14	7.01	8.34
Sediment Retention, %	67.1	47.8	35.7
Time to Overflow, min	21	7	3

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.92 (0.3%)	6.03 (3.6%)	8.84 (1.26%)
Sediment Captured, lb	1.51	2.30	2.95
Sediment Retention, %	51.7	38.1	33.4
Time to Overflow, min	16	6	5

STORM SENTINEL® - ENPAC GROUP

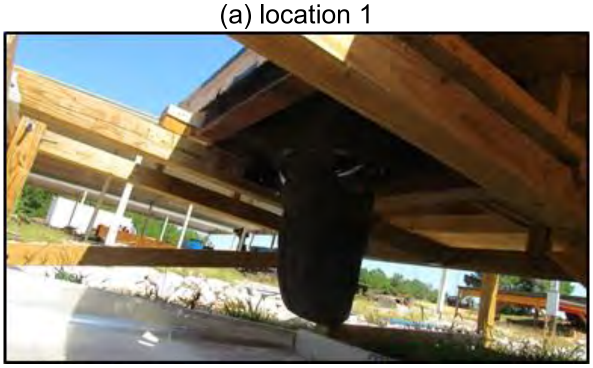
The Storm Sentinel® is a bag-type CBI made out of a nonwoven geotextile fabric that is supported by an adjustable steel wire frame. The bag contains three openings to allow influent to bypass the bag, preventing flow from backing onto the street in the event that the bag becomes overloaded or the fabric is clogged. The Storm Sentinel® is equipped with two nylon handles for easy maintenance and removal. Ranging in dimensions from 16 by 20 in. to 28 by 36 in. and weighing two pounds, the Storm Sentinel® has a load capacity of up to 125 lb, and can handle flow rates up to 1.11 ft^3/s based upon manufacturer claims, which do not specify whether this capacity is based upon clean or sediment-laden flow.

Photos of the Storm Sentinel® installed in the testing catch basin can be seen in Figure C-14.

Figure C-14: Pre-test installation of Storm Sentinel®.

(a) location 1

(b) location 2



(c) location 3

(d) location 4

(e) location 5

(f) location 6

It was observed during the high flow rate tests that the influent flow caused the filter bag to move around the adjustable frame, creating small gaps to open at the entrance to the CBI. The gaps, though small, could allow influent water to bypass the CBI completely and enter the catch basin untreated. The position of the bypass openings also allowed for some flow to directly exit through the openings untreated. These issues can be seen in Figure C-15.

Figure C-15: Openings in Storm Sentinel® allow untreated bypass.

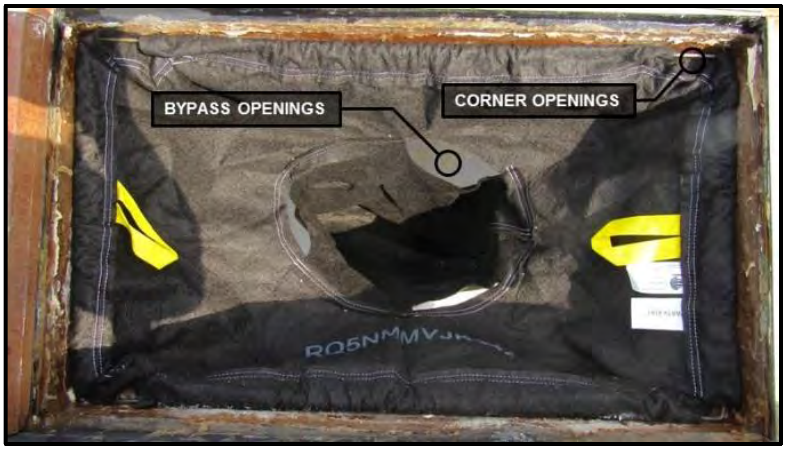


Figure C-16(a-c) shows images of the Storm Sentinel® during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only.

Figure C-16: Storm Sentinel® during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Table C-6(a-c) summarizes performance evaluation data for the Storm Sentinel® when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. Sediment retention was best when introducing OK110 silica sand under direct discharge, low flow conditions, and sediment retention values decreased as flow rate increased.

Table C-6: Summary of Performance Data for Storm Sentinel® for Various Tests and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.40 (4.52%)	13.94 (-1.55%)	21.88 (3.01%)
Sediment Captured, lb	4.38	5.72	4.75
Sediment Retention, %	59.2	41.0	21.7
Time to Overflow, min	27	10	3

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.76 (9.60%)	14.66 (3.53%)	22.46 (5.74%)
Sediment Captured, lb	5.53	5.65	5.83
Sediment Retention, %	71.3	38.5	26.0
Time to Overflow, min	16	5	3

(c) Direct Discharge Testing with Sandy Loam Soil

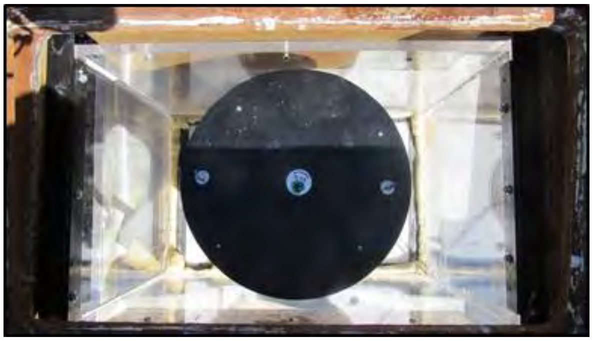
Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	3.05 (4.81%)	5.71 (-1.89%)	8.59 (-1.60%)
Sediment Captured, lb	1.27	1.72	1.74
Sediment Retention, %	41.6	30.1	20.3
Time to Overflow, min	28	6	4

TRITON™ - CONTECH ENGINEERED SOLUTIONS

The Triton™ is a cartridge-type catch basin insert. The Triton™ base fits down into the catch basin and is sealed against the catch basin frame, preventing water from exiting the catch basin without passing through the replaceable filter cartridge that is installed on top of the base. The filter cartridge consists of a fine mesh medium, enclosed by a stainless steel housing that prevents debris from damaging the filter media. The cartridge also has a bypass opening at the top to allow water to exit the catch basin untreated by the filter cartridge in the event that the cartridge is too clogged to allow water to pass through adequately. While all other CBI's under consideration hung from the lip of the catch basin frame, allowing water to flow into the CBI, the Triton™ is designed to be supported from below, and allow water to impound around the device. Therefore, an acrylic box was constructed to simulate the sides of the catch basin. A large hole was cut into the bottom of the box to allow water to exit once it passed through the filter media of the CBI. A Triton™ platform was installed into the bottom of the box and sealed appropriately using a foam caulking to ensure water did not leave the box without passing through the filter.

Photos of the Triton™ installed in the testing catch basin can be seen in Figure C-17.

Figure C-17: Pre-test installation for Triton™.

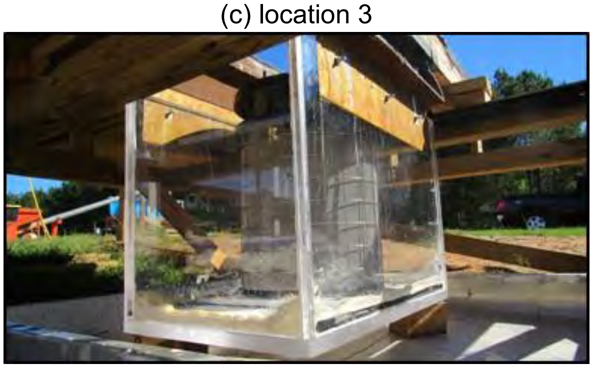


(a) location 1

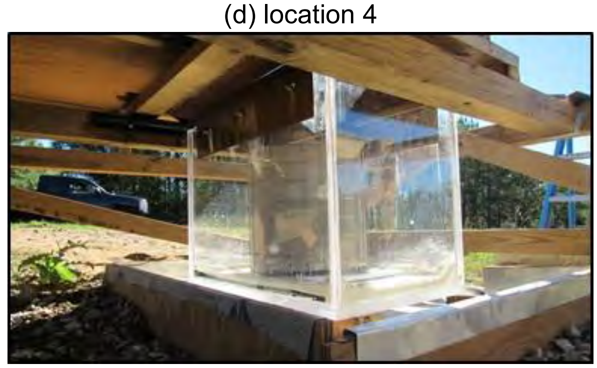
(b) location 2

(c) location 3

(d) location 4



(e) location 5



(f) location 6

Figure C-18 shows images of the Triton™ during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only.

Figure C-18: Triton™ during testing using various test methods and soil types.

0.06 cfs 0.12 cfs 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs 0.12 cfs 0.18 cfs

(c) direct discharge testing with sandy loam soil

Table C-7 summarizes performance evaluation data for the Triton™ when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. The water level did not reach the bypass mechanisms for any of the tests. However, maximum impoundment depths are recorded in Table C-7. Sediment retention values did not meet the 80% target removal rate.

Table C-7: Summary of Performance Data for Triton™ for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.27 (2.68%)	13.49 (-4.73%)	19.90 (-6.31%)
Sediment Captured, lb	4.32	6.61	8.99
Sediment Retention, %	59.4	49.0	45.2
Time to Overflow, min	-	-	-
Max Impoundment, in.	9.5	14.0	15.25

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.23 (2.12%)	13.01 (-8.12%)	21.03 (-0.99%)
Sediment Captured, lb	4.95	7.77	9.44
Sediment Retention, %	68.5	59.7	44.9
Time to Overflow, min	-	-	-
Max Impoundment, in.	13.75	15.0	15.5

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	2.75 (-5.5%)	5.60 (-3.8%)	7.59 (-13.0%)
Sediment Captured, lb	1.11	2.15	2.76
Sediment Retention, %	40.4	38.4	36.4
Time to Overflow, min	-	-	-
Max Impoundment, in.	14.5	14.5	14.75

WATER QUALITY SOLUTIONS

The Water Quality Solutions (WQS) is a tray-type catch basin insert consisting of a hard-plastic outer shell with layers of filters stacked inside for a staged-treatment approach. The upper half of the CBI consists of four plastic mesh filters, each decreasing in mesh size deeper into the shell. The bottom half of the CBI consists of two fine mesh metal screens. The trays are arranged so that larger particles are captured near the top of the device, and finer particles are removed through the metal screens at the bottom of the device before treated flow exits the WQS through large holes in the bottom of the hard-plastic shell. Unlike other CBI's under consideration, the WQS has no bypass mechanism.

Photos of the WQS installed in the testing catch basin can be seen in Figure C-19.

Figure C-19: Pre-test installation for WQS.

(a) location 1
(b) location 2
(c) location 3
(d) location 4
(e) location 5
(f) location 6

Figure C-20 shows images of the WQS during testing with OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. Pictures are not available for the low and high flow rate tests in Figure C-20(a) during the sheet flow testing with OK110 silica sand due to a corrupted file storage device. It was noticed during installation that the plastic lip that supports the WQS on the catch basin frame may not have been strong enough to support the heavy weight of the CBI, causing the lip to become distorted, and allowing some flow to get around the CBI untreated. This can be seen by water flowing down the outside of the filter in Figure C-20(b).

Figure C-20: WQS during testing using various test methods and soil types.

0.06 cfs | 0.12 cfs | 0.18 cfs

(a) sheet flow testing with OK110 silica sand

0.06 cfs | 0.12 cfs | 0.18 cfs

(b) direct discharge testing with OK110 silica sand

0.06 cfs | 0.12 cfs | 0.18 cfs

(c) direct discharge testing with sandy loam soil

Because the WQS has no bypass mechanism, during the medium flow test using sandy loam soil under direct discharge conditions, the water level impounded inside the CBI until it was just below the bottom of the grate. However, during the 0.18 cfs test, water flooded onto the platform by the 15 minute mark. By the 57 minute mark, water flooded the platform to the point of overtopping the 6” simulated curb. Images of the flooded platform can be seen in Figure C-21.

Figure C-21: Flooding during WQS high flow test using sandy loam soil under direct discharge conditions.

(a) from side (b) from downstream (c) from upstream

Table C-8(a-c) summarizes performance evaluation data for the WQS when introducing OK110 silica sand under sheet flow and direct discharge conditions and sandy loam soil under direct discharge conditions only. While sediment retention values did not meet the 80% target removal rate, it is worth noting that, on average, sediment retention values increased as flow rate increased. This was not common to the other CBIs that were evaluated. While it is impossible to monitor water levels inside the WQS during testing because of the many components inside, one possible explanation is that the low flow rate did not allow water to impound within the device, relying solely on the filter media to remove sediment. During higher flow tests, flow impounded during the tests, allowing particles to be removed via the filter media, and to fall out of suspension due to the impoundment.

Table C-8: Summary of Performance Data for WQS for Various Test and Soil Types

(a) Sheet Flow Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb (% error)	7.48 (5.65%)	14.68 (3.67%)	22.43 (5.60%)
Sediment Captured, lb	0.20	4.00	6.01
Sediment Retention, %	2.7	27.3	26.8
Time to Overflow, min	-	-	-

(b) Direct Discharge Testing with OK110 Silica Sand

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb	7.39 (4.38%)	14.47 (2.19%)	22.58 (6.31%)
Sediment Captured, lb	2.00	7.44	12.18
Sediment Retention, %	27.1	51.4	53.9
Time to Overflow, min	-	-	-

(c) Direct Discharge Testing with Sandy Loam Soil

Flow Rate, cfs	0.06	0.12	0.18
Sediment Introduced, lb	2.81 (-3.44%)	5.85 (0.52%)	8.56 (-1.95%)
Sediment Captured, lb	1.20	2.89	4.32
Sediment Retention, %	42.7	49.4	50.5
Time to Overflow, min	-	-	15

LONGEVITY TESTING

ADSORB-IT™

Four longevity tests of the Adsorb-It™ were conducted using each of the soil types. Overflow was not reached during the L1 test but was reached during the remaining three tests at 40, 4 and 1 minutes when using OK110 silica sand. Overflow occurred during all four tests with sandy loam soil at 60 minutes for the L1 test, 2 minutes for the L2 test, and less than on minute for both the L3 and L4 tests. The rapid difference in overflow times between L1 and L2 tests indicate that the soils severely blinded the filter media, inhibiting flow-through rate and causing the device to fill quickly in subsequent tests.

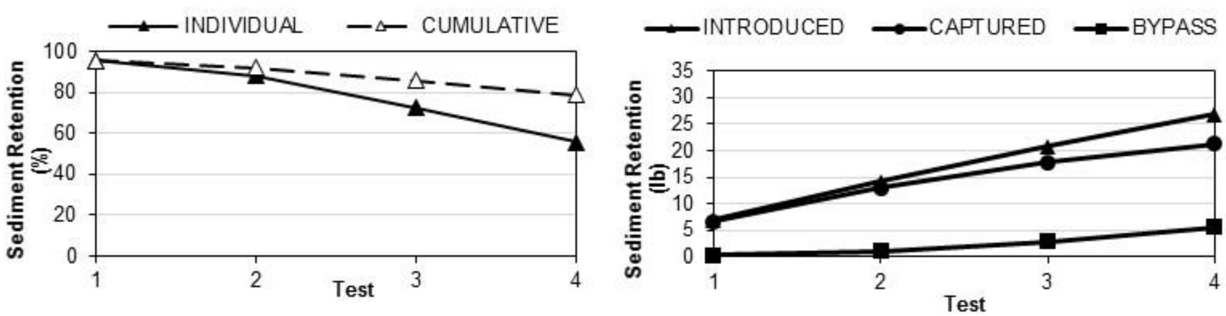
Table C-9 summarizes longevity data for the Adsorb-It™ when introducing OK110 silica sand and sandy loam. During the L1 test with OK110 silica sand, the Adsorb-It™ retained 95.6% of the introduced sediment, which was similar to the 96.1% sediment retention determined when evaluating the Adsorb-It™ under similar conditions during performance evaluation testing. The Adsorb-It™ was then tested again and retained 88.4% of the sediment introduced during the L2 test, bringing the cumulative retention to 92.0%. An L3 test was conducted with a sediment retention of 72.4% and a cumulative retention of 85.7% across the three tests. While the sediment retention performance for the L3 test was below the 80% rate, the cumulative retention was still well above, so it was determined that the Adsorb-It™ would be tested a fourth time, resulting in an individual retention of 55.7% and a cumulative retention of 78.9% falling below the required threshold, concluding longevity testing.

During the L1 test with sandy loam soil, the Adsorb-It™ retained 86.8% of the sediment introduced, which was similar to the sediment retention of 85.4% determined when using sandy loam soil at the low flow rate during performance evaluation testing. The Adsorb-It™ was then tested again and retained 49.8% of the sediment introduced during the L2 test, bringing the cumulative retention to 68.4%. An L3 test was conducted with a sediment retention of 53.6% and a cumulative retention of 63.5% across the three tests. During the testing of the L4 test, the Adsorb-It™ retained 53.8% of the sediment introduced for a cumulative retention of 61.6%, concluding longevity testing for the Adsorb-It™. It is worth noting that the performance across the L2, L3, and L4 tests were very similar, and had similar overflow times. The results indicate that while the Adsorb-It™ is capable of reaching the 80% sediment retention rate with the sandy loam soil, maintenance must occur frequently in order to continue performance.

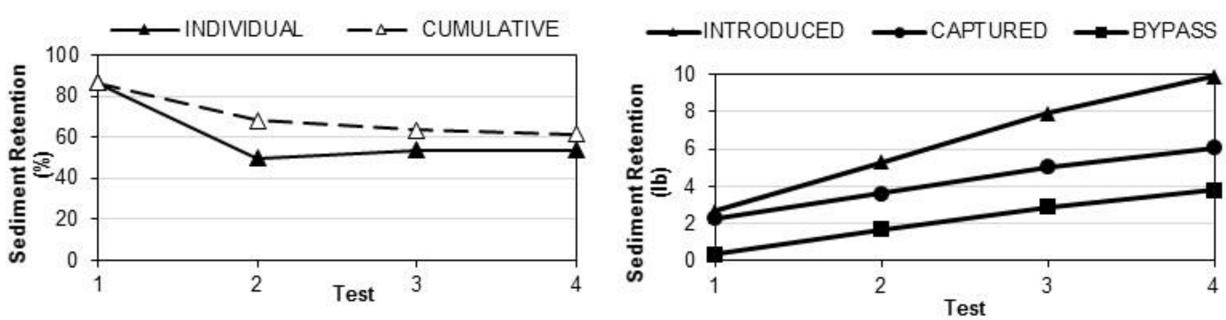
Table C-9: Longevity Testing for Adsorb-It™

(a) Longevity Testing with OK110 Silica Sand				
	L1	L2	L3	L4
Sediment Introduced, lb (% error)	7.04 (-0.6%)	7.09 (0.1%)	6.64 (-6.2%)	6.10 (-13.8%)
Sediment Captured, lb	6.73	6.27	4.81	3.40
Sediment Retention, %	95.6	88.4	72.4	55.7
Cumulative Retention, %	95.6	92.0	85.7	78.9
Time to Overflow, min	-	40	4	1
(b) Longevity Testing with Sandy Loam Soil				
	L1	L2	L3	L4
Sediment Introduced, lb (% error)	2.66 (-8.6%)	2.63 (-9.6%)	2.63 (-9.63%)	1.97 (-32.3%)
Sediment Captured, lb	2.31	1.31	1.41	1.06
Sediment Retention, %	86.8	49.8	53.6	53.8
Cumulative Retention, %	86.8	68.4	63.5	61.6
Time to Overflow, min	60	2	1	1

Figure C-22 shows sediment bypassing increases, or is not being captured at the same rate, over time by the Adsorb-It™, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-22: Sediment retention percentage for Adsorb-It™ over longevity tests.

DrainPac™

Eight longevity tests were conducted on the DrainPac™ using OK110 silica sand. Overflow was not reached during the L1 test, but was reached during the remaining tests at 65, 7, 14, 13, 8, 3, and 11 minutes, respectively. Tests L3 through L8 had little variance between overflow times, indicating that there was little change in flow-through rate after the blinding conditions were reached. Two longevity tests were conducted using the sandy loam soil, with overflow at 33 and 4 minutes, respectively. Overflow was reached much quicker during sandy loam soil tests than with OK110 silica sand, indicating that the high clay content in the sandy loam soil played a role in blinding the material more than the high sand content of the OK110 silica sand.

Table C-10 summarizes longevity data for the DrainPac™ when introducing OK110 silica sand and sandy loam. During the L1 test with OK110 silica sand, the DrainPac™ retained 80.0% of the introduced sediment, which was similar to the 79.8% sediment retention determined when evaluating the Adsorb-It™ under similar conditions during performance evaluation testing. The DrainPac™ was then tested again and retained 81.7% of the sediment introduced during the L2 test, bringing the cumulative retention to 80.9%. An L3 test was conducted with a sediment retention of 68.4% and a cumulative retention of 76.7% across the three tests. Sediment retention fluctuated with each test, increasing in retention, decreasing in retention, and continuing. For this reason, longevity testing was expanded to eight tests in order to further observe the pattern and ensure that the DrainPac™ would not reach the 80% target in another test. After the eighth test, it was determined that longevity testing could be concluded.

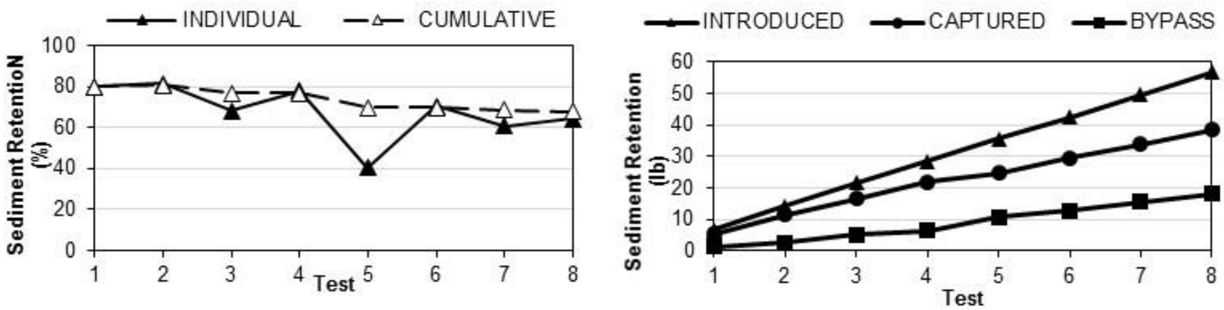
During the L1 test with sandy loam soil, the DrainPac™ retained 60.3% of the sediment introduced, which was similar to the sediment retention of 68.1% determined when using sandy loam soil at the low flow rate during performance evaluation testing. The DrainPac™ was then tested again and retained 45.5% of the sediment introduced during the L2 test, bringing the cumulative retention to 53.0%. At this point, it was determined that longevity testing could be concluded. From the longevity testing, the DrainPac™ did not meet the requirement for retaining 80% of the introduced sediment under the sandy loam soil testing conditions.

Table C-10: Longevity Testing for DrainPac™

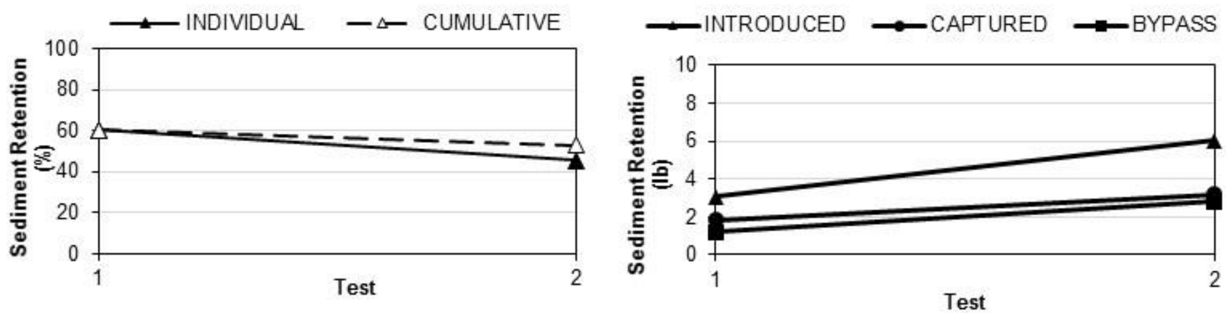
(a) Longevity Testing with OK110 Silica Sand	L1	L2	L3	L4	L5	L6	L7	L8
Sediment Introduced, lb (% error)	6.74 (-4.8%)	7.55 (6.6%)	7.35 (3.8%)	6.84 (-3.4%)	7.10 (0.3%)	6.84 (-3.4%)	7.15 (1.0%)	7.17 (1.3%)
Sediment Captured, lb	5.39	6.17	5.03	5.34	2.88	4.82	4.34	4.61
Sediment Retention, %	80.0	81.7	68.4	78.1	40.6	70.5	60.7	64.3
Cumulative Retention, %	80.0	80.9	76.7	77.0	69.7	69.8	68.5	68.0
Time to Overflow, min		65	7	14	13	8	3	11

(b) Longevity Testing with Sandy Loam Soil	L1	L2	L3	L4	L5	L6	L7	L8
Sediment Introduced, lb (% error)	3.05 (4.8%)	2.97 (2.1%)	-	-	-	-	-	-
Sediment Captured, lb	1.84	1.35	-	-	-	-	-	-
Sediment Retention, %	60.3	45.5	-	-	-	-	-	-
Cumulative Retention, %	45.5	53.0	-	-	-	-	-	-
Time to Overflow, min	33	4	-	-	-	-	-	-

Figure C-23 was included to further analyze the DrainPac™ over the longevity tests. Sediment capture rate decreases overtime while bypass increases, indicating a decline in performance and a need for maintenance. Further analysis of Figure C-23 also shows that, while sediment retention appeared volatile when considering the percentages individually for each test, it can be seen that sediment retention is actually fairly linear across all eight tests, with the exception of the one L5 tests, which could be considered an outlier.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-23: Sediment retention percentage for DrainPac™ over longevity tests.

Another observation during the eight longevity tests was the wear of the device after significant loading. A total of 56.74 lb of sediment was introduced with 38.58 lb of sediment captured over the eight longevity tests. A large portion of this sediment was stored between the metal basket frame and the filter fabric lining, putting excess loading on the bag which started causing the plastic netting to pull away from its anchor point. The damage can be seen in Figure C-24 from both the front and side views.

(a) front view (b) side view

Figure C-24: Damage to DrainPac™ after eight longevity tests.

FLEXSTORM®

Four longevity tests with OK110 silica sand were conducted with the FlexStorm®. While the water level inside the FlexStorm® never reached the untreated bypass mechanism built into the FlexStorm® frame, treated bypass was reached during the four tests at 40, 29, 30, and 31 minutes, respectively. The FlexStorm® also underwent two longevity tests with sandy loam soil. Again, water level inside the FlexStorm® never reached the untreated bypass mechanism built into the FlexStorm® frame. However, treated bypass was reached during the two tests at 45 minutes and 1 minute, respectively. The FlexStorm® was affected differently by the two soil types, based upon the difference in overflow times. When using the OK110 silica sand, there was little change in overflow time, especially between the final three tests. However, with the sandy loam soil, overflow was reached much faster after the first test. This is likely due to the higher clay content in the sandy loam soil. The clay particles can cause the material to blind, or clog, which can reduce the flow-through rate of the material after the initial test.

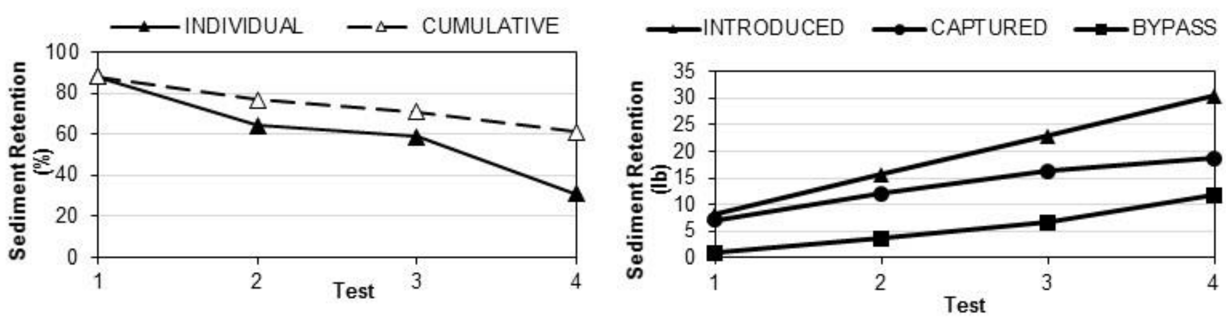
Table C-11 summarizes longevity data for the FlexStorm® when introducing OK110 silica sand and sandy loam. Note, test names are abbreviated, whereas L1 is longevity test 1, L2 is longevity test 2 and so on. During the L1 test with OK110 silica sand, the FlexStorm® retained 88.3% of the introduced sediment, which was higher than the 71.3% sediment retention determined when evaluating the FlexStorm® under similar conditions during performance evaluation testing. The FlexStorm® was then tested again, with the 7.17 pounds of sediment collected from the L1 tests still contained within the product and retained 64.5% of the sediment introduced during the L2 test. However, while the 64.5% was below the desired 80% retention, the cumulative retention percentage between the two tests was still at 76.8%. Therefore, it was determined that an L3 test would be conducted, which resulted in a 58.8% sediment retention, and a cumulative retention of 71.1% across the three tests. While the sediment retention performance did decrease from L2 to L3, the decrease was small. Finally, L4 test was conducted to strain the CBI until a significant drop in performance was seen. The FlexStorm® only retained 31.2% of the introduced sediment during the L4 test, leaving the cumulative retention at 61.3%. At this point, it was determined that longevity testing could be concluded.

During the L1 test with sandy loam soil, the FlexStorm® retained 64.8% of the sediment introduced, similar to the 65.4% sediment retention when using sandy loam soil at the low flow rate during performance evaluation testing. While this performance is already below the 80% target rate, an L2 test was performed to assure that the 80% rate would not be reached in a following event. During the L2 test, only 49.7% of the introduced sediment was retained, for a cumulative retention of 57.0% at which point longevity testing was concluded. The results from longevity testing show that the FlexStorm® is not capable of meeting the 80% sediment removal rate under the testing conditions.

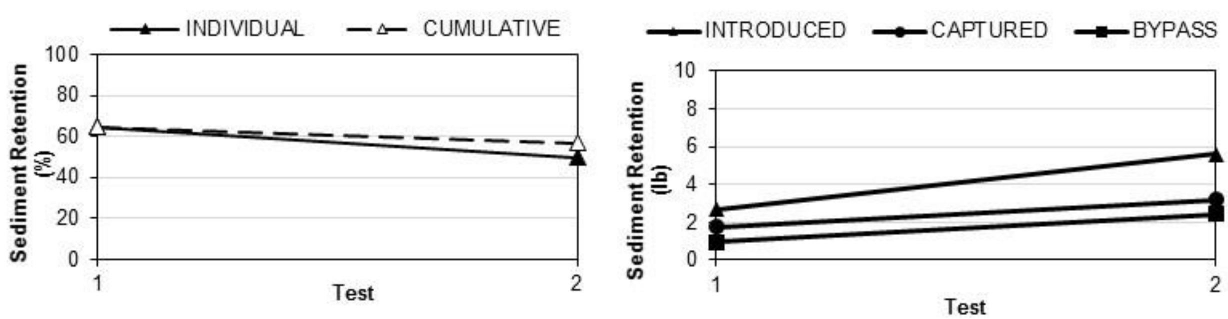
Table C-11: Longevity Testing for FlexStorm®

(a) Longevity Testing with OK110 Silica Sand	L1	L2	L3	L4
Sediment Introduced, lb (% error)	8.12 (14.7%)	7.60 (7.3%)	7.21 (1.8%)	7.50 (5.9%)
Sediment Captured, lb	7.17	4.90	4.24	2.34
Sediment Retention, %	88.3	64.5	58.8	31.2
Cumulative Retention, %	88.3	76.8	71.1	61.3
Time to Overflow, min	40	29	31	30
(b) Longevity Testing with Sandy Loam Soil	**L1**	**L2**	**L3**	**L4**
Sediment Introduced, lb (% error)	2.70 (-7.2%)	2.90 (-0.3%)	--	--
Sediment Captured, lb	1.75	1.44	--	--
Sediment Retention, %	64.8	49.7	--	--
Cumulative Retention, %	64.8	57.0	--	--
Time to Overflow, min	45	1	--	--

Figure C-25 further analyzes the FlexStorm® performance over the longevity tests. Notice the difference between the sediment introduced and sediment capture increases with each test, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-25: Sediment retention percentage for FlexStorm® over longevity tests.

FLO-GARD® PLUS

The Flo-Gard® Plus was only tested once per soil type for longevity because of the low sediment retention that was verified when compared to performance testing results. Similar to performance evaluation tests, there was little to no impoundment within the CBIs and no overflow.

Table C-12 summarizes longevity data for the Flo-Gard® Plus when introducing OK110 silica sand and sandy loam. During the L1 test with OK110 silica sand, the Flo-Gard® Plus retained 2.3% of the introduced sediment, which was similar to, but slightly lower than, the 10.4% sediment retention determined when evaluating the Flo-Gard® Plus under similar conditions during performance evaluation testing. During the L1 test with sandy loam soil, the Flo-Gard® Plus retained 18.0% of the sediment introduced, which was similar to the sediment retention of 24.7% determined when using sandy loam soil at the low flow rate during performance evaluation testing.

Table C-12: Longevity Testing for Flo-Gard® Plus

(a) Longevity Testing with OK110 Silica Sand	L1
Sediment Introduced, lb	6.91
(% error)	(-2.4%)
Sediment Captured, lb	0.16
Sediment Retention, %	2.3
Cumulative Retention, %	2.3
Time to Overflow, min	-
(b) Longevity Testing with Sandy Loam Soil	**L1**
Sediment Introduced, lb	2.72
(% error)	(-6.5)
Sediment Captured, lb	0.49
Sediment Retention, %	18.0
Cumulative Retention, %	18.0
Time to Overflow, min	-

Sediment retention and cumulative performance graphs were not developed for Flo-Gard® Plus results because there was only one data point for each metric on each graph.

GULLYWASHER©

Longevity testing of the Gullywasher© using OK110 silica sand was conducted over three tests. Overflow was reached during the three tests at 24, 7 and 2 minutes, respectively. Longevity testing with sandy loam soil was concluded after two tests, with overflow times of 26 minutes and 1 minute, respectively. The difference in overflow times from L1 to L2 indicate that sandy loam soil severely blinded the fabric after the first tests, inhibiting flow-through rate and causing the CBI to fill to the overflow point very quickly. It can be seen in Figure C-26 that the flow coming through the bypass during the L2 test was much more severe than the flow exiting the bypass during the L1 test.

(a) L1 (b) L2

Figure C-26: Gullywasher© during longevity testing with sandy loam soil.

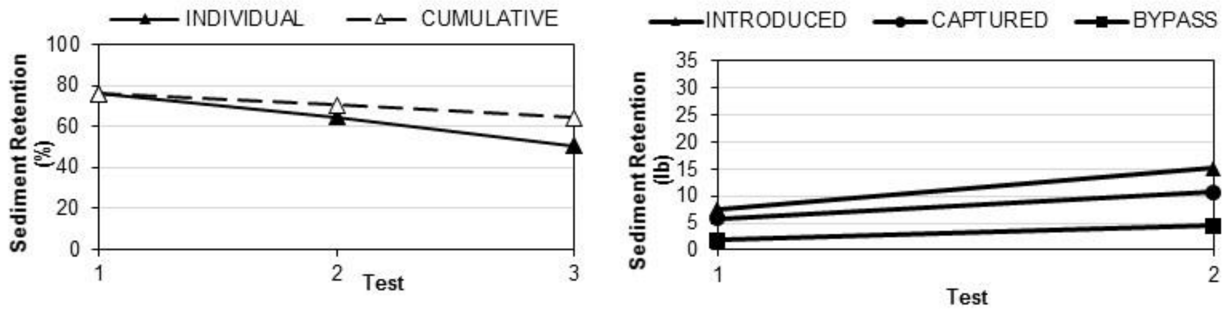
Table C-13 summarizes longevity data for the Gullywasher© when introducing OK110 silica sand and sandy loam. During the L1 test with OK110 silica sand, the Gullywasher© retained 75.9% of the introduced sediment, which was similar to, but slightly higher than, the 67.1% sediment retention determined when evaluating the Gullywasher© under similar conditions during performance evaluation testing. The Gullywasher© was then tested again, with the 5.81 pounds of sediment collected from the L1 test and retained 64.9% of the sediment introduced during the L2 test, bringing the cumulative retention to 70.4%. An L3 test was conducted with a sediment retention of 50.8% and a cumulative retention of 64.2% across the three tests. At this point, it was determined that longevity testing could be concluded. While the Gullywasher© never did actually reach the 80% sediment retention target, results from the testing show the potential to perform near this threshold under these testing conditions. However, the longevity data can also be used to conclude that the Gullywasher© would have to be maintained after almost every small storm event in order to continue performance.

During the L1 test with sandy loam soil, the Gullywasher© retained 53.1% of the sediment introduced, which was similar to the sediment retention of 51.7% determined when using sandy loam soil at the low flow rate during performance evaluation testing. While this performance is already below the 80% target rate, an L2 test was performed assure that the 80% rate would not be reached in a following event. During the L2 test, only 39.8% of the introduced sediment was retained, for a cumulative retention of 46.9%, and longevity testing was concluded. The results from longevity testing show that the Gullywasher© is not capable of meeting the 80% sediment removal rate under the testing conditions.

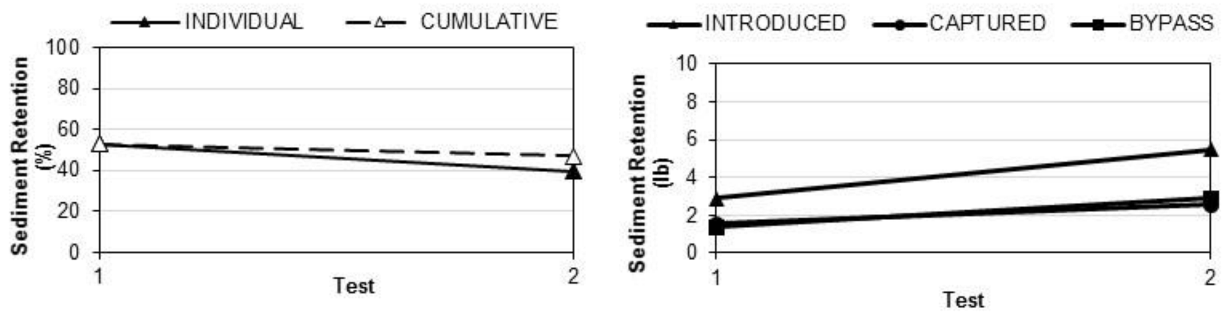
Table C-13: Longevity Testing for Gullywasher©

(a) Longevity Testing with OK110 Silica Sand			
	L1	L2	L3
Sediment Introduced, lb	7.65	7.54	7.12
(% error)	(8.1%)	(6.5%)	(0.6%)
Sediment Captured, lb	5.81	4.89	3.62
Sediment Retention, %	75.9	64.9	50.8
Cumulative Retention, %	75.9	70.4	64.2
Time to Overflow, min	24	7	2
(b) Longevity Testing with Sandy Loam Soil			
	L1	L2	L3
Sediment Introduced, lb	2.90	2.56	-
(% error)	(-0.3%)	(-12.0%)	
Sediment Captured, lb	1.54	1.02	-
Sediment Retention, %	53.1	39.8	-
Cumulative Retention, %	53.1	46.9	-
Time to Overflow, min	26	1	-

Figure C-27 shows the difference between the introduced and captured lines is increasing with each test, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-27: Sediment retention percentage for Gullywasher© over longevity tests.

STORM SENTINEL®

Two longevity tests were conducted on the Storm Sentinel® with both the OK110 silica sand and sandy loam soil. Overflow was reached during the two OK110 silica sand tests at 22 and 13 minutes, and 22 and 21 minutes during the two sandy loam soil tests.

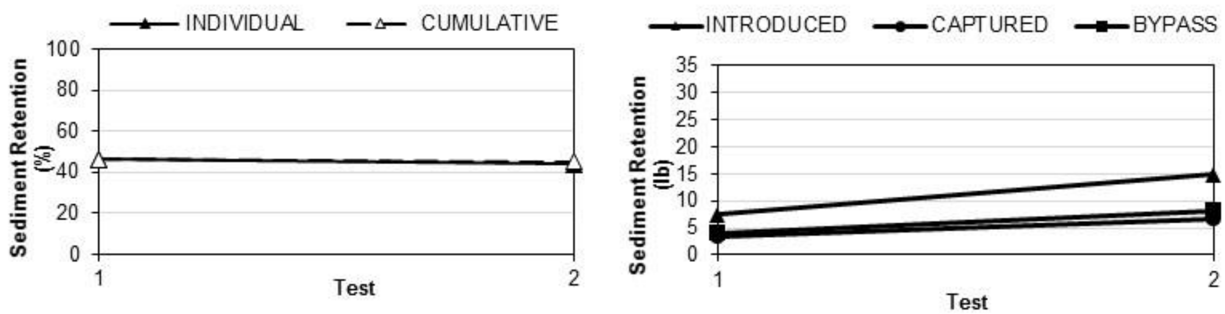
Table C-14 summarizes longevity data for the Storm Sentinel® when introducing OK110 silica sand and sandy loam. During the L1 test with OK110 silica sand, the Storm Sentinel® retained 46.2% of the introduced sediment, which was lower than the 71.3% sediment retention determined when evaluating the Storm Sentinel® under similar conditions during performance evaluation testing. This difference could be contributed to variations in the product material. The Storm Sentinel® was then tested again, with the 3.43 pounds of sediment collected from the L1 tests and retained 44.1% of the sediment introduced during the L2 test, bringing the cumulative retention to 45.2%. Because there was little difference in performance from L1 to L2, and both tests were well below the 80% target rate longevity testing was concluded. The results from longevity testing show that the Storm Sentinel® is not capable of meeting the 80% sediment removal rate under these testing conditions.

During the L1 test with sandy loam soil, the Storm Sentinel® retained 41.6% of the sediment introduced, which was exactly the same sediment retention determined when using sandy loam soil at the low flow rate during performance evaluation testing. While this performance is already below the 80% target rate, an L2 test was performed in order to be sure that the 80% rate would not be reached in a following event. During the L2 test, only 36.0% of the introduced sediment was retained, for a cumulative retention of 38.8%, and longevity testing was concluded. The results from longevity testing show that the Storm Sentinel® is not capable of meeting the 80% sediment removal rate under these testing conditions.

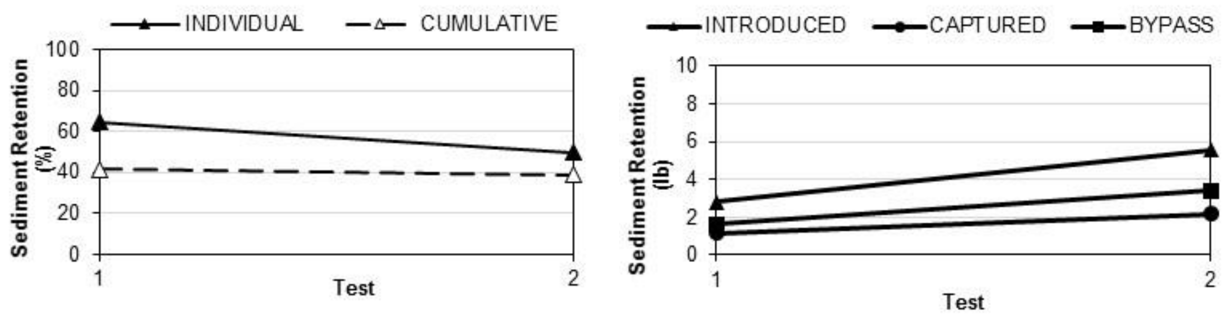
Table C-14: Longevity Testing for Storm Sentinel®

(a) Longevity Testing with OK110 Silica Sand		
	L1	L2
Sediment Introduced, lb (% error)	7.43 (4.9%)	7.43 (4.9%)
Sediment Captured, lb	3.43	3.28
Sediment Retention, %	46.2	44.1
Cumulative Retention, %	46.2	45.2
Time to Overflow, min	22	13
(b) Longevity Testing with Sandy Loam Soil		
	L1	L2
Sediment Introduced, lb (% error)	2.79 (-4.1%)	2.78 (-4.5%)
Sediment Captured, lb	1.16	1.00
Sediment Retention, %	41.6	36.0
Cumulative Retention, %	41.6	38.8
Time to Overflow, min	22	21

Figure C-28 shows the difference between the introduced and captured lines is increasing with each test, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-28: Sediment retention percentage for Storm Sentinel® over longevity tests.

TRITON™

Two longevity tests were conducted on the Triton™ for each soil type. Figure C-29 was included to showcase how the sandy loam soil clogs the cartridge medium and fills the catch basin box faster than with the OK110 silica sand, which also lead to larger impoundment depths, even though untreated bypass was never reached for any of the tests.

(a) L1 test with OK110 silica sand (b) L1 test with sandy loam soil

Figure C-29: Triton™ during longevity testing.

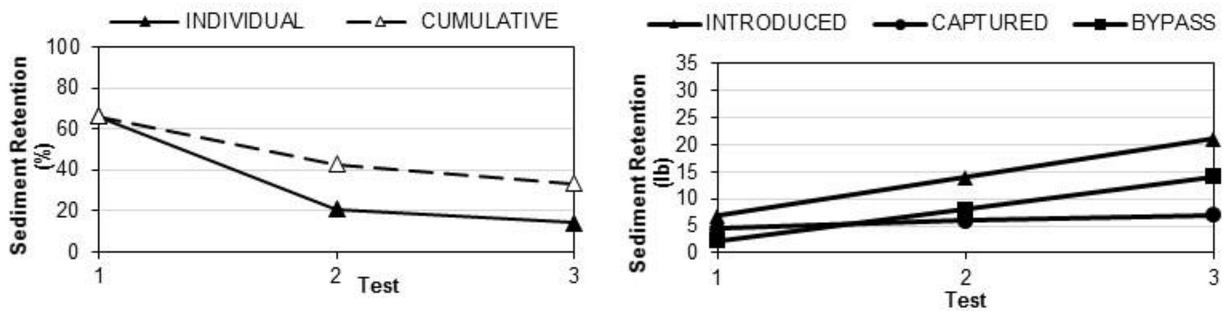
Table C-15 summarizes longevity data for the Triton™ when introducing OK110 silica sand and sandy loam, respectively. During the L1 test with OK110 silica sand, the Triton™ retained 66.2% of the introduced sediment, which was similar to the 68.5% sediment retention determined when evaluating the Triton™ under similar conditions during performance evaluation testing. The Triton™ was then tested again and retained 20.8% of the sediment introduced during the L2 test, bringing the cumulative retention to 42.8%. Results from the longevity testing show that the Triton™ is not capable of meeting performance standards under these testing conditions.

During the L1 test with sandy loam soil, the Triton™ retained 66.7% of the sediment introduced, which was higher than the sediment retention of 40.4% determined when using sandy loam soil at the low flow rate during performance evaluation testing. The Triton™ was then tested again and retained 48.8% of the sediment introduced during the L2 test, bringing the cumulative retention to 57.7%, concluding longevity tests since the Triton™ is not capable of retaining 80% of the introduced sediment under these testing conditions.

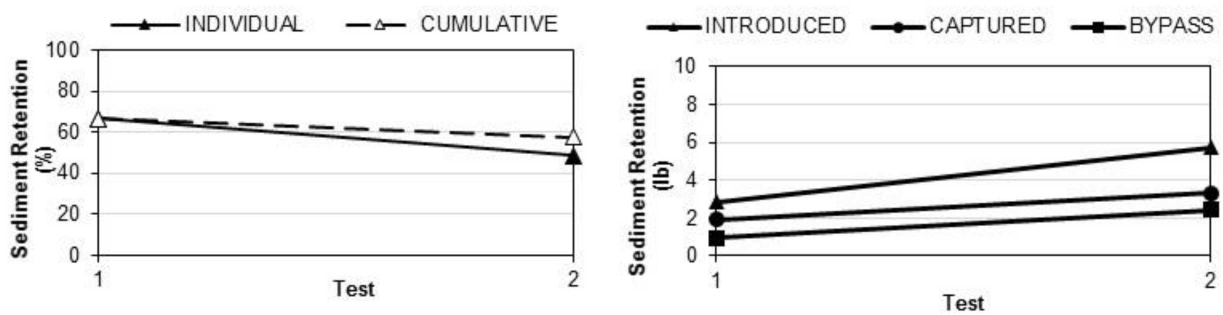
Table C-15: Longevity Testing for Triton™

(a) Longevity Testing with OK110 Silica Sand	L1	L2
Sediment Introduced, lb	6.80	7.22
(% error)	(-4.0%)	(2.0%)
Sediment Captured, lb	4.50	1.50
Sediment Retention, %	66.2	20.8
Cumulative Retention, %	66.2	42.8
Time to Overflow, min	-	-
(b) Longevity Testing with Sandy Loam Soil	**L1**	**L2**
Sediment Introduced, lb	2.85	2.87
(% error)	(-2.1%)	(-1.4%)
Sediment Captured, lb	1.90	1.40
Sediment Retention, %	66.7	48.8
Cumulative Retention, %	66.7	57.7
Time to Overflow, min	-	-

Figure C-30 shows that the amount of sediment bypassing, the Triton™ grows with each test, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-30: Sediment retention percentage for Triton™ over longevity tests.

WATER QUALITY SOLUTIONS (WQS)

Two longevity tests were conducted on the WQS for each soil type. The WQS is not equipped with an overflow bypass mechanism, therefore overflow was not observed during the longevity tests.

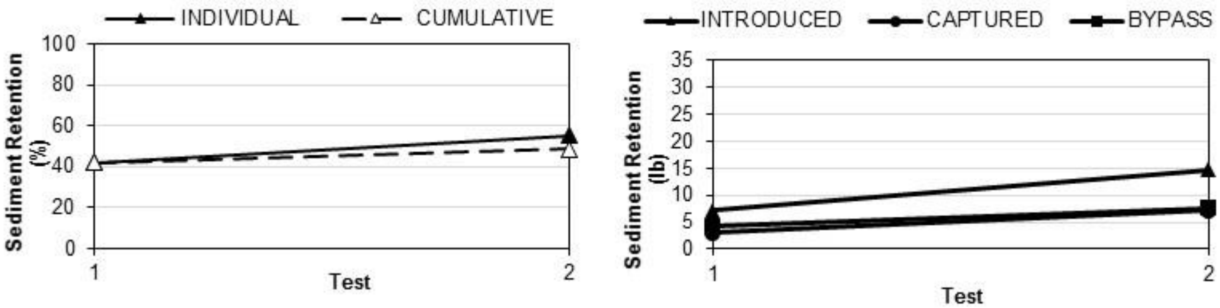
Table C-16 summarizes longevity data for the WQS when introducing OK110 silica sand and sandy loam. Target sediment introductions for the tests were 7.08 lb for OK110 tests and 2.91 lb for sandy loam tests. During the L1 test with OK110 silica sand, the WQS retained 41.9% of the introduced sediment, which was higher than the 27.1% sediment retention determined when evaluating the WQS under similar conditions during performance evaluation testing. The WQS was then tested again and retained 55.3% of the sediment introduced during the L2 test, bringing the cumulative retention to 48.7%, concluding longevity testing with the OK110 soil. Results from the longevity testing show that the WQS is not capable of reaching the 80% sediment retention rate under the OK110 soil testing conditions. Unlike most other CBIs tested, the WQS actually performed better at the L2 test than at the L1 test. However, it is worth noting that sediment retention actually increased at higher flow rates with the WQS, suggesting that the product performance may benefit from pre-captured sediment.

During the L1 test with sandy loam soil, the WQS retained 62.7% of the sediment introduced, which was higher than the sediment retention of 42.7% determined when using sandy loam soil at the low flow rate during performance evaluation testing. The WQS was then tested again and retained 55.7% of the sediment introduced during the L2 test, bringing the cumulative retention to 59.2%. At this point, it was determined that longevity testing could be concluded. The results indicate that the WQS is not capable of reaching the 80% sediment retention rate with the sandy loam soil.

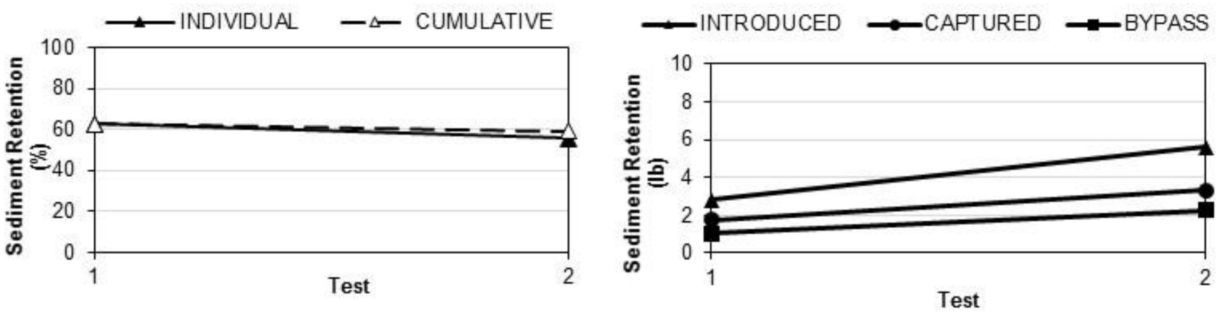
Table C-16: Longevity Testing for WQS

(a) Longevity Testing with OK110 Silica Sand		
	L1	L2
Sediment Introduced, lb	7.23	7.48
(% error)	(2.1%)	(5.6%)
Sediment Captured, lb	3.03	4.14
Sediment Retention, %	41.9	55.3
Cumulative Retention, %	41.9	48.7
Time to Overflow, min	-	-
(b) Longevity Testing with Sandy Loam Soil		
	L1	L2
Sediment Introduced, lb	2.79	2.80
(% error)	(-4.1%)	(-3.8%)
Sediment Captured, lb	1.75	1.56
Sediment Retention, %	62.7	55.7
Cumulative Retention, %	62.7	59.2
Time to Overflow, min	-	-

Figure C-31 shows the distance between the sediment introduction line and the sediment captured line grows greater as testing progresses, indicating a decline in performance and a need for maintenance.



(a) Longevity testing with OK110 silica sand



(b) Longevity testing with sandy loam soil

Figure C-31: Sediment retention percentage for WQS over longevity tests.

TOTAL SUSPENDED SOLIDS DATA SUMMARY REPORT

The purpose of this document is to provide ODOT with the total suspended solids (TSS) data acquired during the lab testing phase of the catch basin insert (CBI) research project. During the lab testing phase of the project, conducted at Auburn University's-Erosion & Sediment Control Testing Facility (AU-ESCTF), CBIs were evaluated for both sediment retention percentage, and TSS reduction percentage. Sediment retention percentage was calculated by weighing the CBIs before and after tests to determine the total weight of captured sediment and dividing by the total weight of sediment introduced. During all performance evaluation tests, 32 oz grab samples were taken upstream and downstream of the CBI at five minute intervals over the duration of the 70-minute test. These grab samples were then analyzed for TSS and compared to determine TSS reduction percentage. Figure C-32 to Figure C-39 provide the upstream and downstream TSS data and the corresponding TSS reduction percentage for each test performed on the eight CBI products. TSS samples for longevity tests were only taken for the DrainPac™ using OK110 silica sand, this data can be viewed in Figure C-40.

Upon completion of the performance evaluation tests, it was determined that sediment retention percentage was a truer way of measuring sediment removal capabilities of CBIs. Sediment retention percentage measured performance over the entirety of the test, while TSS reduction percentage was calculated based off of the twenty-eight, 32 oz grab samples taken every five minutes. In order to truly measure performance, TSS samples would have had to been collected at much smaller intervals, increasing the statistical sample size, and therefore providing a much more accurate representation of the true performance.

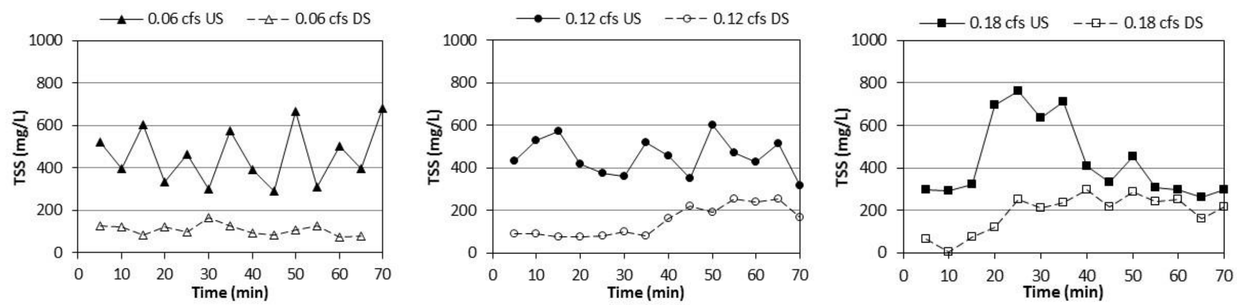
While sediment retention percentage is the primary performance measure used to evaluate CBIs in the "CBIs for Ohio Roadways" report, this addendum was developed to provide ODOT with the additional TSS data collected. Table C-17 provides a summary of the average TSS reduction values for performance evaluation tests.

Table C-17: Average TSS Reduction Summary of Performance Evaluation Tests (%)

	SHEET FLOW OK110			DIRECT DISCHARGE OK110			DIRECT DISCHARGE SANDY LOAM		
	0.06	0.12	0.18	0.06	0.12	0.18	0.06	0.12	0.18
Adsorb-It™	59.1	67.1	56.6	92.4	85.6	69.0	72.1	70.8	61.1
DrainPac™	45.4	56.4	57.6	76.0	64.9	71.6	63.6	51.7	33.8
FlexStorm®	66.2	42.0	51.1	88.0	39.7	20.6	67.3	71.0	53.6
Flo-Gard® Plus	18.5	11.5	16.7	24.6	15.8	28.8	41.2	27.9	51.3
Gullywasher©	79.4	59.3	33.5	71.9	50.4	39.6	62.4	62.8	23.6
Storm Sentinel®	63.6	25.0	11.2	90.7	76.0	35.1	59.9	53.2	42.2
Triton™	74.7	58.4	47.5	92.1	61.4	45.9	40.0	58.1	49.7
WQS	33.0	38.9	4.3	40.2	48.5	52.0	47.6	66.8	62.9

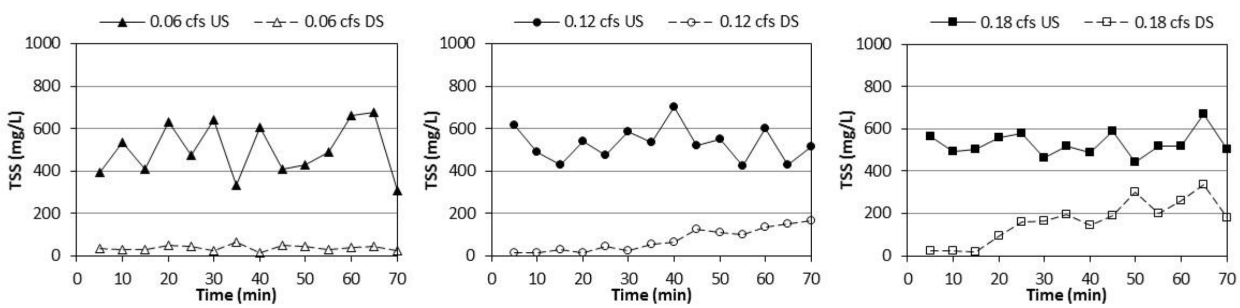
STORMWATER BMP PRODUCTS ADSORB-IT™ STORMFILTERS

Figure C-32 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the Adsorb-It™. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



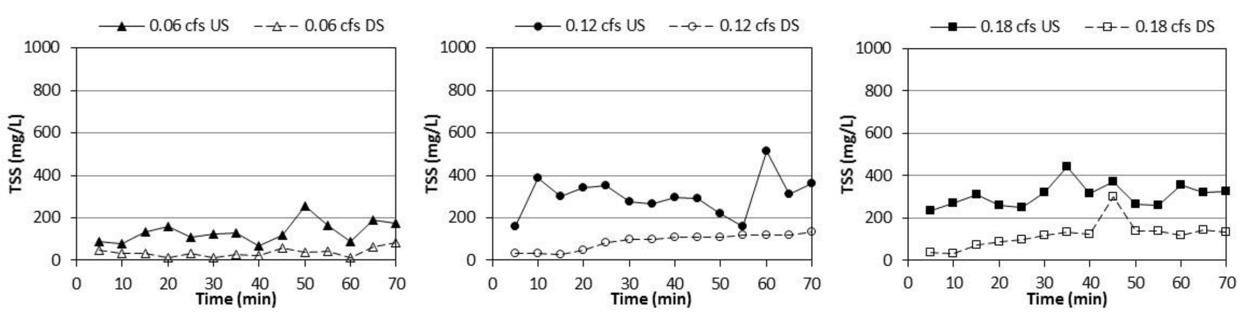
Avg. TSS reduction = 59.1% Avg. TSS reduction = 67.1% Avg. TSS reduction = 56.6%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 92.4% Avg. TSS reduction = 85.6% Avg. TSS reduction = 69.0%

(b) direct discharge testing with OK110 silica sand



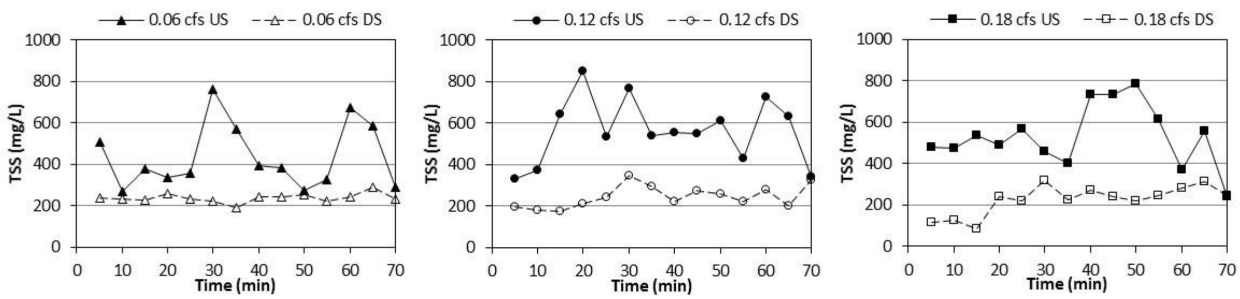
Avg. TSS reduction = 72.1% Avg. TSS reduction = 70.8% Avg. TSS reduction = 61.1%

(c) direct discharge testing with sandy loam soil

Figure C-32 Avg. TSS analysis data for Adsorb-It™ for performance evaluation tests.

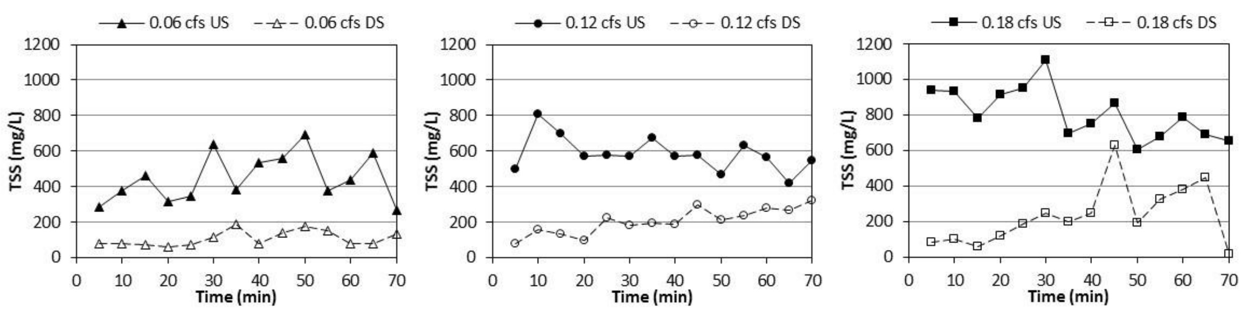
UNITED STORM WATER DRAINPAC™

Figure C-33 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the DrainPac™. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



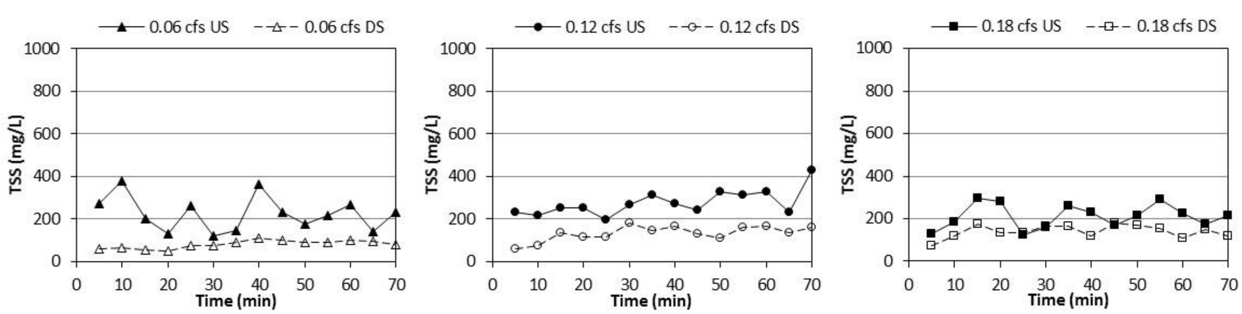
Avg. TSS reduction = 45.4%   Avg. TSS reduction = 56.4%   Avg. TSS reduction = 57.6%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 76.0%   Avg. TSS reduction = 64.9%   Avg. TSS reduction = 71.6%

(b) direct discharge testing with OK110 silica sand



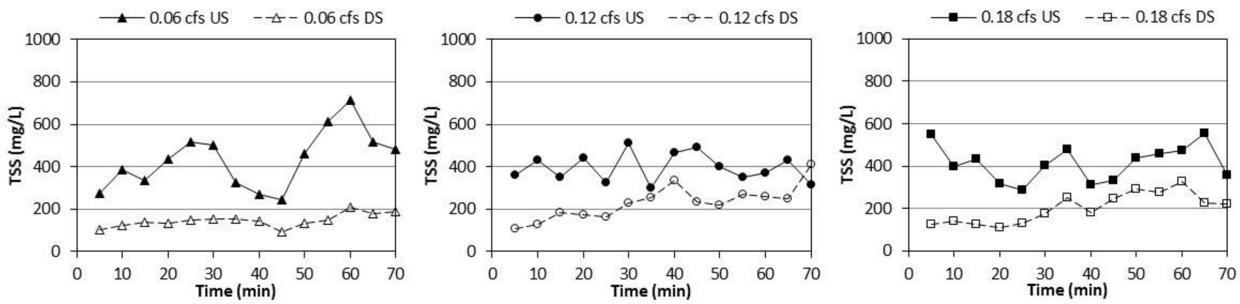
Avg. TSS reduction = 63.6%   Avg. TSS reduction = 51.7%   Avg. TSS reduction = 33.8%

(c) direct discharge testing with sandy loam soil

Figure C-33 Avg. TSS analysis data for DrainPac™ for performance evaluation tests.

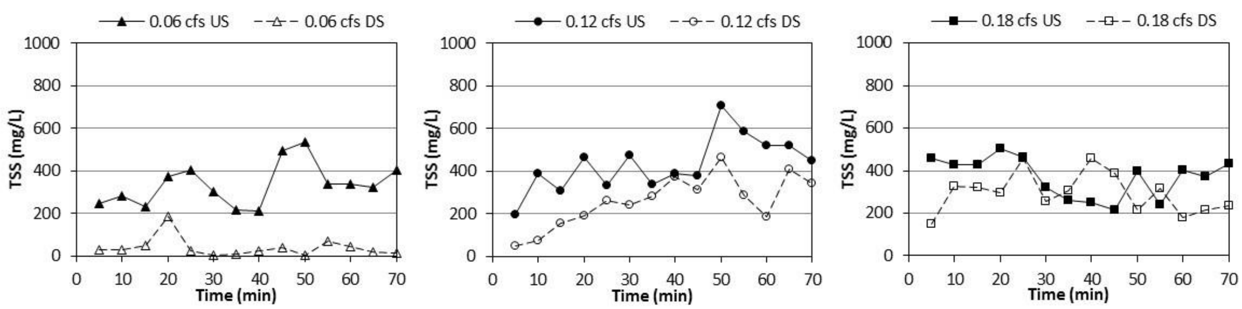
ADVANCED DRAINAGE SYSTEMS FLEXSTORM®

Figure C-34 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the FlexStorm®. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



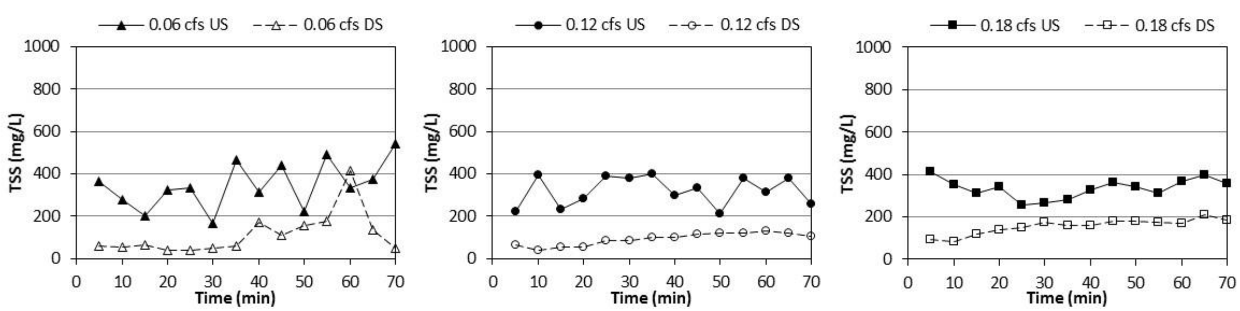
Avg. TSS reduction = 66.2% Avg. TSS reduction = 42.0% Avg. TSS reduction = 51.1%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 88.0% Avg. TSS reduction = 39.7% Avg. TSS reduction = 20.6%

(b) direct discharge testing with OK110 silica sand



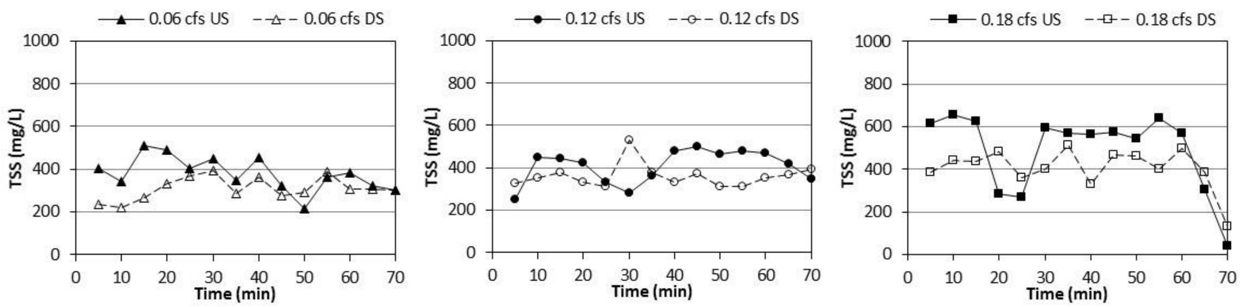
Avg. TSS reduction = 67.3% Avg. TSS reduction = 71.0% Avg. TSS reduction = 53.6%

(c) direct discharge testing with sandy loam soil

Figure C-34 Avg. TSS analysis data for FlexStorm® for performance evaluation tests.

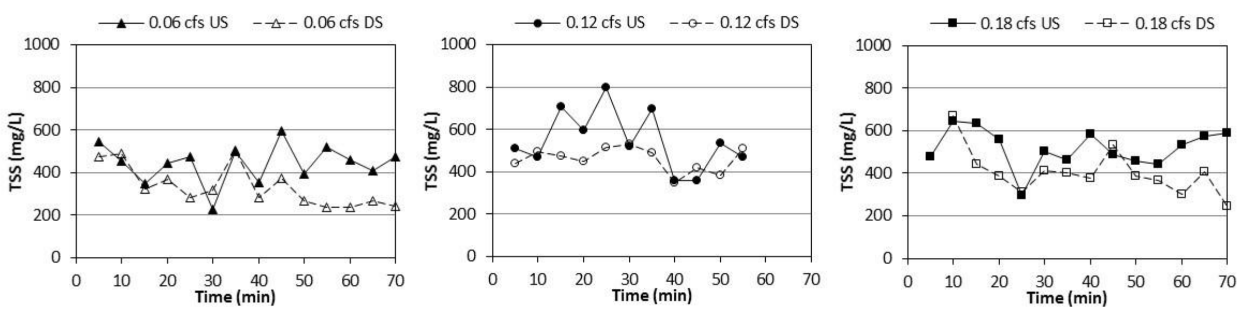
OLDCASTLE STORMWATER SOLUTIONS FLO-GARD® PLUS

Figure C-35 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the Flo-Gard® Plus. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



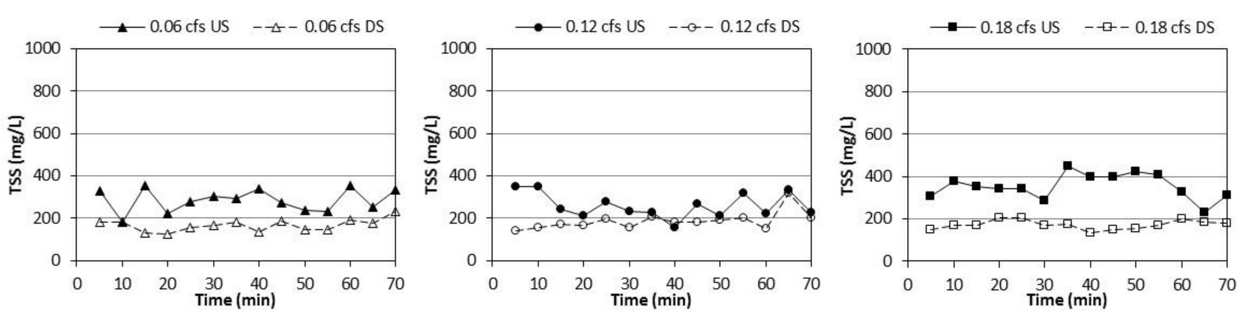
Avg. TSS reduction = 18.5% Avg. TSS reduction = 11.5% Avg. TSS reduction = 16.7%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 24.6% Avg. TSS reduction = 15.8% Avg. TSS reduction = 28.8%

(b) direct discharge testing with OK110 silica sand



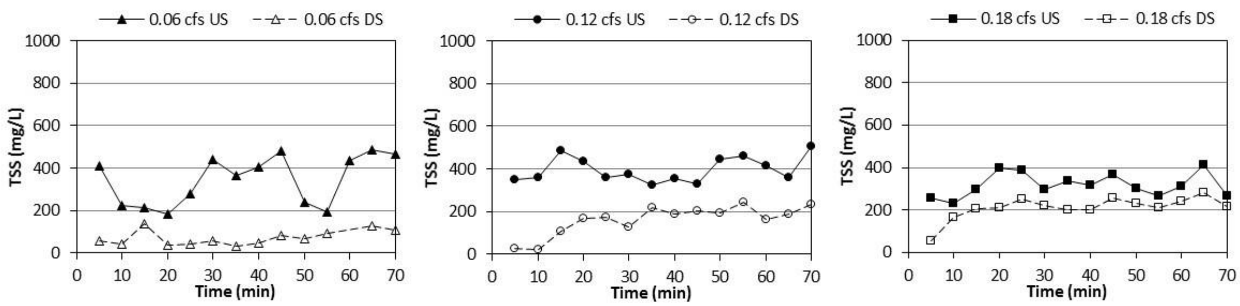
Avg. TSS reduction = 41.2% Avg. TSS reduction = 27.9% Avg. TSS reduction = 51.3%

(c) direct discharge testing with sandy loam soil

Figure C-35 Avg. TSS analysis data for Flo-Gard® for performance evaluation tests.

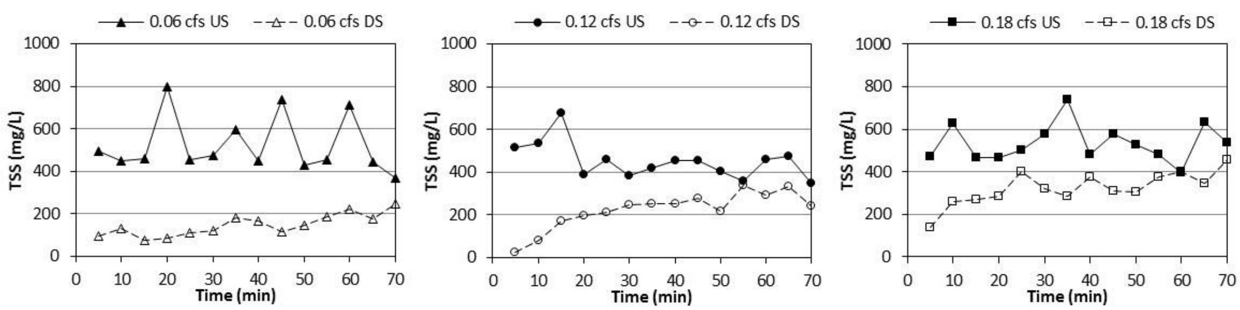
GULLYWASHER© METAL COMPLIANT CBIS

Figure C-36 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the Gullywasher©. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



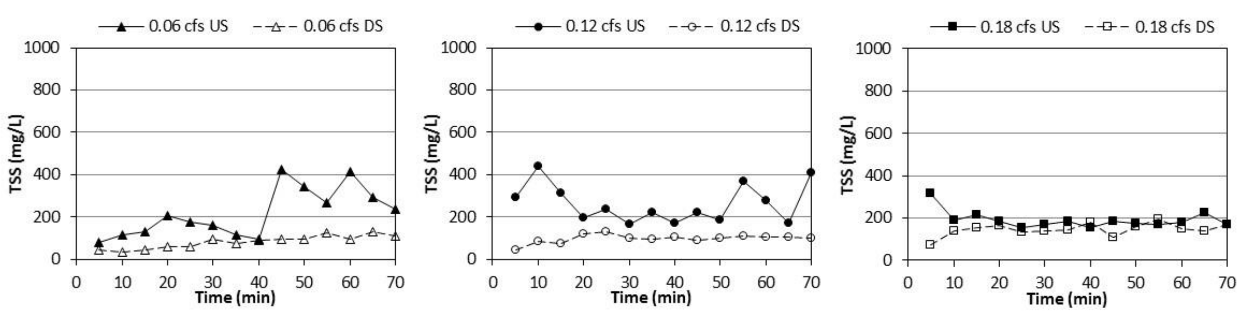
Avg. TSS reduction = 79.4%   Avg. TSS reduction = 59.3%   Avg. TSS reduction = 33.5%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 71.9%   Avg. TSS reduction = 50.4%   Avg. TSS reduction = 39.6%

(b) direct discharge testing with OK110 silica sand



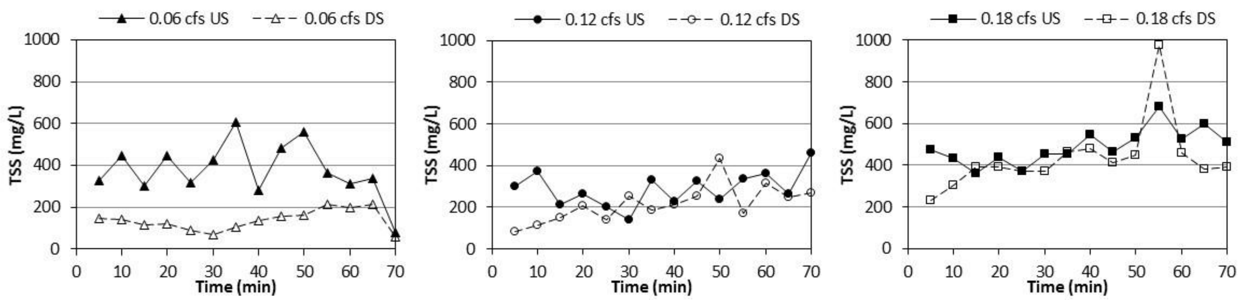
Avg. TSS reduction = 62.4%   Avg. TSS reduction = 62.8%   Avg. TSS reduction = 23.6%

(c) direct discharge testing with sandy loam soil

Figure C-36 Avg. TSS analysis data for Gullwasher for performance evaluation tests.

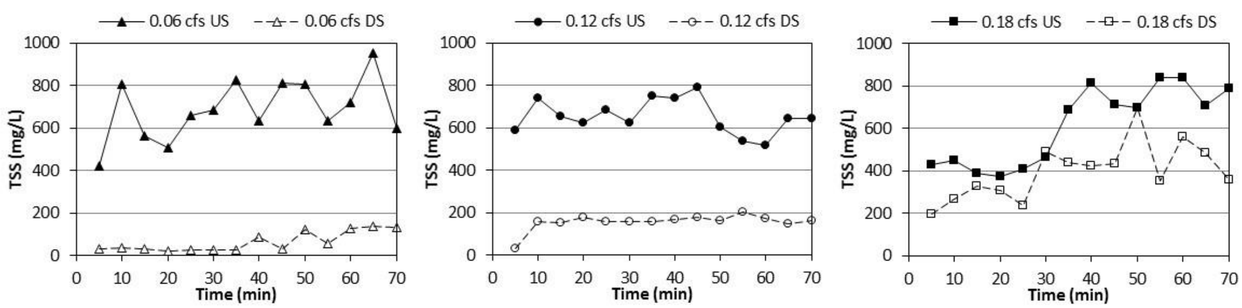
ENPAC STORM SENTINEL®

Figure C-37 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the Storm Sentinel®. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



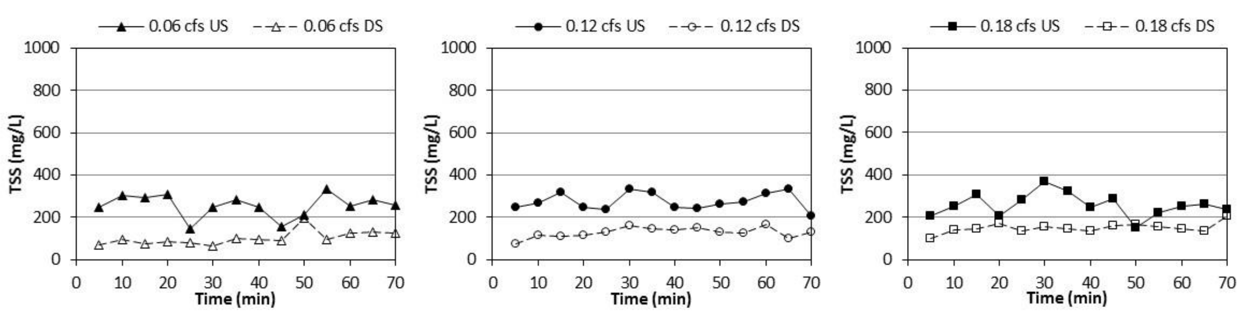
Avg. TSS reduction = 63.6%   Avg. TSS reduction = 25.0%   Avg. TSS reduction = 11.2%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 90.7%   Avg. TSS reduction = 76.0%   Avg. TSS reduction = 35.1%

(b) direct discharge testing with OK110 silica sand



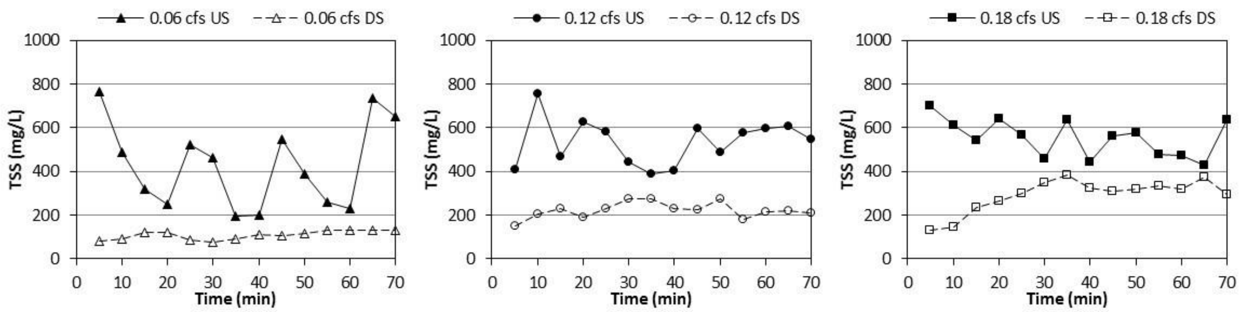
Avg. TSS reduction = 59.9%   Avg. TSS reduction = 53.2%   Avg. TSS reduction = 42.2%

(c) direct discharge testing with sandy loam soil

Figure C-37 Avg. TSS analysis data for Storm Sentinel® for performance evaluation tests.

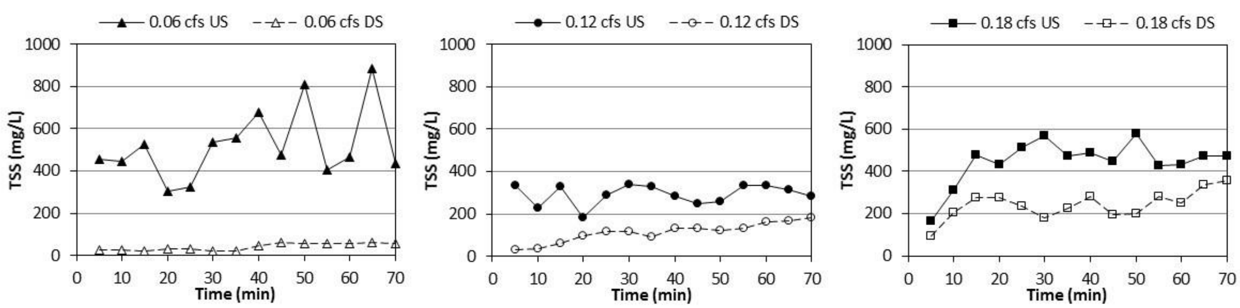
CONTECH ENGINEERED SOLUTIONS TRITON™

Figure C-38 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the Triton™. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



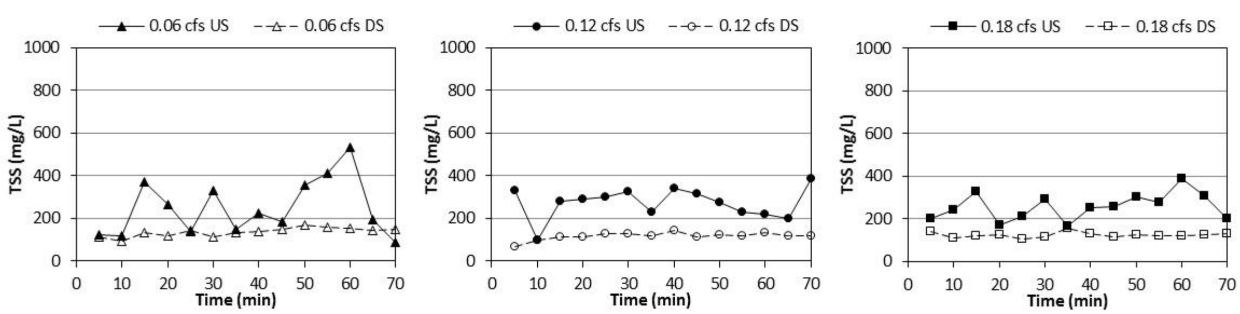
Avg. TSS reduction = 74.7% Avg. TSS reduction = 58.4% Avg. TSS reduction = 47.5%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 92.1% Avg. TSS reduction = 61.4% Avg. TSS reduction = 45.9%

(b) direct discharge testing with OK110 silica sand



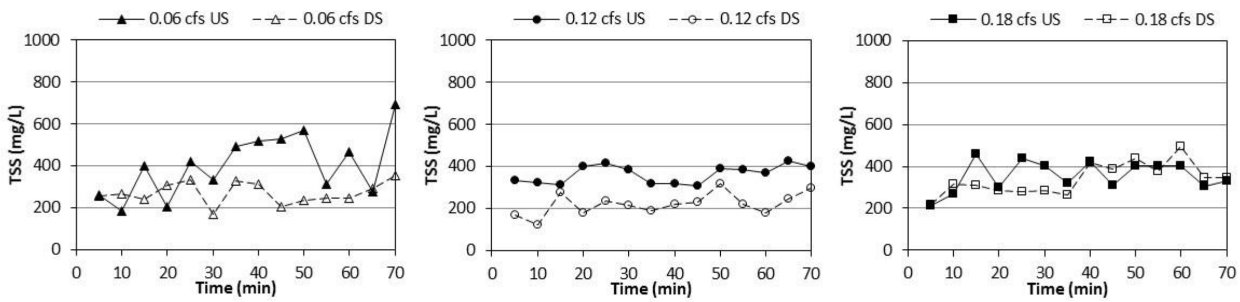
Avg. TSS reduction = 40.0% Avg. TSS reduction = 58.1% Avg. TSS reduction = 49.7%

(c) direct discharge testing with sandy loam soil

Figure C-38 Avg. TSS analysis data for Triton™ for performance evaluation tests.

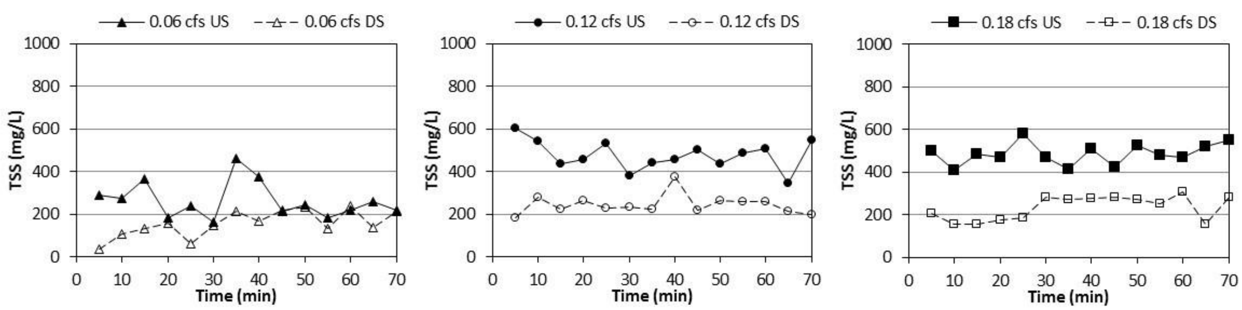
WATER QUALITY SOLUTIONS STORM-WATER EXFILTRATION BMP

Figure C-39 provides upstream and downstream TSS sample data and the corresponding TSS reduction percentages for each test performed on the WQS. Target concentrations for upstream samples was 450 mg/L for tests with OK110 silica sand, and 185 mg/L for tests with sandy loam soil.



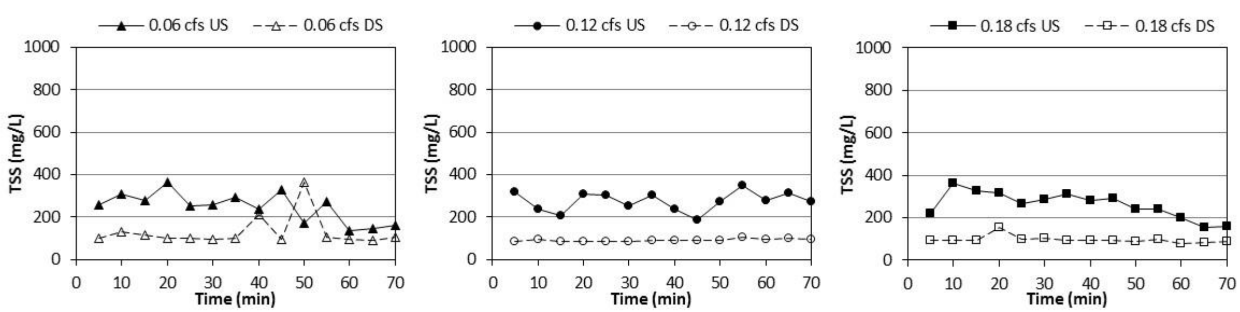
Avg. TSS reduction = 33.0%   Avg. TSS reduction = 38.9%   Avg. TSS reduction = 4.3%

(a) sheet flow testing with OK110 silica sand



Avg. TSS reduction = 40.2%   Avg. TSS reduction = 48.5%   Avg. TSS reduction = 52.0%

(b) direct discharge testing with OK110 silica sand



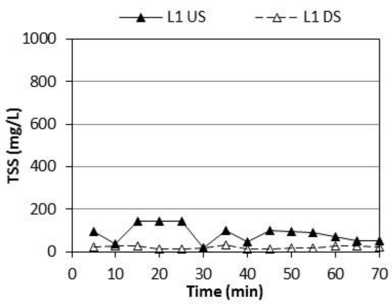
Avg. TSS reduction = 47.6%   Avg. TSS reduction = 66.8%   Avg. TSS reduction = 62.9%

(c) direct discharge testing with sandy loam soil

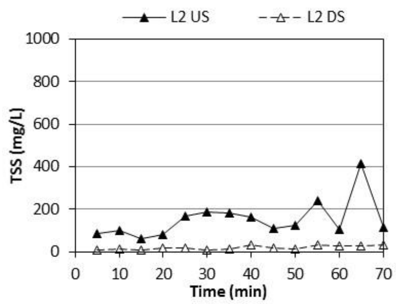
Figure C-39 Avg. TSS analysis data for WQS for performance evaluation tests.

LONGEVITY TESTING

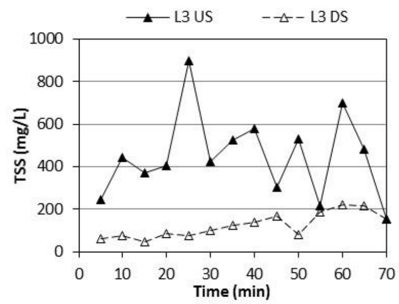
During the longevity testing phase of the research, TSS samples were only taken for tests with the DrainPac™ using OK110 silica sand. After these tests, it was decided that TSS data was no longer necessary for CBI evaluation. TSS data from the eight longevity tests of the DrainPac™ with OK110 silica sand, all at the 0.06 ft^3/s flow rate, can be found in Figure C-40.



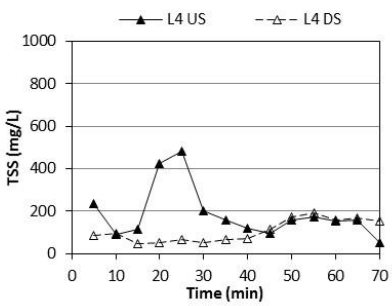
Avg. TSS reduction = 75.6%
(a) L1 test



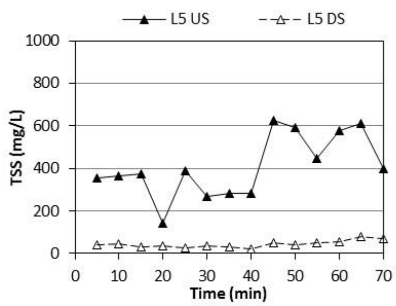
Avg. TSS reduction = 87.2%
(b) L2 test



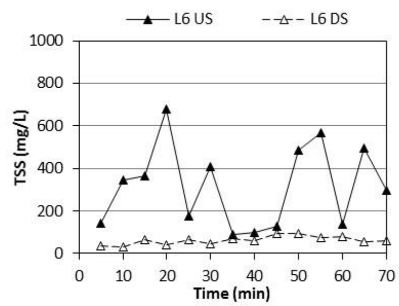
Avg. TSS reduction = 72.4%
(c) L3 test



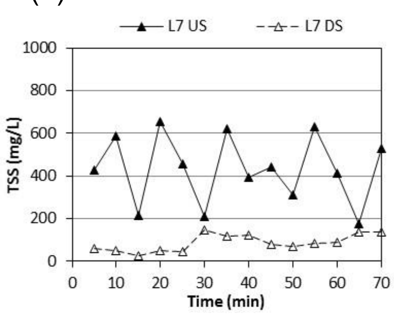
Avg. TSS reduction = 43.1%
(d) L4 test



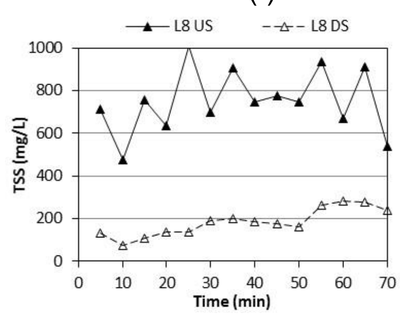
Avg. TSS reduction = 89.1%
(e) L5 test



Avg. TSS reduction = 80.3%
(f) L6 test



Avg. TSS reduction = 80.1%
(g) L7 test



Avg. TSS reduction = 75.6%
(h) L8 test

Figure C-40 Avg. TSS data from Longevity Testing with DrainPac™.

INFLUENT ANALYSIS

Upon completion of CBI testing, it was determined that sediment retention percentage was a better measure of sediment removal performance than TSS reduction, as 14 samples per test was not a large enough sample size to accurately determine the average TSS for each test. However, all upstream samples can be combined to create a large enough sample size to analyze introduction characteristics and ensure that the sediment introduction system was operating within tolerable bounds.

For all tests with OK110 silica sand, target influent concentration was 0.028 lb/ft^3 (450 mg/L). The average upstream TSS concentration for all samples with OK110 silica sand was 462.7 mg/L, a 2.8% error, indicating that the sediment introduction system operated well within tolerable limits. Two-sided hypothesis testing was conducted on this data to determine if x was significantly different than μ.

$$H_0: \mu = 450\, mg/L \qquad H_A: \mu \neq 450\, mg/L \tag{1}$$

H_0	=	null hypothesis
H_A	=	alternate hypothesis

$$z = \frac{x-\mu}{s} = \frac{462.7-450}{152.7} = 0.08 \tag{2}$$

z	=	z-score
x	=	sample mean
μ	=	target mean
s	=	sample standard deviation

A two-sided z-score of 0.08 corresponds to a p value of 0.9362. Since the p-value is greater than 0.05, we cannot say that this mean concentration is significantly different than the target concentration.

For all tests with sandy loam, target influent concentration was 0.012 lb/ft^3 (185 mg/L). The average upstream TSS concentration for all samples with sandy loam was 257.2 mg/L. A two-sided hypothesis test was conducted below. From this calculation, we cannot say that the mean concentration of 257.2 mg/L is significantly different than the target concentration of 185 mg/L.

$$H_0: \mu = 185\, mg/L \qquad H_A: \mu \neq 185\, mg/L \tag{3}$$

H_0	=	null hypothesis
H_A	=	alternate hypothesis

$$z = \frac{x-\mu}{s} = \frac{257.2-185}{90.6} = 0.80 \quad (4)$$

z	=	z-score
x	=	sample mean
μ	=	target mean
s	=	sample standard deviation

A two-sided z score of 0.80 corresponds to a p value of 0.4238. Since the p-value is greater than 0.05, we cannot say that this mean concentration is significantly different than the target concentration.

LINEAR REGRESSION ANALYSES FOR SEDIMENT RETENTION

PRODUCT COMPARISON ANALYSIS

Table C-18 summarizes findings from the statistical comparison portion of the first linear regression analysis, related to the sediment retention capabilities of the CBI products. Based upon the linear regression analysis, the Adsorb-It™ retained sediment at a statistically significant higher rate than any of the other CBI products, while the Flo-Gard Plus® retained sediment at a statistically significant lower rate than any of the other CBI products. When evaluating the results of the regression analysis, if a p-value of less than 0.05 is reported, it suggests that there is a statistically significant difference between the CBI product under consideration compared to other CBI products. A significant p-value paired with a negative comparison coefficient suggests that the CBI product under consideration performs better statistically than the comparison CBI product. In this case, a p-value of less than 0.05 was reported when the Adsorb-It™ was compared to all other CBIs and all comparison coefficients were negative, providing the result that the Adsorb-It™ performed significantly better than all other CBIs tested. Conversely, a significant p-value paired with a positive comparison coefficient suggests that the comparison CBI product performed better statistically than the CBI product under consideration. In this case, the Flo-Gard Plus® had a p-value less than 0.05 when compared to each of the other CBI products and a positive comparison coefficient, providing the result that the Flo-Gard Plus® performed significantly worse than all other CBI products tested.

Table C-18 Product Comparison Using Linear Regression Analysis

Product Name	Product Coefficient	Comparison	Comparison Coefficient	p-value[1]	Statistically significant[2]
Adsorb-It™	74.0	DrainPac™	-15.96	0.007	Yes
		FlexStorm®	-17.06	0.004	Yes
		Flo-Gard Plus®	-60.50	<0.001	Yes
		Gullywasher©	-20.44	<0.001	Yes
		Storm Sentinel®	-31.52	<0.001	Yes
		Triton™	-20.74	<0.001	Yes
		WQS	-32.72	<0.001	Yes
DrainPac™	58.04	FlexStorm®	-1.1	0.849	--
		Flo-Gard Plus®	-44.54	<0.001	Yes
		Gullywasher©	-4.49	0.438	--
		Storm Sentinel®	-15.57	0.009	Yes
		Triton™	-4.78	0.424	--
		WQS	-16.76	0.004	Yes
FlexStorm®	56.94	Flo-Gard Plus®	-43.44	<0.001	Yes
		Gullywasher©	-3.39	0.558	--
		Storm Sentinel®	-14.47	0.015	Yes
		Triton™	-3.68	0.537	--
		WQS	-15.66	0.007	Yes
Flo-Gard Plus®	13.50	Gullywasher©	40.06	<0.001	Yes
		Storm Sentinel®	28.98	<0.001	Yes
		Triton™	39.76	<0.001	Yes
		WQS	27.78	<0.001	Yes
Gullywasher©	53.55	Storm Sentinel®	-11.08	0.059	--
		Triton™	-0.29	0.961	--
		WQS	-12.28	0.033	Yes
Storm Sentinel®	42.48	Triton™	10.79	0.074	Yes
		WQS	-1.20	0.832	--
Triton™	53.26	WQS	-11.98	0.044	Yes

NOTE: [1] : α= 0.05
[2]: -- = the test failed to identify a statistically significant difference.

Flow Rate Comparison Analysis

The regression analysis also assessed the effects that the other factors (e.g., discharge method, soil type, and flow rate) have on sediment retention, which is summarized in Table C-19. Negative coefficients and p-values less than 0.05 suggest that there is a statistically significant decrease in sediment retention for both the medium and high flow tests compared to the low flow tests. However, because the 0.06 ft^3/s flow was used as the constant during this regression analysis, it does not conclude whether there is a difference in sediment retention between medium and high flow tests. Therefore, a separate regression analysis was conducted with 0.12 ft^3/s as the base. The coefficient between the 0.12 ft^3/s and 0.18 ft^3/s flow rate was -7.25 with a p-value of 0.044, suggesting that there is a statistically significant decrease in sediment retention when flow rates increases from 0.12 ft^3/s to the 0.18 ft^3/s. This suggests that a CBI products' performance is directly associated with the amount of flow entering the catch basin (i.e., sediment retention decreases as flow rate increases, or as drainage area increases).

Discharge Method Comparison Analysis

It can also be concluded that there was a statistically significant increase in sediment retention between sheet flow and direct discharge method tests. This supports the observations that many of the products were allowing sheet flow to bypass the CBI via a leak between the CBI and the catch basin frame, and therefore treating a smaller percentage of the runoff, and capturing less sediment. Therefore, from a product testing standpoint, it was beneficial to switch to the direct discharge method to assure each CBI product was tested under the same conditions eliminating the variable of leakage at the CBI seal with the catch basin frame.

Soil Type Comparison Analysis

Finally, while the data does show that there was a small decrease in sediment retention amongst tests with sandy loam compared to tests with the OK110 silica sand, the p-value is greater than 0.05, meaning we cannot conclude that there is a significant difference in sediment retention amongst the two soil types.

Table C-19 Test Characteristic Comparison

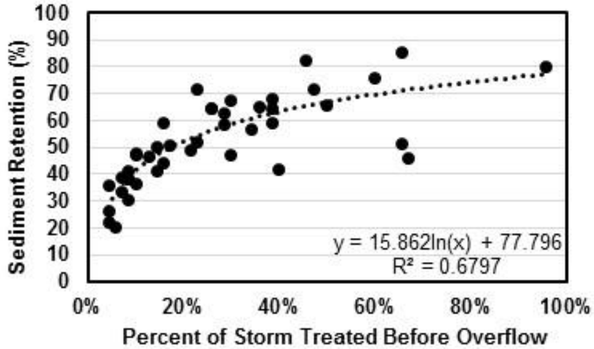
Test Characteristic	Statistical Significance		Statistically Significant[2]
	Coefficients	p-value[1]	
Constant	74.00	0.00	Yes
Flow (Base: 0.06 ft^3/s)			
0.12 ft^3/s	-8.14	0.024	Yes
0.18 ft^3/s	-15.39	<0.001	Yes
Discharge Method (Base: Sheet Flow)			
Direct Discharge	9.27	0.011	Yes
Soil Type (Base: OK110)			
Sandy Loam	-5.87	0.101	--

Note: [1]: α= 0.05
[2]: -- = the test failed to identify a statistically significant difference.

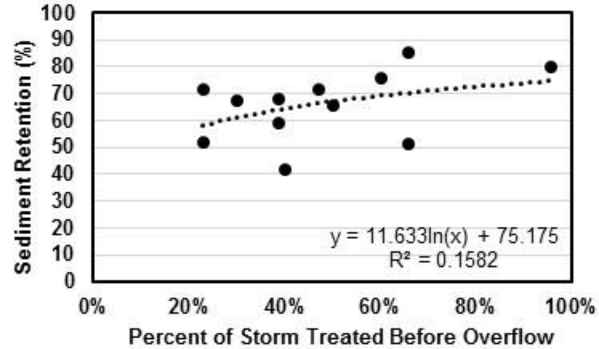
EFFECT OF OVERFLOW ON SEDIMENT RETENTION

Sediment retention data was also used to analyze the effect overflow events had on CBI performance. Sediment retention data was separated into two categories: (1) tests where overflow does not occur, and (2) tests where overflow does occur. To analyze overflow characteristics, Figure C-41(a) plots sediment retention for CBI products that experienced overflow. Products that did not produce overflow were not included in this analysis since high flow through rates would result in no overflow but also little sediment capture, contradicting the results of this analysis. Each CBI that experience overflow was analyzed by comparing the percent of the storm that was treated before overflow occurs. This illustrates the relationship between overflow and sediment retention values. For example, if 90% of the storm is treated before overflow occurs, sediment retention is likely to be greater than if only 10% of the storm was treated before overflow begins. The data was then fit with a logarithmic trendline to measure the relationship between the two variables. It can be seen from the coefficient of determination that there is a positive, moderately strong correlation between time at which overflow occurs and sediment retention. This means that tests that lasted longer before allowing overflow were more likely to retain a higher percentage of the introduced sediment. A logarithmic trendline provided the best-fit trendline because, while sediment retention does continue to increase with increase in time before overflow, sediment retention will eventually approach a maximum and begin to plateau. Therefore, if overflow occurs early, one can expect much less sediment to be captured. However, overflow that begins near the end of the event has little impact on sediment retention. From these analyzes, it appears that the best performing product would be one that minimizes flow through the fabric to the point of water impounding to near the point of overflow. However, overflow should be minimal and begin near the end of the storm event, resulting in the largest percent of particle size capture.

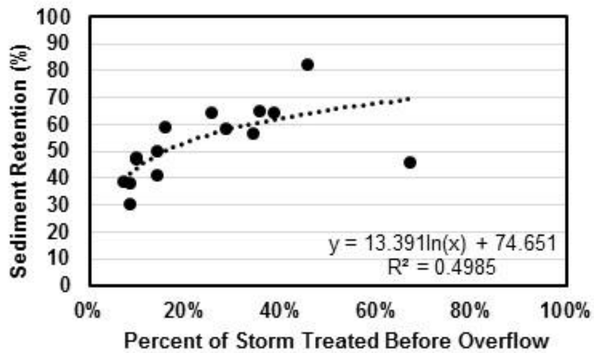
Figure C-41 (b-d) contain the same information as Figure C-41(a) but are separated by the flow rate used for testing. It can be seen that there is little correlation between overflow and sediment retention during low flow tests. However, correlation increases with flow rate. One possible explanation for this is that higher flow rates enter the CBI with greater energy, therefore causing re-suspension of captured particles, and hindering sediment retention. At low flow rates, the influent enters the catch basin with less energy and less potential for re-suspension, therefore having little effect on sediment retention.



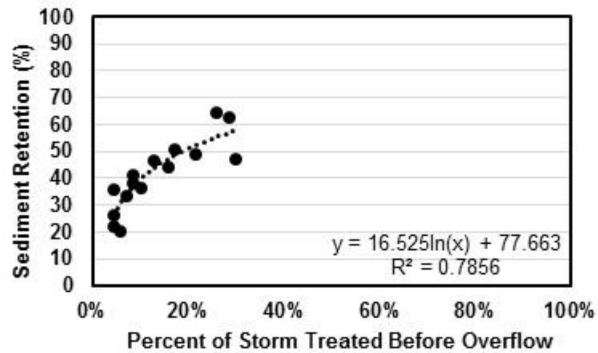
(a) all flow rates



(b) 0.06 ft^3/s



(c) 0.12 ft^3/s



(d) 0.18 ft^3/s

Figure C-41 Comparing overflow to sediment retention