# MAINTENANCE GUIDANCE FOR STORMWATER HYDRODYNAMIC SEPARATORS

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**A Dissertation submitted to the**

**Graduate School-New Brunswick**

**Rutgers, The State University of New Jersey**

**in partial fulfillment of the requirements**

**for the degree of**

**Doctor of Philosophy**

**Graduate Program in Civil and Environmental Engineering**

**written under the direction of**

**Qizhong Guo**

**and approved by**

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**New Brunswick, New Jersey**

**October, 2014**

**ABSTRACT OF THE DISSERTATION**

**Maintenance Guidance for Stormwater Hydrodynamic Separators**

**by JUNG-HOON KIM**

**Dissertation Director:**

**Professor Qizhong Guo**

The goal of this research is to develop effective maintenance procedures and quantify maintenance schedules for stormwater manufactured treatment systems, known as Hydrodynamic Separators (HDS). The HDS has started to be widely used with the purpose of removing pollutants from stormwater runoff and its use is expected to continue in the foreseeable future. Therefore, determining optimum maintenance procedures, intervals and costs is vital for their successful utilization.

Information on characteristics and location of each installed HDS was collected and identified through a field monitoring and maintenance study. Based on this information, twelve (12) HDS were selected and three (3) data forms were developed: asset data form, inspection data form, and maintenance data form to help level the playing field, properly track the devices, and inspect and maintain the devices in a timely fashion and in a cost-effective way.

Before initiation of the continuous monitoring program, stormwater and bottom sediment, the quantities of bottom sediment, oil, and buoyant debris in the devices were measured and the samples of trapped water and bottom sediment were taken for the quality analysis. Measured quantity and quality of the trapped stormwater solids varied widely from site to site. Total depth of the bottom sediment ranged from 2.7 feet

(exceeding the maintenance limit of 2 feet) to 0.5 feet. On average, about 90 percent of the solids trapped on the bottom had a mean particle size larger than 75 microns: coarse sediment. Organic content of the bottom sediment ranged from 3 to 34 percent. Measured concentrations of all the heavy metals (copper, zinc, lead, cadmium, and arsenic) in the bottom sediment were much lower than the New Jersey residential soil contamination limits indicating that the bottom solids could be disposed of at standard sanitary landfills. Concentrations of phosphorus and nitrogen in the bottom sediment were much lower than those in typical sewage sludge.

The units were frequently (every two to three months) and continuously monitored from the clean state across a full spectrum of storms. After three years of monitoring, six (6) devices had reached capacity, and they were cleaned out and restarted for monitoring.

As a result of the monitoring and evaluation, an ideal and efficient maintenance procedure and interval were determined. For the sites of general conditions, the maintenance intervals were measured to be from three to four and one half years. For planning future maintenance/cleanout activities, it is recommended that the predictive model be used with the number of vehicles on the road(s) and the impervious drainage area as inputs.

## ACKNOWLEDGEMENTS

Foremost, I would like to express my deepest gratitude to my advisor, Professor Qizhong Guo, for his excellent guidance, fundamental ideas, patience, and providing me with an excellent atmosphere for doing research. I have benefited greatly from his experience. I could not have imagined having a better advisor and mentor for my Ph.D study.

Besides my advisor, I would like to thank the rest of my thesis committee: Prof. Perumalsamy N. Balaguru, Prof. Steven Medlar and Prof. Christopher Uchrin for their encouragement, insightful comments, and consistent advices.

My sincere thanks also go to NJDOT staff members: Edward Kondrath, Jay Walsh and Silvia Eskander.

I thank my fellow labmates in Rutgers University: Arjun Raju, Carlos Correa, Joseph Yamin, Victoria Fernandez-Martinez, and Yunjie Li. Appreciations are also extended to the faculty and staff of the Department of Civil and Environmental Engineering of Rutgers University and CAIT staff members.

Last but not the least, I would like to thank my family: my wife (Eun mi), sons (Hayden and Harry) and parents for constant love and support.

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# Chapter 1

# Introduction

## 1.1 Stormwater management in roads and highways

Stormwater runoff in roads and highways carries litter, organic waste, hydrocarbons, heavy metals, and other pollutants. Lead, cadmium, zinc, and copper are among the contaminants that have been reported in highway stormwater runoff sediment (Jartun et al., 2008; Mikkelsen et al., 1997). These pollutants are toxic to both aquatic and terrestrial organisms and many of them bioaccumulate along the food chain. Humans can be exposed to these pollutants by drinking water or by consuming plants and animals that have been exposed to them.

Managing and preventing the discharge of these pollutants has become increasingly important as more roads and highways are built and as more and more vehicles transit on them. It is known that most pollutants carried with highway stormwater runoff adsorbed to sediment or float as oils and debris. In order to understand how pollutants are carried in stormwater runoff and how regulations have been defined to try to control this pollution, it is necessary to define gross solids.

## 1.2 Regulations for Stormwater Discharge

### 1.2.1 Federal Regulations

The Clean Water Act (1977) required The United States Environmental Protection Agency (US EPA) to develop regulations for stormwater discharges under the National Pollutant Discharge Elimination System (NPDES). NPDES permits started being implemented in 1990 and cover several state highway departments (US EPA, 1999b), which are required to adhere to guidelines for stormwater discharges. US EPA allows most states to manage NPDES permits. NPEDS permits were issued under CWA section 04.

### 1.2.2 NJ DEP Storm Water Management Regulations

In New Jersey, the New Jersey Department of Environmental Protection (NJ DEP) is in charge or regulating NPDES permits (2004). NJ DEP has issued Stormwater Management rules (N.J.A.C. 7:8, 2010)  to regulate stormwater discharges in new developments and redevelopments. The amended rules emphasized the storm water management goals to include measure to reduce soil erosion from any development or construction project, prevent an increase in non-point pollution, minimize pollutants from new and existing development and protect public safety through the proper design and operation of stormwater management.

## 1.3 Stormwater BMPs

In order to comply with the rules and regulations, several structural and non-structural stormwater Best Management Practices (BMPs) have been developed to manage stormwater runoff.

### 1.3.1 Non-structural BMPs

Non-structural stormwater BMPs encompass measures that do not require adding physical infrastructure. Some non-structural BMPs include pollution prevention procedures, education programs, and strategic planning (Taylor and Wong, 2002).

### 1.3.2 Structural BMPs

Structural stormwater BMPs on the other hand include physical systems built to mitigate the effects of stormwater runoff in receiving waters. Structural stormwater BMPs include constructed wetlands, infiltration basins, bioretention systems, pervious pavement systems, and Manufactured Treatment Devices (MTDs) among others (NJ DEP, 2009). MTDs are prefabricated stormwater treatment systems used to trap sediment, litter, and organic material carried by stormwater runoff. MTDs are usually installed where other BMPs cannot be installed due to limited space availability. The use of MTDs is expected to continue being an integral part of highway stormwater runoff management practices in the future. There are two types of MTD: filters and hydrodynamic separators (HDS). Filter type MTDs work by providing a physical barrier that only allows solids beyond a set threshold to pass, retaining the rest. Hydrodynamic separators are the main focus of this proposal and will be described in the next section.

## 1.4 Hydrodynamic Separators

Hydrodynamic separators take advantage of the centripetal forces of a vortex to separate settleable solids from the stormwater. The general principle of operation of hydrodynamic separators can be described as follows. Stormwater flows enter the unit tangentially to the swirl chamber, which promotes a gentle swirling motion. As polluted water circles within the swirl chamber, pollutants migrate toward the center of the unit where velocities are lowest. The majority of settleable solids are left behind as the stormwater exits the swirl chamber. Buoyant debris and oil and grease are separated from water flowing under a baffle wall or device due to their low specific gravity relative to water. As stormwater exits the system, a portion of both the floating and settleable pollutants in the inflow are removed.

A field study (Rushton, 2006) indicates that an overwhelming majority of solids trapped in HDS (90% in mass) consists of gross solids (larger than 75 microns) rather than fine solids (or suspended solids). Stormwater differs from wastewater by being intermittent in nature and often having high volumes of gross solids. An accurate quantification and characterization of gross pollutants is needed in determining maintenance requirements and schedules. Also, most gross pollutants cannot be measured by using autosamplers and standard techniques typically used to evaluate the TSS removal efficiencies.

Several manufacturers of HDS have obtained permanent or interim certification from New Jersey Department of Environmental Protection (NJDEP) to be used throughout the State of New Jersey.

**MTDs Certified for Use in the State of New Jersey**

Based on the list provided by the NJDEP on its web site, http://www.njstormwater.org/treatment.html, as of May 2010, a total of 21 types of Manufactured Treatment Devices (MTDs) have been certified for use in the State of NJ.

Among the certified MTDs, 14 are hydrodynamic separators (HDS). They were given a credit of 50% TSS removal efficiency. Since most of the devices were approved for use in NJ only in the last few years, most of the listed devices have not yet been installed in NJDOT projects.

- Aqua-Swirl Concentrator
- BaySeparator
- Downstream Defender
- FloGard Dual-Vortex Hydrodynamic Separator
- High Efficiency Continuous Deflective Separator (CDS) Unit
- Hydroguard
- Nutrient Separating Bafflle Box
- Stormceptor OSR
- Stormceptor STC
- TerreKleen Stormwater Device
- Up-Flo Filter by Hydro
- V2B1
- Vortechs Stormwater Treatment System
- VortSentry System

There are 6 certified filter devices. NJDOT has not allowed the filter devices to be used, primarily due to the concern of heavy maintenance. They were given a credit of 80% TSS removal efficiency:

- AquaFilter Filtration Chamber
- Bayfilter
- Jellyfish Filter
- Media Filtration Systems
- Stormwater Management StormFilter
- VortFilter System

There is one (1) certified underground storage device. It was given a credit of 80% TSS removal efficiency. NJDOT has been using the underground storage devices as a storage device for flood control instead of water quality:

- StormVault

Types of HDSs that have received interim certification from NJDEP for a specific TSS removal efficiency and have been installed in NJDOT projects are listed below:

- Aqua-Swirl® ( by AquaShield, Inc.): 50%
- CDS® (by CDS Technologies, Inc.): 50%
- Downstream Defender® (by Hydro International): 50%
- Stormceptor® (by Rinker materials): 50%
- TerreKleen Stormwater Device® (by Terre Hill Concrete Products): 50%
- VortSentry® (by Contech Stormwater Solutions): 50%

- Vortechs® (distributed by Contech Stormwater Solutions): 50%

(Source: http://www.nj.gov/dep/stormwater/treatment.html)

### 1.4.1 Vortechs® Hydrodynamic Separator

The HDS most commonly used by NJDOT is the Vortechs® Stormwater Treatment System. Vortechs® units typically have three distinct chambers: a swirl chamber, a baffle chamber and an outlet chamber. Figure 1 shows the typical configuration of a Vortechs® unit.

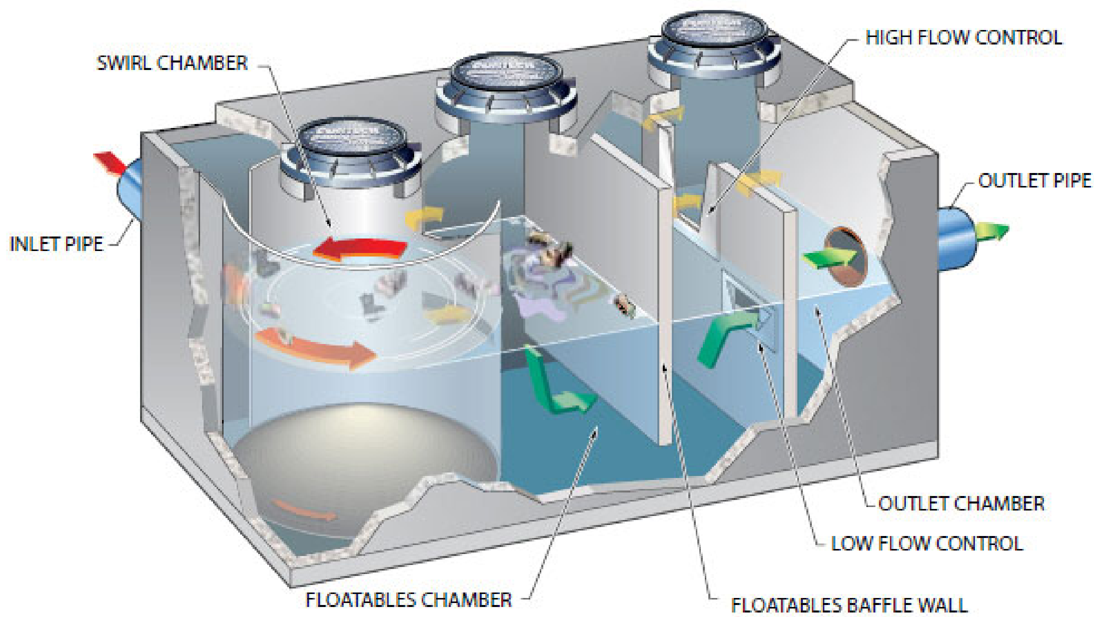



**Figure. 1.1 Vortechs® stormwater treatment system (from CONTECH, 2011)**

A conical pile containing sediment and associated metals, nutrients, hydrocarbons and other pollutants tends to accumulate in the center of the swirl chamber over time.

Floating debris and oil and grease form a floating layer trapped in front of the baffle wall. Accumulation of these pollutants can be accessed through manholes over each chamber. Maintenance is typically performed through the manhole over the swirl chamber.

The units are typically sized to remove 80% of the annual load of suspended solids, based on laboratory generated performance curves for 50-micron sediments particles. However, the solids removal performance of these manufactured stormwater treatment devices varies widely with operating conditions, evaluation (lab or field) techniques, as well as runoff characteristics such as particle sizes (Guo, 2005). Therefore, removal efficiency for total suspended solids (TSS) was certified by the New Jersey Department of Environmental Protection (NJDEP) to be only 50% for a specific design flow rate. The unit is usually pre-fabricated off site and there are other manufacturers with similar devices. The acquisition and installation cost of an individual unit is typically less than one hundred thousand dollars.

## 1.5 Objectives of Current Study

From the system maintenance/cleaning point of view, it is important to know the amount of solids, oil, grease, and buoyant debris that are trapped in the unit across a full spectrum of storm events continuously over a long period of time, and for a variety of highway drainage area characteristics such as size, slope, soil type, traffic volume, and location. Knowing the amount of contaminants trapped in the unit continuously over a long period of time can also provide a more reliable assessment of water quality performance of the unit. However, actual field data of this type is lacking at NJDOT and federal and state highway agencies.

The goals of this research are to develop effective maintenance procedures and quantify maintenance schedule for HDS. HDS have started to be widely used with the goal of removing pollutants from stormwater runoff and are expected to continue in the foreseeable future. Therefore, determining optimum maintenance procedures and intervals is vital for their successful utilization.

The major objectives of this research are to:

- Select representative sites and devices for monitoring and evaluation.
- Monitor the amounts of sediment, oil, grease, and buoyant debris that would be actually trapped in the HDS.
- Analyze quantity and quality of trapped material for evaluation.
- Relate the trapped amounts of sediment, oil, grease, and buoyant debris to variables such as rainfall intensity and duration, characteristics of drainage area, traffic count, source control, seasonality and deicing practices.
- Provide quantitative guidance on the maintenance/cleanup schedule.
- Establish maintenance/cleanup procedure.
- Develop information for properly inspecting and maintaining the HDS.
- Recommend design considerations to facilitate maintenance
- Recommend measures to reduce maintenance costs.

# Chapter 2

# Review of Literature

This literature search and review mainly concentrated on the following aspects: (1) highway runoff quality and quantity; (2) HDS maintenance rules/regulations; (3) maintenance guidelines and interval for HDS.

Due to the limited scientific literature available on HDS maintenance, gray literature and documents produced by the manufacturers were included. Also NJDEP regulations and maintenance manuals for each type of HDS were consulted, as well as maintenance guidelines by ASCE/EWRI.

## 2.1 Highway runoff quality and quantity

Pointer et al. (2003) monitored a wetland system for control of highway runoff over 18 months. Their result showed that there were progressive changes for BOD, COD and metal concentrations in the sediment fractions.

Sediments from retention/detention ponds receiving highway runoff contained high nutrient and heavy metal content but were not hazardous waste. (Yousef et al. 1991)

## 2.2 Hydrodynamic Separators maintenance rules/regulations

All the regulatory agencies require that stormwater BMPs be maintained properly. In the State of New Jersey, the NJDEP Stormwater Management Rules require a maintenance plan to be developed for all stormwater management measures incorporated into the design of a major development.

The paragraph of the New Jersey Stormwater Best Management Practices Manual (NJDEP, 2009) regarding the required maintenance plan reads as follows:

“This maintenance plan must contain specific preventative and corrective maintenance tasks, schedules, cost estimates, and the name, address, and telephone number of the person or persons responsible for the measures’ maintenance.”

Specific maintenance requirements for the manufactured treatment devices are presented in Section 9.6: Standard for Manufactured Treatment Devices (MTDs). These requirements must be considered in the MTDs maintenance plan. They are reproduced as follows:

- General Maintenance

This section require that all MTDs should be inspected and maintained in terms of the manufacturer’s instructions, and other requirements associated with the device’s certification by the NJDEP Office of Innovative Technology.

- Structural Components

″All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.”

- Other Maintenance Criteria

Further, the maintenance plan should specify the maximum allowed accumulation level of sediment, and debris, etc. before removal is needed. At the same time, these levels should be monitored during the regular device inspection to help determine the need for removal and other device maintenance.

## 2.3 Maintenance guidelines and interval for HDS

Few field studies have been conducted to quantify the actual maintenance interval for HDS and to relate it to the drainage area characteristics. Kim et al. (2007) indicated regular maintenance of HDS is critical to maintain effluent concentration. They found that lack of maintenance can lead to misbehavior such as scour and re-partitioning. It is suggested that structural BMP systems must include hydrologic restoration, frequent maintenance, sludge/solute management and should be considered only after source control measures have been shown not to be effective.

**Maintenance schedule**

In the studies consulted, it was difficult to find a standardized maintenance schedule for HDS with supporting data.

A protocol for HDS based on laboratory analysis provided an equation to compute sediment removal interval (NJDEP, 2009). The equation estimated interval based on 50% of the HDS's maximum sediment storage volume utilizing the HDS's annual TSS removal rate, annual average New Jersey rainfall, an estimated runoff coefficient, sediment loading rate, and wet sediment density, and an appropriate safety factor.

The required sediment removal interval of the tested HDS shall be computed by the following equation:

Required Sediment Removal Interval (Months) =

$$\frac{(50\% \text{ of HDS's Maximum Sediment Storage Volume})(3.57)}{(\text{Maximum Treatment Flow Rate})\ (\text{TSS Removal Efficiency})}$$

Connecticut Department of Transportation (ConnDOT) projects recommend a maintenance frequency of once a year (ConnDOT, 2010). However, this seems to be a general estimation based on manufacturer's recommendation.

Maintenance schedule from individual manufacturers

Each manufacturer recommends specific maintenance schedule and methods for their product.

Aqua-Swirl®:

During the first year of operation, the manufacturer recommends that the unit be inspected every three (3) months to determine the schedule of maintenance. It is also recommended that the inspection schedule be revised to reflect the site-specific conditions encountered (AquaShield, 2010).

CDS®:

It is recommended that the unit be cleaned when the level of sediment has reached 75% of capacity in the isolated sump or when an appreciable level of hydrocarbons and trash has accumulated (CONTECH, 2010). It is also recommended that the unit be pumped out and the screen inspected for damage at least once per year. (EPA, 1999)

Downstream Defender®:

During the first year of operation, the manufacturer recommends that the unit be inspected every six (6) months to determine the rate of sediment and floatables accumulation. The maintenance schedule can be established based upon these inspection records. (Hydro International, 2010)

Stormceptor®:

Maintenance is determined through inspection of the device. Generally, annual maintenance is recommended by the manufacturer. It is also recommended that the frequency of maintenance be increased or reduced based on local conditions. For example, if the sediment load is high, frequency of maintenance may be semi-annual. (Stormceptor, 2010)

Terre Kleen®:

During the first year of operation, the manufacturer recommends that unit be inspected every three (3) months to determine the type and amount of pollutants in the unit. The frequency of maintenance can be established based upon the quarterly inspections. (TERRE HILL, 2010)

Vortechs®:

The manufacturer recommended that the unit be inspected twice per year typically and more frequently based upon site condition. It is recommended that the unit be cleaned when inspection reveals that the sediment depth has accumulated to within 12 to 18 inches (300 to 450 mm) of the dry-weather water surface elevation. (CONTECH, 2010).

VortSentry®:

The manufacturer recommended that the unit be inspected twice per year typically and more frequently based upon site condition. It is recommended that the unit be cleaned when inspection reveals that the sediment depth has accumulated to a depth of three (3) feet in the treatment chamber. (CONTECH, 2010).

**Inspection and maintenance methods / procedures:**

<u>Inspection and maintenance guidance for manufactured BMPs (ASCE)</u>

ASCE/EWRI has assembled a Task Committee on guidelines for certification of manufactured stormwater BMPs. A nine-member subcommittee for maintenance was tasked by the larger committee to develop maintenance guidelines for manufactured stormwater BMPs.

According to the report, the subcommittee has developed recommendations for manufactured BMP maintenance in the following seven areas:

- Designing for maintenance.
- Defining standard maintenance triggers.

- Defining maintenance fundamentals for all manufactured BMPs.
- Defining maintenance tasks by BMP design; hydrodynamic or filter design.
- Identifying entities best able to maintain manufactured BMPs, and training requirements.
- Identifying entities to train maintenance providers
- Reviewing recommended disposal techniques for captured pollutants.

Maintenance trigger:

When the BMP is handed over to the property owner/ manager, the BMP must be essentially clean. It is the responsibility of the installer or contractor to leave the BMP in a clean state. After a clean BMP has been accepted by the maintenance authority, inspections should be made quarterly for one year to determine the appropriate cleanout intervals.

Cleanout operations should be triggered by any one of or combination of the following circumstances:

- "A regularly scheduled cleanout interval pre-determined by the manufacturer."
- "Sediment accumulations reach the depth recommended by the manufacturer for cleaning. The appropriate depth of sediment determination should be facilitated by a mark or object placed in the BMP. This indication should be readily visible under low light conditions."
- "In filter devices, the water drawdown time exceeds the drawdown time recommended by the manufacturer. An easily readable plaque should be placed inside the BMP indicating the recommended drawdown time."

It is possible that providing an upstream pretreatment of gross solids can increase the time intervals and decrease the expense of BMP cleaning. However removal of pollutants by a pre-treatment device only shifts the burden of maintenance to a device further upstream. There is no conclusive evidence that the total expense of maintaining a system of BMPs is reduced if pre-treatment is used.

Disposal of wastes:

Since a drainage basin is privy to pollutant loadings from a wide array of sources, there exists a potential for high concentrations of various pollutants within the BMPs. Therefore the reports recommended that all materials removed from a BMP should be disposed of in a properly permitted landfill in accordance with applicable local or state guidelines. The committee did not come to consensus as to whether the prospective waste material should be tested for pollutant concentrations.

Maintenance plan from the protocol (NJDEP, 2009).

- "Minimum required maintenance frequency for each component in order to achieve the annual TSS removal rate, including the required sediment removal interval and associated sediment depths."
- "Description of what conditions trigger the need for maintenance and how neglect of specified maintenance activities (e.g., sediment removal, filter media replacement, oil removal) causes BMP underperformance;"
- "Location of Access Points and type of inspection needed – whether above ground or underground;"
- "Training needed to Perform Maintenance. This may include training videos to be made available to maintenance staff."

- "Equipment needed for maintenance and discussion of obtaining replacement parts. This must indicate what portions of the MTD are only available through the vendor."

Maintenance guidelines from the manufacturer

CONTECH, the manufacturer of Vortechs®, recommends specific maintenance and Inspection methods (CONTECH, 2010). A stadia rod should be used to inspect the sediment level in the swirl chamber. Two measurements should be taken out: one from the manhole cover to the top of the sediment, and another from the manhole cover to the surface of water. When the depth of sediment has been accumulated to a level of 18 to 24 inches, the cleanout should be performed.  A vacuum truck is used to remove the sediments and the floatables by inserting a vacuum hose into the swirl chamber.

Maintenance guidelines from the stormwater profession

The stormwater profession has also started to act together to generate maintenance guidance. The subcommittee was set up by a large ASCE/EWRI task committee to generate the MTDs maintenance guidelines (Hunt et al. 2008) and developed recommendations for manufactured BMP maintenance.

# Chapter 3

# Information for Selecting, Inspecting, and Maintaining HDS

## 3.1 Introduction

In order to select, inspect, and maintain hydrodynamic separators (HDS) properly, it is necessary to have complete information on characteristics and location of each HDS. Also, keeping track of the dates of each inspection, cleanout procedure and conditions at each site along time will facilitate maintenance forecasting and will allow adjusting the preventive maintenance plan as conditions and seasons change. To facilitate this task, the location of HDS was distributed and three data forms (1.asset data, 2.inspection data, 3.maintenance data) were developed

## 3.2 Location and mapping of HDS in New Jersey

Requests for information on installed Hydrodynamic Separators (HDS) were made to vendors and to the New Jersey Department of Transportation (NJDOT)

The four (4) main sources of information used were:

1. NJDOT Bureau of Research - Stormwater System Monitoring and Evaluation (NJDOT, 2010). During research for this project, the information had been obtained from NJDOT and vendors for HDS installed between 2000 (the plan approval year) and 2007.
2. Lists of devices sold by vendors between 2008 and February 2010.
3. NJDOT lists of projects bid upon between September 2005 and January 2010 that were thought to contain HDS.

4. NJDOT list of projects under design or not yet advertised that were thought to contain HDS.

As the study progressed, other sources of information were added. Internet searches, for example, allowed the identification of one device not contained in any of the four (4) sources mentioned above.

The information gathered from these sources was organized and compiled in a list of devices that could potentially be HDS. That list served as a starting point for identifying and locating HDS.

**Data mining from plans and additional sources**

After exploring different alternatives to locate the listed devices, it was determined that the best approach would be to identify them on plans. Some of the projects in the original list of devices did not have a project number associated with them, which made it more difficult to locate the plans. NJDOT successfully identified the project number for many of the projects, while others were found by reviewing the construction bid awards available on the NJDOT website (NJDOT, 2010).

The review of the plans provided confirmation of the type of device (HDS or other stormwater BMPs), their location and other useful information. Each plan was scanned thoroughly to identify the HDS. A description of the location of the HDS was tabulated as well as the name of the device on the plans, the standard item number and the sequence number. The page number in which each device was found on the plans was also recorded. The location details include the road on which the device is located (or the nearest road), the direction in which the vehicle would need to be moving to locate the

HDS without crossing the road, the nearest cross road, the estimated mile post and additional landmark information that can aid to locate the device on site.

The key sheet (usually the front page of the plans, see Figure 3.1) was used to confirm details like the project name, project number, plan approval date and design company. Since some projects were listed under different names by different sources, the project name and number from the plans helped identify devices that had been listed twice. The plan approval date served as an additional cross reference by matching it with device delivery dates and construction awards lists.

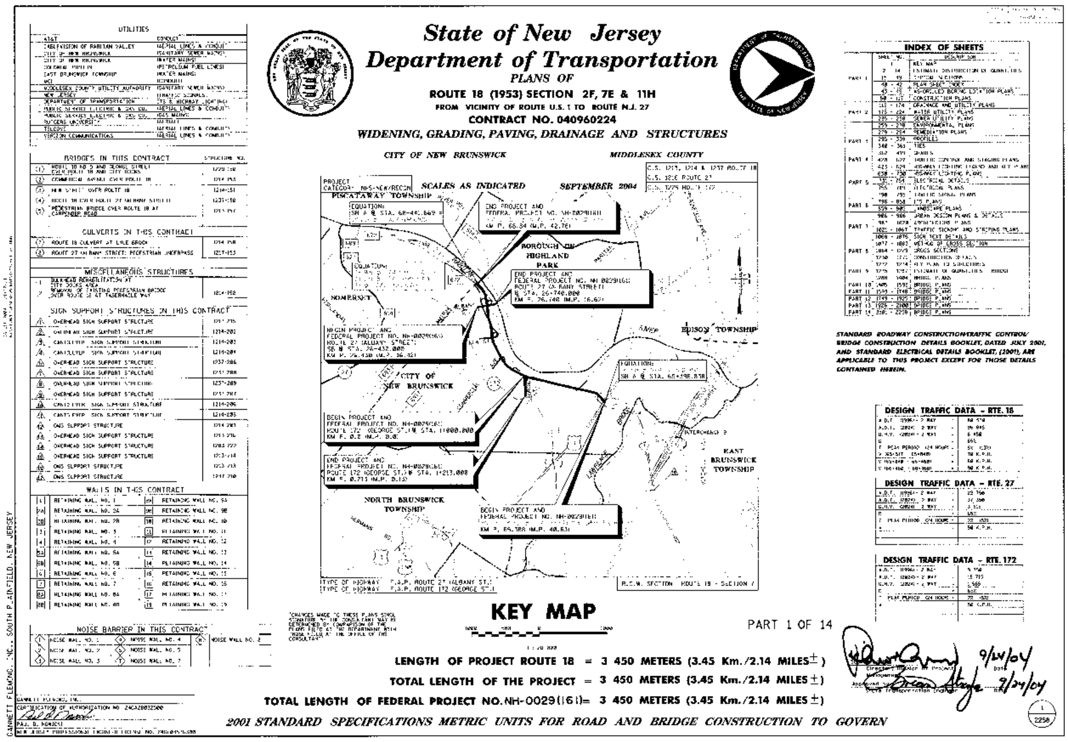



**Figure 3.1 Key sheet sample**

Other references such as straight line diagrams and special provisions pages were also consulted in an effort to produce information as accurately as possible.

The most recent straight line diagrams (SLDs), available on the NJDOT website (http://www.state.nj.us/transportation/refdata/sldiag/) were used to estimate the mile post where the device is located relative to the main road. In the cases where the device is located on a secondary road, the mile post reference was left blank since only the state road SLDs were available.

The devices location table includes columns to tabulate the latitude and longitude that can be obtained with a GPS during physical inspection of the device.

**Mapping**

In parallel with mining data from the plans, each device identified on the plans was marked on a Google street map that shows the adjacent roadways and the scale of the map (see Figure 3.2 for a sample). In most cases the device location must be accurate within fifty (50) feet.


**Figure 3.2 Sample of map showing location of a HDS**

A county map of New Jersey was used to mark a roughly estimated location of all the projects found to have hydrodynamic separators (HDS) and the number of devices per project. The map (Figure 3.3) gives an overview of the distribution of HDS in New Jersey. Because NJDOT has not allowed the filter devices, all identified MTDs in this study are HDS.

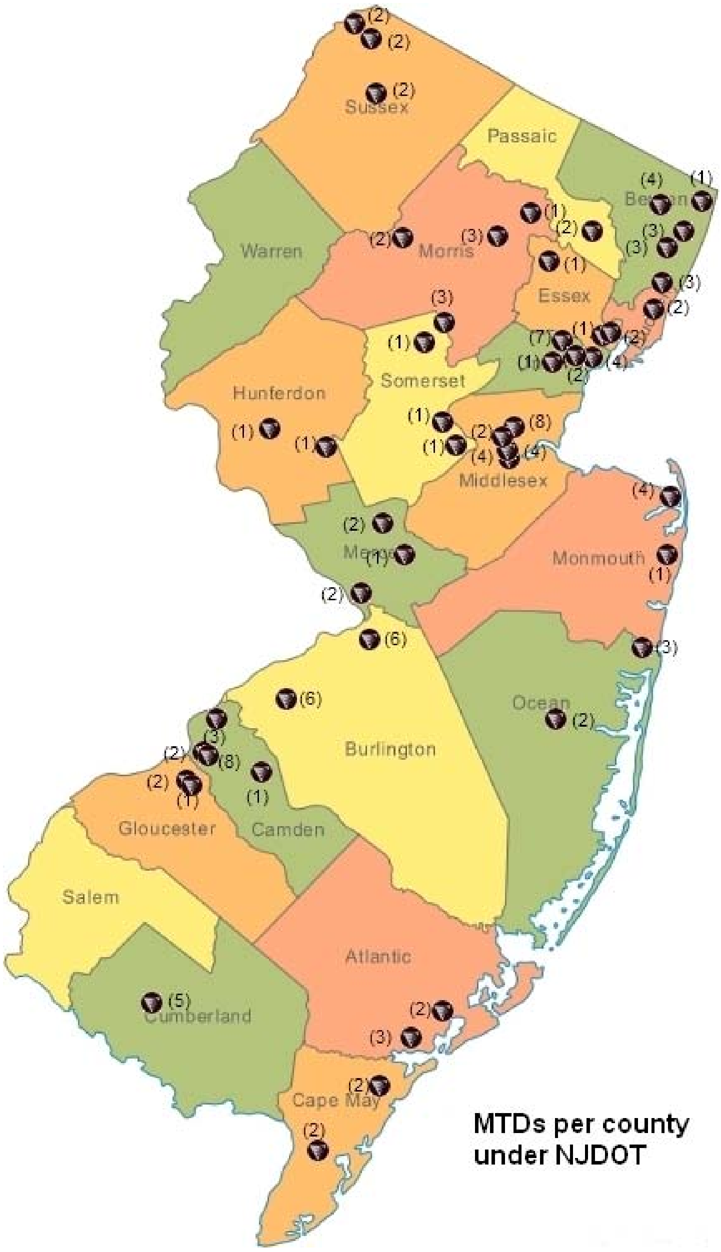



**Figure 3.3 MTDs (HDS) distribution on county map of New Jersey**

The results of HDS identification are summarized in Table 3.2.

**Table 3.1 Summary of Results of HDS Identification**

| Category | Number of Project | Number of Devices/BMPs |
|---|---|---|
| HDS Installed and Under NJDOT Jurisdiction | 50 | 132 |
| Projects under NJDOT Jurisdiction but still under Design or not Yet Advertised that May or May Not Have HDS | 7 | Unknown |
| HDS for which No Plans were Located and are Likely Not Under NJDOT Jurisdiction | 5 | 8 |
| Projects that Do Not Have HDS but May or May Not Have Other Types of Stormwater BMPs | 38 | Unknown |

Seventy nine (79) sets of project plans were searched for HDS, of which only fifty (50) contained HDS. One hundred and thirty two (132) individual HDS under NJDOT jurisdiction were found on plans. A detailed HDS location table was produced for these devices. The HDS location table contains detailed location information for each HDS including road and cross road, and estimated mile post (when available) among other data.

## 3.3 Development of information, inspection and maintenance forms

For proper selecting, inspecting, and maintaining stormwater HDS, It is recommended that at least three data forms are used to keep track of pertinent information: 1) Asset data form, 2) Inspection form, 3) Maintenance form.

Initially these forms were developed for the Vortechs device during a maintenance-research. For concerning information of other type of devices, forms for 6 more types of HDS; Aqua-Swirl®, CDS®, Downstream Defender®, Stormceptor® STC, Terre Kleen®, and VortSentry® are developed. All forms are shown in Appendices. There are many common data fields for these different types of devices, such as watershed and location.

**Stormwater HDS asset data form**

Asset data form contains detailed information on the type of device, the mode of installation (online or offline), the site where it is installed, etc. This form will generally be filled only once, but it might need to be updated as conditions around the site change.

Data must be obtained in order to evaluate, compare, and select the type of devices. Table 3.2 shows asset data form for Vortechs® and asset data forms for all types of HDS are shown in Appendix A.

**Table 3.2 Asset Data Form for Vortechs®**

**HDS Location Info**

<table>
<tr><td>HDS ID</td><td>Device Name</td><td>Model</td><td>Serial No.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>Nearest Road</td><td>[NB,SB,EB,WB]</td></tr>
<tr><td></td><td>▼</td></tr>
</table>

<table>
<tr><td>Municipality</td><td>County</td><td>Region</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>GPS Latitude</td><td>GPS Longitude</td><td>Elevation (ft)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>State lane Coordinate X</td><td>State Plane Co rdinate</td><td rowspan="4"></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Nearest Cross Road</td><td>Nearest Landmark</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><td>Nearest Milepost</td><td>Distance from Milepost (ft)</td><td>Depth from Ground Surfac to Device Bottom (ft)</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>Distance from Roadway Centerline (ft)</td><td>Physical Location</td><td>Is Device in Vehicle Traffic?</td></tr>
<tr><td></td><td>▼</td><td>▼</td></tr>
</table>

Location Map


(sample image: background image from Google street map)

**NJDOT Project Info**

| Project Name | Project No. | Plan Approval Date | Project Completion Date |
|---|---|---|---|
| | | | |

| Project Description | |
|---|---|

| NJDOT Project Manager | Designer Company/Organization | Designer Name |
|---|---|---|
| | | |

| NJDOT Environment Person | Contractor Company/Organization | Contractor Name | NJDOT Construction Field Manager |
|---|---|---|---|
| | | | |

| Env. Permit Issuer | Permit No. | Permit Date | Design Traffic Data (A.D.T) | | |
|---|---|---|---|---|---|
| | | | Road | Present (vpd) | Future (vpd) |
| | | | | | |

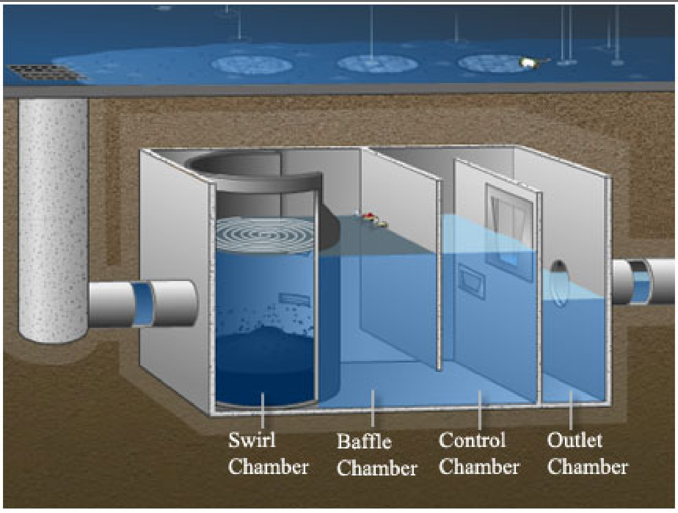
| Water Quality Design Storm | Flood Control Design Storm (Maximum) | Groundwater Recharge Design Storm |
|---|---|---|
| ▼ | ▼ | ▼ |

| NJDOT UPC | NJDOT Job Number | Route No. | Milepost | Federal Project No. |
|---|---|---|---|---|
| | | | | |
| Municipality 1 | Municipality 2 | Municipality 3 | County 1 | County 2 |
| | | | | |

| Bid Date | BD Number | |
|---|---|---|
| | | |

**Device Characteristics Info**

Schematic of Device: Vortechs®




| Device Height (ft) | Device Width (ft) | Device Length (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|---|
| | | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Swirl Chamber Diameter (ft) | Swirl Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Baffle Chamber Dimensions (approx.) | | Baffle Cham -ber Area (sq. ft) | Trash/ Debris/ Oil Storage Capacity ($ft^3$) | Trash/ Debris/ Oil Storage Depth (ft) | Trash/ Debris Cleanout Thickness Thres-hold (ft) | Trash/ Debris Cleanout Area Thres-hold (%) | Oil Cleanout Thick-ness Thres-hold (ft) | Oil Cleanout Area Thres-hold (%) |
|---|---|---|---|---|---|---|---|---|
| L (ft) | W (ft) | | | | | | | |
| | | | | | | | | |

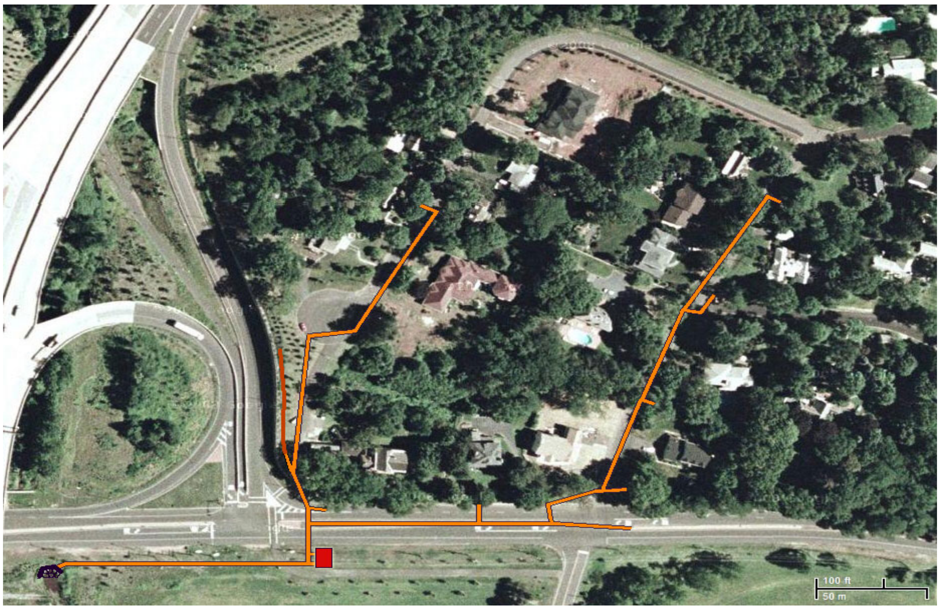
| TSS Removal Rate Certified by NJDEP (%) | Maximum Treatment Flow Rate (cfs) | Maximum Hydraulic Flow Rate (cfs) | Head Loss at Maximum Treatment Flow (ft) | Head Loss at Maximum Hydraulic Flow (ft) |
|---|---|---|---|---|
| | | | | |

| Device Vendor | Invoice Date | Delivery Date | Installation Date | Device Cost (includes S&H) | Installation Cost |
|---|---|---|---|---|---|
| | | | | | |

| Item Sequence No. on Plan | Item No. on Plan | Item Name on Plan | Plan Sheet No. | Special Provisions Page No. |
|---|---|---|---|---|
| | | | | |

**Device Watershed Info**

Aerial Satellite Image and Drainage Network



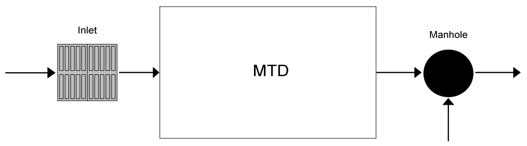
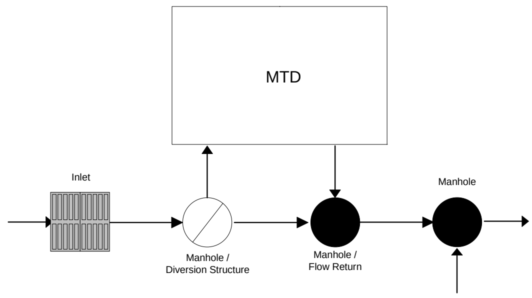
(sample image: satellite image from Google map)

| Drainage Area (acre) | Watershed Land Use | Watershed Soil Type | Percentage of Impervious Area (%) |
|---|---|---|---|
| | ▼ | ▼ | |

| Longest Flow Path Length (ft) | Slope along Flow Path | Manning's Roughness Coefficient along Flow Path | Time of Concentration (minutes) |
|---|---|---|---|
| | | | |

| Runoff Coefficient | NRCS Curve Number |
|---|---|
| | |

**Device Spatial Relation Info**

| Online System | Offline System |
|---|---|
|  |  |
| Is Device Offline? | ▼ |

| | | | | | |
|---|---|---|---|---|---|
| For both Offline and Online Device | ID of Upstream Inlet, Catch Basin or Manhole | Dimensions (Length x Width) of Upstream Inlet or Catch Basin, or Diameter of Upstream Manhole | Invert Elevation of Upstream Inlet, Catch Basin, or Manhole | Ground Elevation of Upstream Inlet, Catch Basin, or Manhole | |
| | | | | | |
| | ID of Downstream Manhole or Catch Basin | Diameter of Downstream Manhole or Dimensions (Length x Width) of Catch Basin | Invert Elevation of Downstream Manhole or Catch Basin | Ground Elevation of Downstream Manhole or Catch Basin | |
| | | | | | |
| | ID of Upstream Pipe | Diameter of Upstream Storm Sewer Pipe (ft) | Invert Elevation of Upstream Storm Sewer Pipe (ft) | Slope of Upstream Storm Sewer Pipe (ft) | Material of Upstream Storm Sewer Pipe (ft) |
| | | | | | |
| | ID of Downstream Pipe | Diameter of Downstream Storm Sewer Pipe (ft) | Invert Elevation of Downstream Storm Sewer Pipe (ft) | Slope of Downstream Storm Sewer Pipe (ft) | Material of Downstream Storm Sewer Pipe (ft) |
| | | | | | |
| For Offline Device Only | Diameter of Upstream Diversion Manhole | Invert Elevation of Upstream Diversion Manhole | Ground Elevation of Upstream Diversion Manhole | | |
| | | | | | |
| | Diameter of Downstream Return Manhole | Invert Elevation of Downstream Return Manhole | Ground Elevation of Downstream Return Manhole | | |
| | | | | | |
| | ID of Upstream Diversion Pipe | Diameter of Upstream Diversion Pipe | Invert Elevation of Upstream Diversion Pipe | Slope of Upstream Diversion | Material of Upstream Diversion |

| | | | | | |
|---|---|---|---|---|---|
| | (ft) | (ft) | (ft) | Pipe (ft) | Pipe (ft) |
| | | | | | |
| | ID of Downstream Diversion Pipe (ft) | Diameter of Downstream Return Pipe (ft) | Invert Elevation of Downstream Return Pipe (ft) | Slope of Downstream Return Pipe (ft) | Material of Downstream Return Pipe (ft) |
| | | | | | |

| | | |
|---|---|---|
| Device Outlet Drains to | Direction of Downstream Drain | |
| ▼ | ▼ | |
| Outfall ID | Outfall Drains to Waterway | Waterway ties into |
| | ▼ | ▼ |
| Name of Waterway | | |
| | | |

Additional Comments

| |
|---|
| |

**Drop-down Menu Contents:**

[NB,SB,EB,WB] ▼ : NB,SB,EB,WB

Physical Location ▼ : On the Median, On Road, On Shoulder, On Sidewalk, On Mild-Slope Bank, On Steep-Slope Bank, On Large Traffic Island, On Small Traffic Island, On Parking Lot, on Flat Large Area Open Space, Other

Is Device in Vehicle Traffic? ▼ : Yes, No

Water Quality Design Storm▼ : NJDEP Uniform WQ Design Storm, Non-uniform WQ Design Storm

Flood Control Design Storm (Maximum) ▼ : 100-Year Storm, 50-Year Storm, 25-Year, 10-Year Storm, 5-Year Storm, 2-Year Storm

Groundwater Recharge Design Storm▼ : Average Annual Storm, 2-Year Storm

All Components Visible from Ground? ▼ : Yes, No

All Compartments Accessible by Vacuum Hose? ▼ : Yes, No

Watershed Land Use▼ : Commercial, Residential, Mixed(Commercial & Residential), Industrial, Rural, Open Space (Park, Woodland, Golf course, etc.)

Watershed Soil Type ▼ : Sand, Silt, Clay

Is the Device Offline? ▼ : Yes, No

Device Outlet Drains to ▼ : Other Types of Stormwater BMPs, Outfall

Direction of Downstream Drain (Other Types of Stormwater BMPs or Outfall) ▼ : N, NE, E, SE, S, SW, W, NW

Outfall Drains to Waterway ▼ : Ocean, River, Stream, Lake, Pond, Ditch, Wetland, Detention/Retention Area

Waterway ties into ▼ : State System, County System, Municipal System, Private Property, Unknown

**Stormwater HDS inspection form**

The inspection form contains information relative to the observations made during the regularly scheduled inspections to the HDS and will allow to schedule timely cleanout and maintenance activities.

The inspection form is divided into subsections with the first section containing identifying information, meteorological conditions, and date and time of inspection among other basic data. The second part of the inspection form contains the measurements of sediment, oil, and debris depth, as well as the schematic of the device showing where the measurements should be taken.

Data must be recorded during inspection in order to determine whether the devices should be cleaned out immediately or to project when the next cleanout should occur.

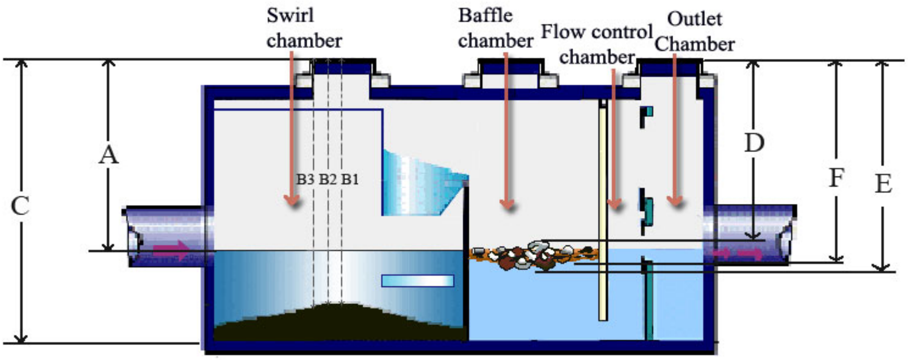
**Table 3.3 HDS Inspection Form for Vortechs®**

<table>
<tr><td colspan="2">HDS ID</td><td colspan="2">HDS_Inspection_RecID</td><td colspan="2">Weather*</td><td>Air Temp. ($^oF$)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Inspection Date</td><td colspan="2">Inspection Time</td><td colspan="3">Purpose of Inspection</td><td>Inspector</td></tr>
<tr><td rowspan="2">MM-DD-YYYY</td><td>Start</td><td>End</td><td colspan="3" rowspan="2">Routine Inspection ( )<br>Inspection Immediately before Cleanout ( )<br>Inspection Immediately after Cleanout ( )<br>Other ( )</td><td rowspan="2"></td></tr>
<tr><td>HH:MM</td><td>HH:MM</td></tr>
<tr><td rowspan="2">Inspection Cost</td><td rowspan="2">Last Inspection Date</td><td rowspan="2">Inspection Interval (months)</td><td rowspan="2">Projected Next Inspection Date</td><td colspan="3">Recent Precipitation Event</td></tr>
<tr><td colspan="2">Date</td><td>Depth (in)</td></tr>
<tr><td></td><td>(Function)</td><td></td><td>(Function)</td><td colspan="2">MM-DD-YYYY</td><td></td></tr>
</table>

* Weather: Sunny, Windy, Cloudy, Rainy, Stormy, Blizzard

**Measurements from Ground above the Device (Routine Inspection or Inspection Immediately before Cleanout)**

Schematic for Measurements: Vortechs®




A: Distance from Water / Oil Surface to Top of Manhole Rim
B1: Distance from Center of Sediment Surface to Top of Manhole Rim
B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim
B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim
C: Distance from Bottom to Top of Manhole Rim
D: Distance from Trash/Debris Surface to Top of Manhole Rim
E: Distance from Trash/Debris Bottom to Top of Manhole Rim
F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| Swirl Chamber | | | |
|---|---|---|---|
| As (ft) | | Trash/Debris Areal Coverage (%) | |
| Bs1 (ft) | | Ds (ft) | |
| Bs2 (ft) | | Es (ft) | |
| Bs3 (ft) | | Oil Areal Coverage (%) | |
| Cs (ft) | | Fs (ft) | |

| Baffle Chamber | | | |
|---|---|---|---|
| Ab (ft) | | Trash/Debris Areal Coverage (%) | |
| Bb1 (ft) | | Db (ft) | |
| Bb2 (ft) | | Eb (ft) | |
| Bb3 (ft) | | Oil Areal Coverage (%) | |
| Cb (ft) | | Fb (ft) | |

| Outlet Chamber | | | |
|---|---|---|---|
| Ao (ft) | | Trash/Debris Areal Coverage (%) | |
| Bo1 (ft) | | Do (ft) | |
| Bo2 (ft) | | Eo (ft) | |
| Bo3 (ft) | | Oil Areal Coverage (%) | |
| Co (ft) | | Fo (ft) | |

Observations of Device and Surrounding Drainage Area Characteristics (Routine Inspection or Inspection Immediately before Cleanout)

| Traffic Density | Gross Solids - Litter | Gross Solids – Debris | Gross Solids – Coarse Sediment |
|---|---|---|---|
| (Low, Medium, Heavy) | (Small, Medium, Large) | (Small, Medium, Large) | (Small, Medium, Large) |

| Any Soil Erosion and Sediment Deposition in Watershed? | If Severe, Location(s) of Erosion and Deposition in Watershed |
|---|---|
| (Low, Moderate, Severe) | |

| Construction Activities in Watershed? | If Yes, Condition of Source Control Management Practices | If Poor, Location of Source Control Management Practices | If Poor, Describe Condition of Source Control Management Practices |
|---|---|---|---|
| (Yes / No) | (Good, Moderate, Poor) | | |

| Winter Sanding Operation? | Space Available for Cleanout Activities without Traffic Blockage? |
|---|---|
| (Yes / No) | (Yes / No) |

| Insects (Mosquitoes, Larvae, etc…) in HDS? | Vegetation Growth in HDS? | Any Blockage to Flow Path in HDS? | If Yes, Name Location of the Blockage |
|---|---|---|---|
| (Yes / No) | (Yes / No) | (Yes / No) | |

| Any Blockage in Inlet, Manhole, Catch Basin, or Pipe Upstream and Downstream of the Device? | Location of Blockage | Type of Solids in Inlet, Manhole, Catch Basin or Pipe |
|---|---|---|
| (Yes / No) | | (Gravel, Sand, Silt, Clay, Mud, Debris, Litter) |
| Dry Weather Flow in inlet pipe and outlet Pipe? | Backwater to outlet pipe from downstream? | Blockage at Outfall? |
| (Yes / No) | (Yes / No) | (Yes / No) |

| Outfall Structure | | | | | |
|---|---|---|---|---|---|
| Sediment discharged from HDS? | (Yes / No) | Trash/Debris discharged from HDS? | (Yes / No) | Oil Spill Out from HDS? | (Yes / No) |

Device Structural Inspection - Visual Observation from Ground above the Device (Routine Inspection or Inspection Immediately before Cleanout)

| | | | |
|---|---|---|---|
| Damage to Manhole Cover(s) | (No, Minor, Serious) | Description of Damage | |
| Damage to Side Walls | (No, Minor, Serious) | Description of Damage | |
| Damage to Inlet Pipe | (No, Minor, Serious) | Description of Damage | |
| Damage to Outlet Pipe | (No, Minor, Serious) | Description of Damage | |

Vortechs®

| | | | |
|---|---|---|---|
| Damage to Swirl Chamber Aluminum Wall, Baffle Wall, Flow Control Wall or Orifice Plates | (No, Minor, Serious) | Description of Damage | |

Photos Taken during Routine Inspection or Inspection Immediately before Cleanout

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments from Routine Inspection or Inspection Immediately before Cleanout

| |
|---|
| |

Device Structural Inspection – Visual Observation and Physical Testing from Inside of the Device (Inspection Immediately after Cleanout)

| | | | |
|---|---|---|---|
| Damage to Side Walls, Ceiling or Bottom | (No, Minor, Serious) | Description of Damage | |
| Damage to Inlet Pipe | (No, Minor, Serious) | Description of Damage | |
| Damage to Outlet Pipe | (No, Minor, Serious) | Description of Damage | |

Vortechs®

| | | | |
|---|---|---|---|
| Damage to Swirl Chamber Aluminum Wall, Baffle Wall, Flow Control Wall or Orifice Plates | (No, Minor, Serious) | Description of Damage | |

Photo Taken During Structural Inspection Immediately after Cleanout

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments from Structural Inspection Immediately after Cleanout

| |
|---|
| |

Calculation and Decision for Cleanout based on Measurements

| Water Depth (ft) | | Sediment Depth (ft) | |
|---|---|---|---|
| | | | |
| Device Cleanout Trigger: Sediment Depth (ft) | | Cleanout Necessary Based on the Measured Sediment Depth? | Yes or No |
| Device Cleanout Trigger: Trash/Debris Thickness (ft) | | Cleanout Necessary Based on the Measured Trash/Debris Thickness? | Yes or No |
| Device Cleanout Trigger: Trash/Debris Areal Coverage (%) | | Cleanout Necessary Based on the Measured Trash/Debris Areal Coverage? | Yes or No |
| Device Cleanout Trigger: Oil Thickness (ft) | | Cleanout Necessary Based on the Measured Oil Thickness? | Yes or No |
| Device Cleanout Trigger: Oil Areal Coverage (%) | | Cleanout Necessary Based on the Measured Oil Areal Coverage? | Yes or No |

**AUTO Functions:**

1. [Last Inspection Date]: From the Previous Inspection Record

2. [Projected Next Inspection Date] = [Last Inspection Date] + [Inspection Interval]

3. [Water Depth] and [Sediment Depth] are calculated automatically from measured [Distance from Water Surface to Top of Manhole Rim], [Distance from Sediment Surface to Top of Manhole Rim] and [Distance from Bottom to Top of Manhole Rim].

   [Water Depth] = (The Average [Distance from Sediment Surface to Top of Manhole Rim] of [Center], [In Between], and [Side]) – [Distance from Water Surface to Top of Manhole Rim]

   [Sediment Depth] = [Distance from Bottom to Top of Manhole Rim] – (The Average [Distance from Sediment Surface to Top of Manhole Rim] of [Center], [In Between], and [Side])

4. Cleanout Necessary Based on Sediment Depth?

   Yes, if [Sediment Depth] is equal or larger than [Device Cleanout Trigger: Sediment Depth], No otherwise.

5. [Trash/Debris Thickness] = [E (Distance from Bottom of Trash/Debris to Top of

Manhole Rim)] - [D (Distance from Trash/Debris Surface to Top of Manhole m)]

6. Cleanout Necessary Based on Trash/Debris Thickness?

   Yes, if [Trash/Debris Thickness] is equal or larger than [Device Cleanout Trigger: Trash/Debris Thickness], No otherwise.

7. Cleanout Necessary Based on Trash/Debris Areal Coverage?

   Yes, if [Trash/Debris Areal Coverage] is equal or larger than [Device Cleanout Trigger: Trash/Debris Areal Coverage], No otherwise.

8. [Oil Thickness] = [F (Distance from Bottom of Oil to Top of Manhole Rim)] - [A (Distance from Oil Surface to Top of Manhole Rim)]

9. Cleanout Necessary Based on Oil Thickness?

   Yes, if [Oil Thickness] is equal or larger than [Device Cleanout Trigger: Oil Thickness], No otherwise.

10. Cleanout Necessary Based on Oil Areal Coverage?

    Yes, if [Oil Areal Coverage] is equal or larger than [Device Cleanout Trigger: Oil Areal Coverage], No otherwise.

**Stormwater HDS maintenance form**

The maintenance form will be used to describe the tasks performed when the HDS is cleaned out or serviced.

Data must be recorded immediately after the cleanout, such as structural inspection and disposal of cleanout materials. A uniform data collection system would help level the playing field, properly track the devices, and inspect and maintain the devices in a timely fashion and in a cost-effective way.

**Table 3.4 HDS Maintenance Form for Vortechs®**

General Information

| HDS ID | HDS_Inspection_Rec_ID | HDS_ Maintenance _Rec_ID | Weather | Air Temp. (oF) |
|---|---|---|---|---|
| (Link to Asset Data Form) | (Link to Inspection Data Form) | | ▼ | |

<table>
<tr><td rowspan="2">Maintenance Date</td><td colspan="2">Maintenance Time</td><td rowspan="2">Purpose of Maintenance</td><td rowspan="2">Maintenance Company</td><td rowspan="2">Number of HDS Maintenance Persons</td><td rowspan="2">Inspector</td></tr>
<tr><td>Start<br>HH:MM</td><td>End<br>HH:MM</td></tr>
<tr><td>MM-DD-YYYY</td><td>Start<br>HH:MM</td><td>End<br>HH:MM</td><td>▼</td><td></td><td></td><td></td></tr>
</table>

| Maintenance Cost | Last Maintenance Date | Maintenance Interval (months) | Projected Maintenance Date |
|---|---|---|---|
| | (Auto) | | (Auto) |

Info for Cleanout Planning

| Need Blockage to Traffic? | Check Weather Forecast for Dry Day? |
|---|---|
| ▼ | ▼ |

| Estimated Volume of Sediment (cubic feet) | Estimated Volume of Water (cubic feet) | Estimated Volume of Trash/Debris (cubic feet) | Estimated Volume of Oil (cubic feet) | Vacuum Truck Storage Capacity (cubic feet) |
|---|---|---|---|---|
| (Auto) | (Auto) | (Auto) | (Auto) | |

| Any Other Device to be Cleaned out during the Same Trip? | | | | | ▼ | |
|---|---|---|---|---|---|---|
| (If Yes) Number of HDS for Cleanout | (If Two HDS total ) | | (If Three HDS total) | | (If Four HDS total) | |
| | The 2nd HDS_ Maintenance _Rec_ID | Distance (miles) | The 3rd HDS_ Maintenance _Rec_ID | Distance (miles) | The 4th HDS_ Maintenance _Rec_ID | Distance (miles) |
| | | | | | | |

Sediment Disposal

| Name of Sediment Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|
| | | |

Water Disposal

| Possible to Dispose Water into the Downstream Drainage Network? | (If No) Name of Water Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Trash/Debris Disposal

| Need to Remove Trash/Debris before Cleanout? | (If Yes) Name of Trash/Debris Disposal Facility | Distance from HDSLocation to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Oil Disposal

| Need to Remove Oil before Cleanout? | (If Yes) Name of Oil Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|
| ▼ | | | |

| Need to Clean out Sediment/Trash/Debris/Oil Adjacent to HDS? | | | ▼ | | |
|---|---|---|---|---|---|
| Inlet Pipe? | Outlet Pipe? | Inlet? | Manhole? | Catch Basin? | Outfall Structure? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

| Need to Block Inlet or Outlet Pipe by Pipe Plugs during Operation? | ▼ |
|---|---|

Records of Cleanout (common for all types of devices)

Sediment Disposal

| Name of Sediment Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|
| | | |

Water Disposal

| Was Water Disposed into the downstream Drainage Network? | (If No) Name of Water Disposal Facility | Distance from HDSLocation to Facility (miles) | Disposal Cost |
|---|---|---|---|

| | | | |
|---|---|---|---|
| ▼ | | | |

Trash/Debris Disposal

| Were Trash/Debris Removed before Cleanout? | (If Yes) Name of Trash/Debris Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Oil Disposal

| Was Oil Removed before Cleanout? | (If Yes) Name of Oil Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|---|
| ▼ | | | |

| | | | |
|---|---|---|---|
| Was Traffic Blocked? | ▼ | Was Inlet or Outlet Pipe Blocked by Pipe Plugs during Operation? | ▼ |
| Is Further Cleaning of HDS by Water Jet Necessary? | ▼ | (If Yes) Was HDS Further Cleaned Using Water Jet? | ▼ |

| | | | | | |
|---|---|---|---|---|---|
| Was Sediment/Trash/Debris/Oil Adjacent to HDS Cleaned out? | | | ▼ | | |
| Inlet Pipe? | Outlet Pipe? | Inlet? | Manhole? | Catch Basin? | Outfall Structure? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Photos Taken Immediately after Cleanout

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments on Cleanout

| |
|---|
| |

Records of Repair: Vortechs®

| | | | | | |
|---|---|---|---|---|---|
| Were Any Components Repaired? | | | ▼ | | |
| Manhole Cover(s)? | Side Walls? | | Ceiling? | Bottom? | |
| ▼ | ▼ | | ▼ | ▼ | |
| Swirl Chamber Aluminum Wall? | Baffle Wall? | Flow Control Wall? | Orifice Plates? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Photos Taken Immediately after Repair

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments on Repair

| |
|---|
| |

Records of Replacement: Vortechs®

<table>
<tr><td colspan="3">Were Any Components Replaced?</td><td colspan="3">▼</td></tr>
<tr><td>Manhole Cover(s)?</td><td colspan="2">Side Walls?</td><td colspan="2">Ceiling ?</td><td>Bottom?</td></tr>
<tr><td>▼</td><td colspan="2">▼</td><td colspan="2">▼</td><td>▼</td></tr>
<tr><td>Swirl Chamber Aluminum Wall?</td><td>Baffle Wall?</td><td>Flow Control Wall?</td><td>Orifice Plates?</td><td>Inlet Pipe?</td><td>Outlet Pipe?</td></tr>
<tr><td>▼</td><td>▼</td><td>▼</td><td>▼</td><td>▼</td><td>▼</td></tr>
<tr><td colspan="3">Was Entire Device Replaced?</td><td colspan="3">▼</td></tr>
</table>

Photos Taken Immediately after Replacement

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments on Replacement

| |
|---|
| |

**Notes:**

HDS_ Maintenance _Rec_ID: Unique Maintenance id to indentify each maintenance record related to the same HDS ID

**Drop-down Menu Contents:**

General Information

Weather: Sunny, Windy, Cloudy, Rainy, Stormy, Blizzard

Purpose of Maintenance ▼ : Cleanout, Repair, Replacement

Need Blockage to Traffic? ▼ : Yes, No

Check Weather Forecast for Dry Day? ▼ :Yes, No

Any Other Device to be Cleaned out during the Same Trip? ▼ : Yes, No

Info for Cleanout Planning

Possible to Dispose Water into the Downstream Drainage Network? ▼ :Yes, No

Need to Remove Oil before Cleanout? ▼ :Yes, No

Need to Remove Trash/Debris before Cleanout? ▼ :Yes, No

Need to Clean out Sediment/Trash/Debris/Oil Adjacent to HDS? ▼ :Yes, No

Inlet Pipe? ▼ :Yes, No

Outlet Pipe? ▼ :Yes, No

Inlet? ▼ :Yes, No

Manhole? ▼ :Yes, No

Catch Basin? ▼ :Yes, No

Outfall Structure? ▼ :Yes, No

Need Blockage to Inlet or Outlet pipe by Pipe Plugs during Operation?▼ :Yes, No

Records after Cleanout

Was water disposed into the downstream drainage network? ▼ :Yes, No

Was Oil Removed before Cleanout? ▼ :Yes, No

Were Trash/Debris Removed before Cleanout? ▼ :Yes, No

Was Sediment/Trash/Debris/Oil Adjacent to HDS Cleaned out? ▼ :Yes, No

Inlet Pipe? ▼ :Yes, No

Outlet Pipe? ▼ :Yes, No

Inlet? ▼ :Yes, No

Manhole? ▼ :Yes, No

Catch Basin? ▼ :Yes, No

Outfall Structure? ▼ :Yes, No

Was Traffic Blocked? ▼ :Yes, No

Was Inlet or Outlet Pipe Blocked by Pipe Plugs during Operation? ▼ :Yes, No

Is Further Cleaning of HDS by Water Jet Necessary? ▼ : Yes, No

(If Yes) Was HDS Further Cleaned Using Water Jet? ▼ : Yes, No

Records after Repair: Vortechs®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ▼ : Yes, No

Bottom? ▼ : Yes, No

Swirl Chamber Aluminum Wall? ▼ : Yes, No

Baffle Wall? ▼ : Yes, No

Flow Control Wall? ?▼ : Yes, No

Orifice Plates? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

<u>Records after Replacement: Vortechs®</u>

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ▼ : Yes, No

Bottom? ▼ : Yes, No

Swirl Chamber Aluminum Wall? ▼ : Yes, No

Baffle Wall? ?▼ : Yes, No

Flow Control Wall? ▼ : Yes, No

Orifice Plates? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

**Auto Functions**

Last Maintenance Date: Import [Maintenance Date] data from previous record.

Projected Maintenance Date: [Maintenance Date] + [Maintenance Interval]

'Water Volume', 'Sediment Volume', 'Trash/Debris Volume', and 'Oil Volume' are estimated/calculated automatically based on the measured quantities from the "Inspection Form."

**Vortechs®**

[Estimated Water Volume] = [Water Depth] (from Inspection Form) X [Device Footprint Area (from Asset Data Form)]

The water volume above maybe over-estimated since water in the baffle chamber, the flow control chamber, and the outlet chamber, if judged to be clean, does not need to be pumped out.

[Estimated Sediment Volume] = [Sediment Depth (in Swirl Chamber) (from Inspection Form)] X [Swirl Chamber Area (from Asset Data Form)]

If there is sediment in Baffle Chamber, add [Sediment Volume in Baffle Chamber], where

[Sediment Volume in Baffle Chamber] = [Sediment Depth in Baffle Chamber (from Inspection Form)] X [Device Width (from Asset Data Form)] X [2.58

(use 3.00 if ‘Model’ is 16000 or larger (from Asset Data Form)]

If there is sediment in Outlet Chamber, add [Sediment Volume of Outlet Chamber], where

[Sediment Volume in Outlet Chamber] = [Sediment Depth in Outlet Chamber] X [Device Width (from Asset Data Form)] X [2.00]

[Estimated Trash/Debris Volume] = [Average Trash/Debris Thickness in Swirl Chamber and Baffle Chamber (from Inspection Form)] X [Device Width (from Asset Data Form)] X [Device Length (from Asset Data Form) – 3.50]

If there are Trash/Debris in Outlet Chamber, add [Trash/Debris Volume in Outlet Chamber], where

[Trash/Debris Volume in Outlet Chamber] = [Trash/Debris Thickness in Outlet Chamber] X [Device Width (from Asset Data Form)] X [2.00]

[Estimated Oil Volume] = [Average Oil Thickness in Swirl Chamber and Baffle Chamber (from Inspection Form)] X [Device Width (ft) (from Asset Data Form)] X [Device Length (from Asset Data Form) – 3.50]

If there is Oil in Outlet chamber, add [Oil Volume in Outlet Chamber], where

[Oil Volume in Outlet Chamber] = [Oil Thickness in Outlet Chamber (from Inspection Form)] X [Device Width (from Asset Data Form)] X [2.00]

## 3.4 Conclusions

The information needs for selection, inspection, and maintenance for stormwater HDS were identified and organized.

**The HDS location information**

The location information gathered from various sources such as NJDOT, vendors and Internet search. One hundred and thirty two (132) individual HDS under NJDOT jurisdiction were found on fifty (50) sets of plans. Location of devices was identified on plans and tabulated by tables and mapping.

**The HDS information form**

Three types of information form are developed; asset data from, Inspection form and maintenance form. It is necessary for proper selecting, inspecting, and maintaining stormwater HDS. Each form has been developed for 7 types of HDS to obtain data. The field data specific to certain devices, such as structural components, was identified and developed. The forms were also made more user-friendly to facilitate their use in the field.

# Chapter 4

# Assessment for Maintenance Activity

## 4.1 Introduction

It was required to select devices and develop the proper cleanout procedure of HDS before monitoring. In addition, the suitable measurement and sampling methods for trapped materials in the devices were prepared.

## 4.2 Selection of devices for monitoring

Among the sixty three (63) identified devices, twelve (12) Vortechs® devices were chosen for monitoring since they were the most common device type (Table 4.1). Selecting the same type of HDS for all monitoring sites allowed comparing devices with the same capacity and configuration. Monitoring the same type of device across sites also eliminated the need to adjust data based on device characteristics. The 12 selected devices were distributed among eight NJDOT project sites (Figure 4.1). It was presumed that the eight sites were representative of regions with high, medium, and low maintenance requirements. Each device was assigned a unique identifying number (ID). The first part of the device ID number consisted of the prefix RU and an assigned site number, while the second part corresponded to an assigned device number on the site. The numbering system permitted quickly visualizing the devices located at the same site for ease in scheduling monitoring activities.

**Table 4.1 Twelve (12) Vortechs® Selected for Initial Monitoring**

| Device ID | Municipality | County | Location |
|---|---|---|---|
| RU01-01 | Piscataway | Middlesex | Rt. 18 Extension along Landing Lane |
| RU01-02 | Piscataway | Middlesex | Rt. 18 Extension along River Road |
| RU01-03 | Piscataway | Middlesex | Rt. 18 Extension along Campus Road |
| RU01-04 | Piscataway | Middlesex | Rt. 18 Extension along River Road |
| RU02-01 | Edison | Middlesex | Evergreen Road and State Highway 27 |
| RU02-02 | Edison | Middlesex | Evergreen Road and State Highway 27 |
| RU04-02 | Elizabeth | Union | Pearl Street & Grove Street |
| RU06-01 | North Bergen | Hudson | 36th Street & U.S. Rt. 1/9 |
| RU07-01 | Deptford | Gloucester | Rt. 47 near Cattell Road |
| RU09-01 | Lakewood | Ocean | Rt. 9 near Lake Carasaljo |
| RU14-01 | Parsippany | Morris | Rt. 46 & New Road |
| RU16-01 | Frankford | Sussex | Rt. 15 & U.S. 206 |

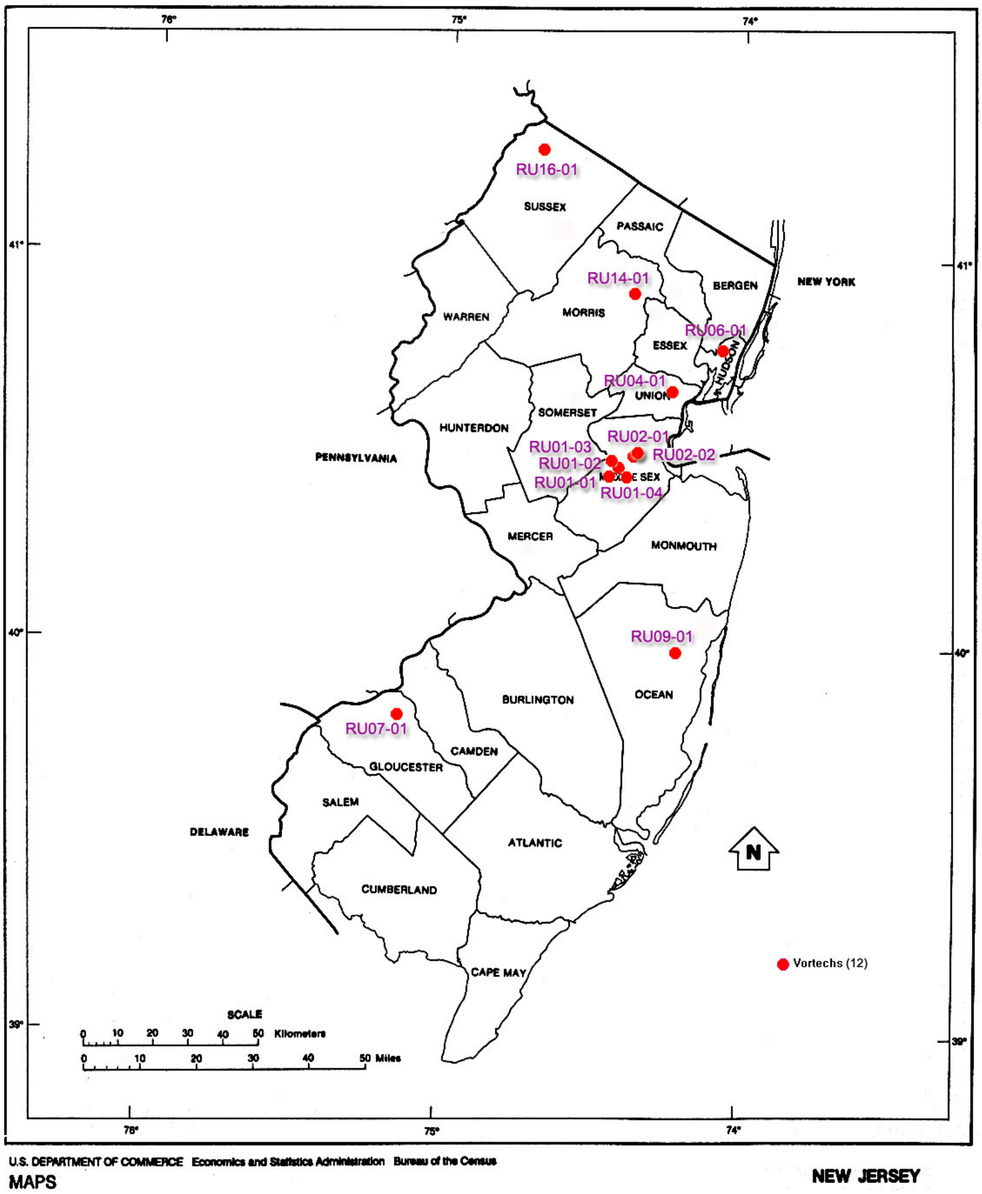



**Figure 4.1 Locations of 12 Vortechs® installed at 8 NJDOT project sites that were selected for extensive monitoring**

**Selection of Two Additional Types of Devices**

In 2007, twelve (12) devices were chosen for cleanout and subsequent monitoring. All of those twelve devices were Vortechs® HDS. After 3 years monitoring, six devices were chosen for second cleanout and further monitoring.

In order to propose general evaluation and maintenance guidelines for HDS, it is necessary to conduct research and monitoring of other types of HDS as well.

Seven (7) types of HDS have been installed in NJDOT projects. From the seven types of devices, one Aqua-Swirl device and one Downstream Defender device were chosen for monitoring. This brings the total of devices chosen for extensive monitoring to fourteen (12 Vortechs®, 1 Aqua-Swirl®, 1 Downstream Defender®).

**Table 4.2 Two (2) Additional HDS for Monitoring**

| Device ID | Type of HDS | Municipality | County | Location |
|---|---|---|---|---|
| RU15-01 | Downstream Defender | Fair Lawn | Bergen | Route 33 over Conrail Bridge |
| RU18-01 | Aqua-Swirl | Robbinsville | Mercer | SB Rt. 208 and Saddle River Rd |

**Table 4.3 Depth of Sediment Trapped and Inspection before Cleanout (Two Devices)**

| Site ID | Construction plans approval date | Inspection Just before Cleanout | |
|---|---|---|---|
| | | Inspection / Cleanout Date | Sediment Depth (feet) |
| RU15-01 | 2000-07-11 | 2011-06-01 | 4.5 |
| RU18-02 | 2008-04-07 | 2011-05-11 | 3.8 |

## 4.3 Cleanout Procedures

The cleanout operation consisted of the following procedure:

Preparation before site visit

1. Check weather forecast looking for dry day before making arrangement for sampling day. Also, check forecast the day before working day to again confirm adequate weather.
2. Make arrangements for crash truck and vacuum truck
3. Make arrangements for sending samples.
4. Obtain supplies:
    - Pens
    - Labels
    - Papers
    - Camera
    - Permission letter
    - Custody
    - Shipping labels
5. Obtain safety equipment:
    - Traffic cones
    - Outfits (i.e. reflector vests)
    - Noxious gas detector

6. Obtain sampling and measurement equipment:

    - Gloves
    - Boots
    - Manhole hook
    - Claws
    - Telescoping measurement rod
    - Paper towels
    - Bleach
    - Ethanol or DI water
    - Scoops and shovels
    - Pool skimmer
    - Oil absorbent booms
    - Plastic sheets
    - Weighing scale
    - Mesh bags
    - Coolers (Ice + Container + Shipping label)
    - Flashlights
    - Bottles

7. Clean sampling equipment by washing with DI water and ethanol

Pre-procedure before using vacuum truck

1. Arrange sampling and measurement equipment

2. Grit chamber:
   - Open manhole cover with equipment (i.e. hook and claw) and measure depth of floatables, water and sediment.
   - Remove floatables with pool skimmer and place in the mesh bag.
   - Collect oil with oil absorbent booms.
   - Measure oil weight with scale.

3. Floatables chamber
   - Open manhole cover with equipment (i.e hook and claw) and measure depth of floatables and water
   - Remove floatables with pool skimmer and place in mesh bag.
   - Collect oil with oil absorbent booms.
   - Measure oil with scale.

4. Outlet chamber:
   - Open manhole cover with equipment (i.e hook and claw) and measure depth of water.

The depths for floatables, water and sediment were measured by using the prescribed telescoping measurement rod. The measurement of sediment depth was taken at three locations within the swirl chamber: (1)center, (2)side and (3)midway between the center & side (the average of the three measurements was taken as the depth of sediment).

Floatable debris was skimmed off both the grit and baffle chambers. Mesh and/or plastic bags were used for storing floatables until they were sorted at a later stage.

Oil absorbents were used to remove oil in the chamber.

<u>Procedure during vacuum Out</u>

1. Swirl chamber
    - Make an estimate of how much material was collected and what kind of material collected.
    - Pump out water.
    - If it is necessary, dewater to the drainage system.
    - Take two water quality samples and store in the cooler.
    - Vacuum up sediment.
    - Dispose all sediment at maintainable, or other available yard
    - Take two sediment samples.
    - Mail samples to the lab for analysis.

2. Floatables chamber
    - Vacuum water.

3. Outlet chamber
    - Vacuum water.

Vacuum out procedure was divided into two separate operations. First, water was pumped and decanted to the drainage system, minimizing disturbance was required during pumping procedure.

Water samples were collected at the beginning and end of decanting. Each set consisted of two bottles taken at each sample time. One polyethylene bottle was treated with sulfuric acid ($H_2SO_4$) and refrigerated, where the other bottle was only refrigerated.

Second, sediment was vacuumed out and disposed of at a maintenance yard. NJDOT provided a contractor's yard located in Burlington, NJ; however, a maintenance yard on Rutgers University's Livingston Campus was chosen for convenience.

**Figure 4.2 Pump out water first and then pump out solids (Typically)**

Procedure for processing vacuumed materials

1. Litter and debris
    - Wash floatables and place on plastic sheets to air dry.
    - Categorize litter.
    - Measure volume and weight of collected debris.

2. Sediment
    - Mix to sediment pile
    - Package samples (two 8 oz. jars) and place in the cooler
    - Send to the lab for analysis

- Take samples and perform Particle Size Distribution (PSD) using soil sieves.
- Determine organic contents
- Measure volume and weight of total sediment removed.

Two sediment samples were taken on opposite sides of pile.

## 4.4 Sampling, measurement and analytical methods

### 4.4.1 Oil and grease sampling

Polypropylene oil-only absorbents were used to collect the oil from the surface of the water inside the devices. Polypropylene absorbents are designed to absorb and retain oil and oil-based liquids while rejecting water. The absorbents used in this study were sump skimmers with an eight inch diameter and 18 inch length. Each skimmer consisted of a polyester mesh sock filled with 100% polypropylene absorbent strips with a capacity of 1.8 gallons of oil.

The oil in the swirl and baffle chambers of each device was collected separately using a different skimmer for each one. A digital scale with 10 pound capacity and 0.2 ounce increments was used to weigh the skimmers in the field. The skimmers were weighed, then attached to a rope and dropped inside the chamber. Once the skimmer was floating horizontally on the surface of the water, it was moved along the surface of the water using the rope to direct it. After the skimmer had been moved along the whole surface and no oil could be observed, it was hauled up using the attached rope. The rope was then removed and the skimmer weighed again to determine the weight of oil removed.

### 4.4.2 Floatables sampling

Floatable litter and organic debris were skimmed off the water surface of the grit and baffle chambers using a pool skimmer. Collected floatables were transferred from the skimmer to plastic or mesh bags for transport to the laboratory. Collected material was air-dried in the laboratory. The dry material was sorted, and weighed. A digital scale with a capacity of 4100 g and 10 mg increments was used to weigh floatables.

### 4.4.3 Water and sediment depth measurements

A stadia rod was used to measure the depth of water in the grit, floatables, and outlet chambers. Once the manhole cover had been removed, the telescoping rod was lowered into the chamber until the bottom of the rod was touching the surface of the water. The height of water inside the device was calculated by subtracting the measured value from the total chamber height.

The depth of sediment was measured in the swirl chamber by lowering the rod until it reached the top of the sediment layer. Since sediment does not often deposit uniformly inside the chamber, the procedure was repeated in three locations: center, side, and midway point of the chamber. The average sediment depth was calculated by averaging the three measurements and subtracting from the total chamber height.

### 4.4.4 Water sampling and analysis

A vacuum truck was used to pump the water out of the swirl chamber and into the drainage system. Four water samples were taken as water was being discharged into the drainage system. The first two water samples were taken immediately after pumping started while the third and fourth immediately prior to the end of the pumping cycle. Two-liter polyethylene bottles were used to collect and store the water samples. The first and third sample were collected in bottles treated with sulfuric acid as recommended by the analysis methods used to determine chemical oxygen demand (COD), total phosphorus content (TP), and total Kjeldahl nitrogen (TKN). The second and fourth water samples, to be used for determining total suspended solids (TSS) and Biochemical Oxygen Demand (BOD), were collected in untreated bottles. The samples were refrigerated for pickup by the analytical laboratory. *Standard Methods for the Examination of Water and Wastewater 20$^{th}$ edition* (Clescerl et al., 1999) were used for TSS, BOD, and TP analysis and sampling. Hach method 8000 for COD and US EPA method 351.2 for TKN were used for analysis and sampling respectively.

### 4.4.5 Sediment sampling and analysis

A vacuum truck was used to pump out the sediment from the bottom of the swirl chamber. The vacuum truck transported and deposited the sediment in a maintenance yard. Two samples were collected in eight-ounce jars immediately after the sediment was deposited by the vacuum truck. The two samples were collected from opposite sides of the sediment pile to account for variations in composition. The samples were then placed in a cooler and sent to a third-party laboratory for analysis of arsenic, cadmium, copper, lead, zinc, total Kjeldahl nitrogen and total phosphorus concentrations. Arsenic, cadmium, copper, lead and zinc concentrations were tested using the methods contained in US EPA publication SW846: Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (US EPA, 1999a). Total Kjeldhal nitrogen was tested using US EPA Method 351.2. Total phosphorus concentration was tested using Standard Method 4500-P.

The sediment pile was left to air dry for several days. The pile was covered at night and during rain events to avoid the sediment composition from being altered due to run off from the pile. Once dry, the sediment was weighed using a scale available on site. The full contents of the HDS were weighed only for the 2008 clean out, but not for the 2011 clean out. After weighing, the sediment was mixed thoroughly with a shovel to make it as uniform as possible for subsequent sampling.

A 2.5 pound sample was taken from the dry sediment pile. This sample was used to perform a loss-on-ignition test to determine the organic content in the sediment. ASTM D2974 Method C was used to determine the organic content of the sediment.

### 4.4.6 Sediment particle size distribution

Two 2.5 pound samples were taken from opposite sides of the dry sediment pile for particle size distribution (PSD) analysis. The two samples were placed in sealed coolers and transported for analysis in the laboratory. PSD was done with a sieve analysis with five standard sieve sizes: #4 (4.75mm), #30 (0.595 mm), #50 (0.297 mm), #100

(0.149 mm) and #200 (0.074 mm). The sediment was placed on the #4 sieve and sifted until no more material was passing through the sieve. The procedure was repeated with each subsequently smaller sieve size. Once the material had been sifted through the five sieves, the material retained in each sieve was weighed. The material that had passed through all the sieves (smaller than 74 microns) was also weighed. A digital scale with a capacity of 4100 g and 10 mg increments was used. The procedure was repeated with the second sample. The results from both samples were averaged to obtain the PSD of sediment in each device.

## 4.5 Results and Discussion

### 4.5.1 Selection of devices

Initially, the 12 devices at 8 NJDOT project sites were selected to be included in total for the high, medium and low maintenance regions. For the first monitoring, the same type of devices was selected in each region for consistency in comparison. For the second monitoring, two other types of HDS were added to propose general evaluation and maintenance guidelines for HDS

### 4.5.2 Cleanout activity

Most cleanout operation was completed with provided procedure. However, some cleanout activities encountered problems and solved them with specific methods.

Mostly vacuum truck pumped both water and solids out and disposed them together at a pre-treatment facility. If heavy oil is visual, pump both water and solids out and dispose them together at an acceptable facility such as the hazardous waste landfill.

## Problems Encountered and Solutions

### Inflow / Backflow

Although a dry day was chosen for clean up, previous rain events caused inflow from inlet or backflow from outlet. An air compressor, pipe plugs and sand bags were used to prevent inflow or backflow during vacuum procedures.

### Deep Underground Devices

Some devices, for design reasons, were placed deep underground. The truck used assembled pipe sections to reach the bottom for vacuuming, however, could not reach the edge of the device. The pipes had a limited sweep angle due to the relatively small hole diameter and depth of device. The combination of high pressure water jetting attached to a vacuum truck is recommended to allow for a more thorough cleaning of the device. Also, it is possible to send a laborer down into the device with a portable power washer or tool to clean the edges of the chamber. However, it is imperative that precautions are taken to ensure the safety of personnel. This includes, but is not limited to: (1) harness system to allow for emergency egress from device, (2) protective clothing, (3) noxious gas detector, etc.

### Turbid Water

Laborers performed the vacuum operation, minimizing disturbance, so water could be decanted in the outlet drainage. In the case of RU06-01, turbidity was caused by mush sediment in the device. Therefore, water should be decanted into the downstream drainage network, via manhole. Although water was decanted at a slow rate, some turbid water flowed back into the device and mush sediment settled down in the outlet chamber of the device. The depth of sediment in the outlet chamber was approximately 0.3 ft.

**Manhole Location**

Sites where manhole covers were located in the center of the road are excluded from cleanout and monitoring. For this study, traffic could not be shut down or detoured to enable proper monitoring of the devices. In most cases, manhole covers were located outside the road such as in shoulders, sidewalks and some case parking lots. Traffic safety for a shoulder closing was required, and was accomplished using a truck mounted attenuators (TMA) and traffic blockages.

### 4.5.3 Measurement and sampling for analysis

The depth of sediment, water, oil and floatables were measured or skimmed off before cleanout devices. Water and sediment were sampled during cleanout operations, and then the samples were analyzed.

# Chapter 5

# Quantity and Quality of Stormwater Solids Trapped by HDS

## 5.1 Introduction

Numerous HDS have been installed to improve the quality of highway runoff and meet new stormwater management requirements. The use of HDS is expected to continue in the foreseeable future. Meanwhile, there is a demand for determination of the proper maintenance measures, optimum maintenance intervals, and expected maintenance costs for the HDS. For this purpose, quantity and quality of trapped water, solids and floatables are analyzed. This chapter reports the results from monitoring the devices before and after cleanout.

## 5.2 Analysis of water samples

Water samples were collected from twelve (12) Vortechs® devices installed at eight (8) NJDOT project sites.

Due to the nature of the operation there was concern about polluted and turbid water being decanted during cleanout. In order to monitor pollutant levels and water quality, samples were collected. Based on sampling and handling requirements, each set of samples consisted of two bottles. One of the sample bottles was refrigerated as well as treated with sulfuric acid; the second bottle was only refrigerated. These samples, using two bottles each, were taken at the beginning and end of decanting.

**Table 5.1 Water Sample Guidelines and Analysis Methods. (Information from QC Laboratories)**

| Constituents | Method Reference | Minimum Sample Volume | Lab. Reporting Limits (RLs) | Preservation | Maximum Storage Time |
|---|---|---|---|---|---|
| Total Suspended Solids (TSS) | SM 20th Ed. 2540 | 1000 ml | 2.0 mg/l | Refrigerate | 7 days |
| Biochemical Oxygen Demand (BOD) | SM 20th Ed. 5210B | 1000 ml | 5.9 mg/l | Refrigerate to 4°C | 48 hours |
| Chemical Oxygen Demand (COD) | HACH Method 8000 | 500 ml | 10.0 mg/l | $H_2SO_4$ to pH<2, and refrigerate | 28 days |
| Total Phosphorus (TP) | SM 20th Ed. 4500-p B.5 E | 500 ml | 0.07 mg/l | $H_2SO_4$ to pH<2, and refrigerate | 28 days |
| Total Kjeldahl Nitrogen (TKN) | EPA 600 Method 351.2 | 500 ml | 1.0 mg/l | $H_2SO_4$ to pH<2, and refrigerate | 28 days |

The QC Laboratories was contracted to perform water quality and sediment analysis. Arrangements were made with the laboratory a week before cleanout as well as the day before, to ensure timely pick-up of the water samples. The samples were analyzed within the holding times specified by standard industry methods.

Water quality results were compared to typical untreated domestic wastewater (Metcalf and Eddy, 2003) and are shown in the following figures.

**Total Suspended Solids (TSS)**

The TSS concentrations from the twelve devices ranged from 306 to 388,000 mg/L. Although laborers manually performed the vacuuming procedures, which minimized disturbance, the TSS levels were nonetheless higher than 210 mg/L, which is TSS concentration in typical untreated domestic wastewater at medium strength flow rate (Metcalf and Eddy, 2003). The highest TSS concentration was observed at the RU06-01 site. In this case, turbidity was caused by the presence of mush sediments as well as the relatively small size of the device.

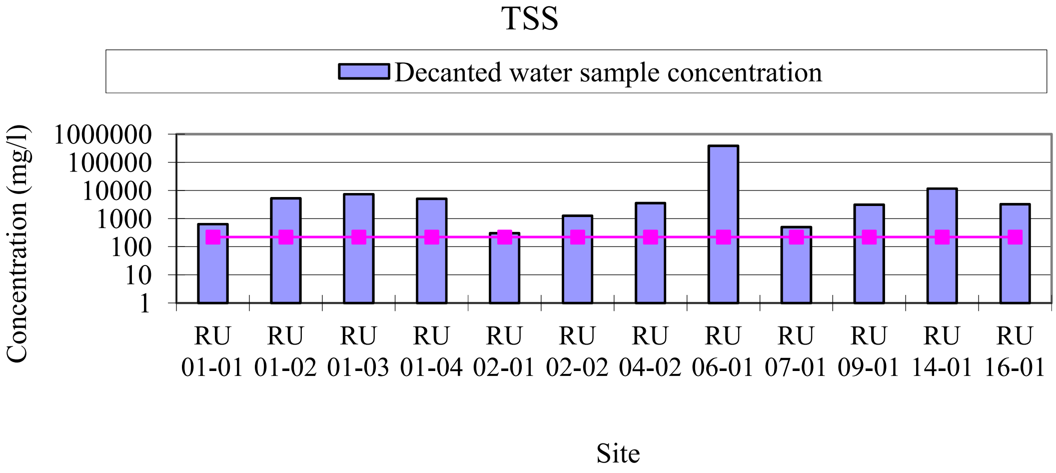



**Figure 5.1 Comparison of total suspended solids (TSS) concentration in decanted water samples and typical untreated municipal wastewater at medium strength flow rate (460 l/capita·d)**

**<u>Biochemical Oxygen Demand (BOD)</u>**

The BOD concentrations from the twelve devices ranged from 11 to 1,720 mg/L. Most of the BOD concentrations were lower than those in typical untreated domestic wastewater (190 mg/L) at medium strength flow rate. The highest BOD concentration was 1,720 mg/L from the RU01-03 site and the second highest was 1,177 mg/L from RU06-01. During the cleanout activity, water from RU01-03 and RU06-01 was turbid due to the presence of mush sediments. Site RU01-03, located on the Busch Campus of Rutgers University, had long drainage ditches located beside the turf field. It was observed that sediment in the device contained a large amount of organic matter. Percent organic matter of the sediments was 33.8 %.

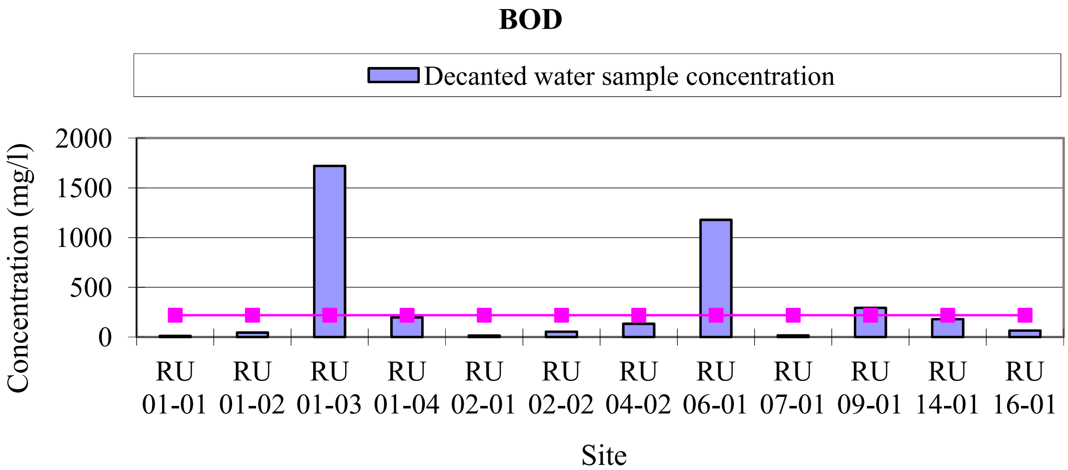



**Figure 5.2 Comparison of biochemical oxygen demand (BOD) concentration in decanted water samples and typical untreated municipal wastewater at medium strength flow rate (460 l/capita·d)**

**Chemical Oxygen Demand (COD)**

The COD concentrations from the twelve devices ranged from 204 to 51,700 mg/L. Most of the COD concentrations were higher than those in typical untreated domestic wastewater (430 mg/L) at medium strength flow rate. The highest COD concentration was observed at the RU06-01 site, which had the largest TSS levels. Sites that included commercial areas such as RU04-02 (Elizabeth, NJ), RU09-01 (Lakewood, NJ) and RU14-01 (Parsippany, NJ) showed higher levels of COD.

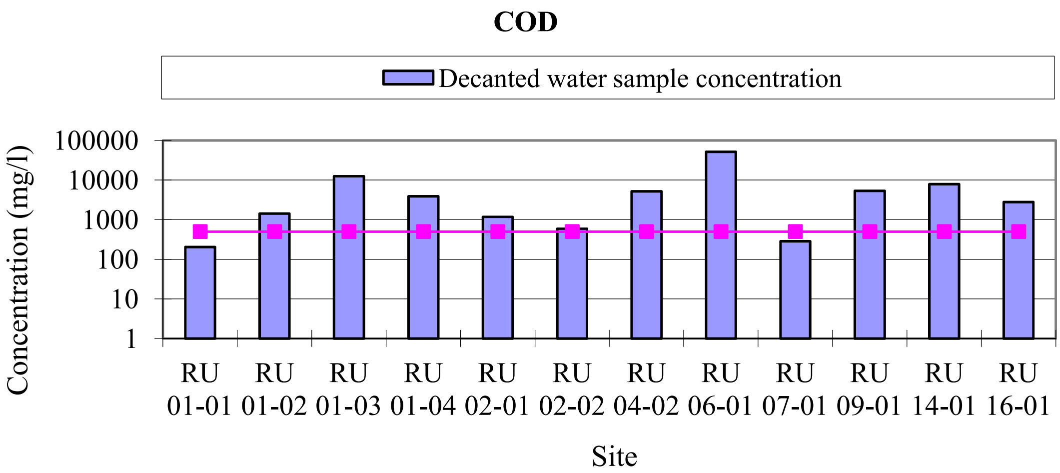



**Figure 5.3 Comparison of chemical oxygen demand (COD) concentration in decanted water samples and typical untreated municipal wastewater at medium strength flow rate (460 l/capita·d)**

**Total Phosphorus (TP)**

The TP concentrations from the twelve devices ranged from 0.6 to 58.6 mg/L. The highest COD concentration was observed at the RU14-01 site. Most of TP levels were lower than those in typical untreated domestic wastewater (7 mg/L) at medium strength flow rate.

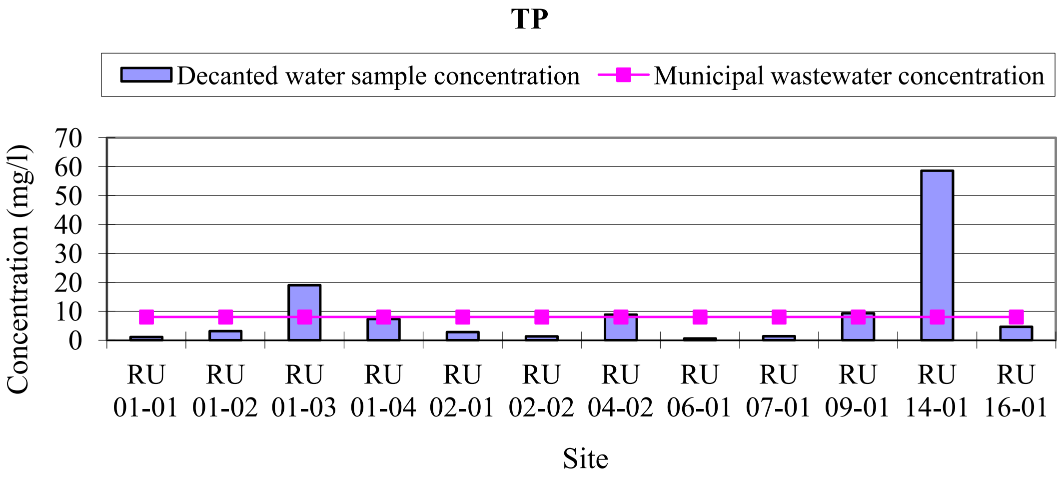



**Figure 5.4 Comparison of total phosphorus (TP) concentration in decanted water samples and typical untreated municipal wastewater at medium strength flow rate (460 l/capita·d)**

**Total Kjeldahl Nitrogen (TKN)**

The TKN concentrations from the twelve devices ranged from 3.3 to 154.5 mg/L. The highest TKN concentration was observed at the RU06-01 site. Most of the TKN levels were lower than those in typical untreated domestic wastewater (40 mg/L) at medium strength flow rate. In the case of RU01-03, there was a period of time where TKN equipment failed at the contract laboratory. The laboratory subcontracted the TKN analysis to another lab. The reported TKN concentrations from the second lab showed detectable levels within the sediment; however, the water samples had no detectable levels of TKN. The fact that there was TKN in the sediment, but not in the water, does raise questions about the validity of the results from the lab – but no clarifications were presented.

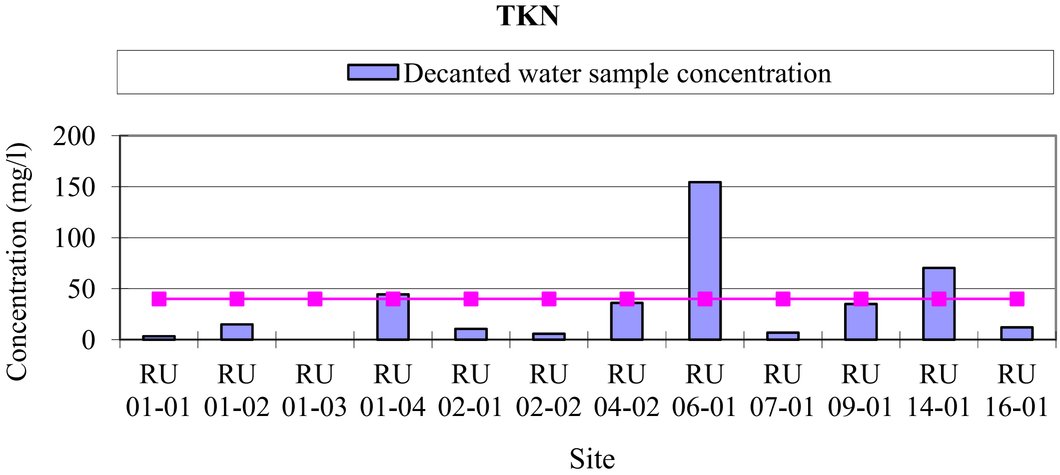



**Figure 5.5 Comparison of total kjeldahl nitrogen (TKN) concentration in decanted water samples and typical untreated municipal wastewater at medium strength flow rate (460 l/capita·d)**

## 5.3 Analysis of trapped solids and floatables

Initially, twelve (12) Vortechs® devices were selected and cleaned out in 2007 and 2009. After first cleanout, six (6) of the twelve (12) selected and monitored devices reached or were close to reach the cleanout threshold in 2011. They were cleaned out and analyzed by utilizing the same methodology in 2008.

**Oil and Grease**

The amount of oil in the devices was measured using oil-only absorbents. For this study, the PIG®Sump skimmer, an absorbent polypropylene fiber material was chosen. This material absorbs and retains oil and oil-based liquids including lubricants, fuels and cleaning agents. Each skimmer is designed to absorb 1.8 gallons of oil without absorbing water.

The weight of trapped oil collected in the 2008 clean out ranged from 0.4 to 2.8 kilograms among the 12 devices. In the 2011 clean out, the weight of trapped ranged from 0.8 to 2.4 kilograms among the five devices sampled. One device (RU04-02) could not be sampled for oil in 2011 despite having been cleaned out.

The results suggest that the amount of oil and grease retained in the HDS is directly related to traffic rather than to sediment level in the device. Larger quantities of oil were retained in devices located at sites with heavy traffic (e.g. RU06-01: North Bergen, and RU14-01: Parsippany).

Three of the devices retained approximately the same amount of oil and grease in both 2008 and 2011. Two devices showed some variation between the 2008 and the 2011 samplings. This can be explained by the fact that when the devices were first sampled in 2008, they had been in operation for different lengths of time, while in 2011 they had started from a clean state at approximately the same time. The 2011 measurements give a better estimate of the amount of oil expected to be retained by each device between clean outs. Figure 5.6 compares the weight of oil trapped in each device in 2008 and 2011.

The results suggest that it is important to consider the oil retention capabilities of the HDS chosen for a site based on the amount of traffic expected. For urban, commercial and industrial areas where heavy traffic is expected, it is critical to insure that the device will provide a retention system that impedes the oil from being carried out during storm events with high precipitation. Further research is needed to determine the amount of oil being retained relative to the total amount of oil being carried by runoff into the HDS.

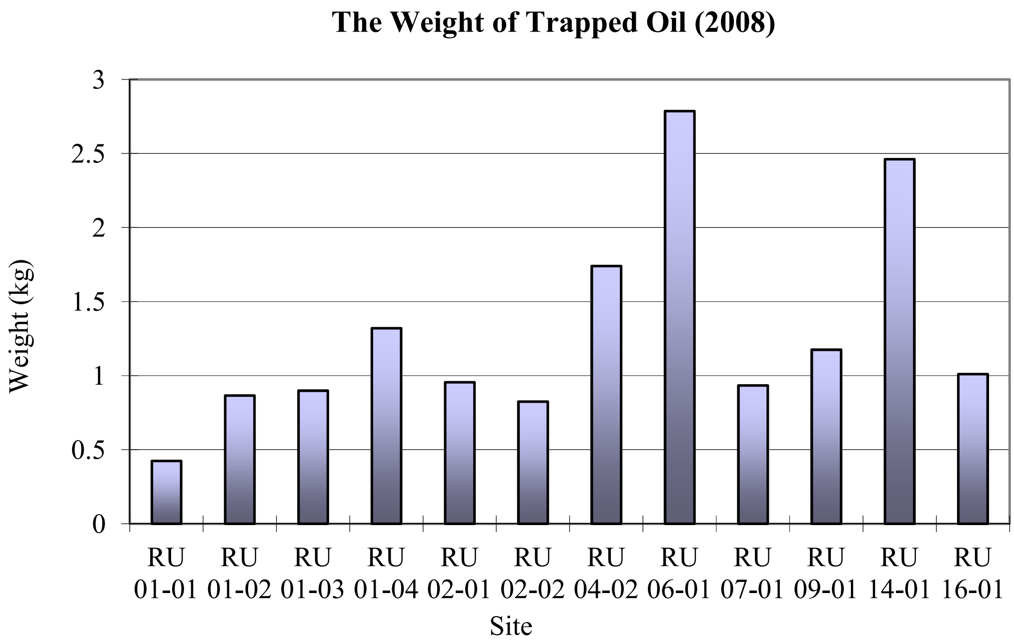



**Figure 5.6 The weight of Oil trapped by HDS at clean out in 2008**

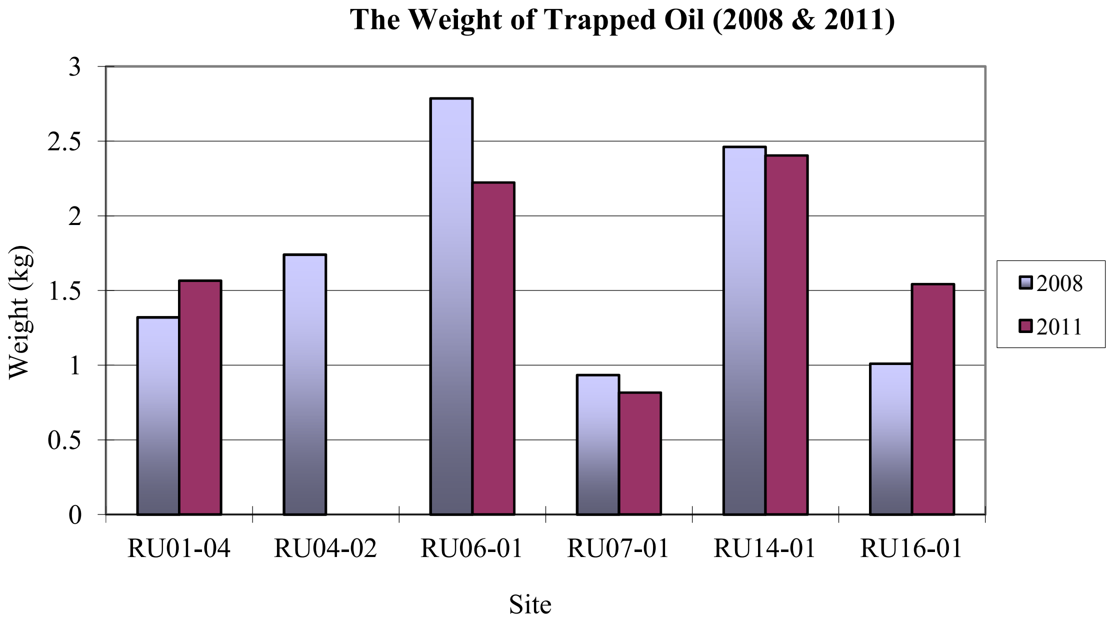



**Figure 5.7 Comparison of weight of Oil trapped by HDS at clean out in 2008 and in 2011**

**Floatables**

Immediately before the cleanout, floatable litter and organic debris were skimmed off the water surface. All litter bags collected from the site and collected floatables in the bag were emptied into a sorting tub. As a result, the sediment sampled and analyzed did not contain floatable litter. Collected floatables from each site were air dried and the volume and weight were measured in the laboratory (Table 5.2). The measurement was conducted based on litter investigations by New York City (HydroQual, Inc., 1995).

**Table 5.2 The Volume and Weight of Floatables Collected in The Device (2008)**

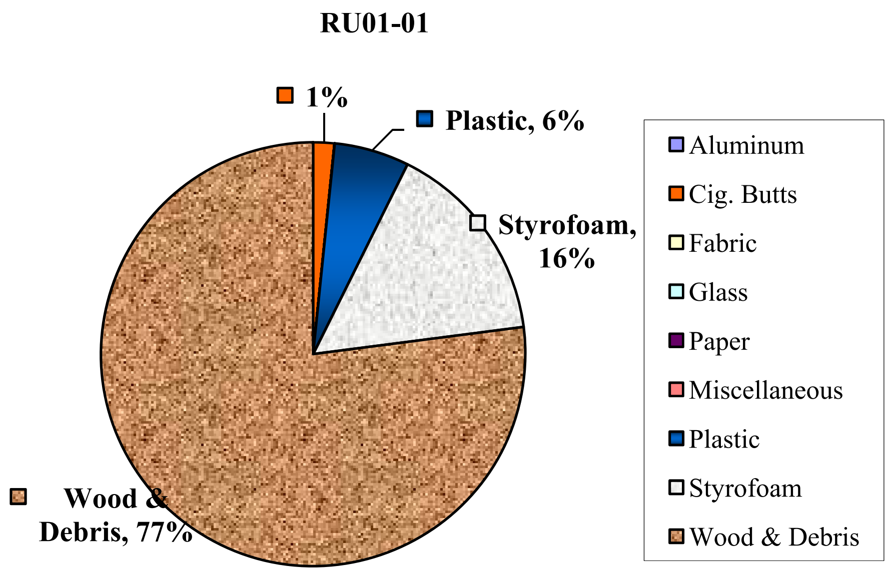
The Volume ($ft^3$)

| ID | Alumi-num | Cig. Butts | Fabric | Glass | Paper | Misc. | Plastic | Styrofo-am | Wood & Debris | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| RU01-01 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.005 | 0.026 | 0.034 |
| RU01-02 | 0.018 | 0.005 | 0.000 | 0.000 | 0.000 | 0.014 | 0.110 | 0.086 | 0.051 | 0.284 |
| RU01-03 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.018 | 0.215 | 0.239 |
| RU01-04 | 0.021 | 0.032 | 0.000 | 0.008 | 0.011 | 0.028 | 0.131 | 0.184 | 0.441 | 0.857 |
| RU02-01 | 0.007 | 0.020 | 0.000 | 0.000 | 0.000 | 0.011 | 0.112 | 0.161 | 0.240 | 0.574 |
| RU02-02 | 0.000 | 0.015 | 0.000 | 0.000 | 0.000 | 0.011 | 0.112 | 0.125 | 0.184 | 0.445 |
| RU04-02 | 0.004 | 0.017 | 0.000 | 0.003 | 0.004 | 0.018 | 0.127 | 0.194 | 0.032 | 0.397 |
| RU06-01 | 0.004 | 0.001 | 0.000 | 0.003 | 0.000 | 0.014 | 0.040 | 0.039 | 0.000 | 0.101 |
| RU07-01 | 0.000 | 0.007 | 0.000 | 0.003 | 0.004 | 0.021 | 0.081 | 0.221 | 0.148 | 0.486 |
| RU09-01 | 0.000 | 0.040 | 0.000 | 0.002 | 0.000 | 0.014 | 0.025 | 0.159 | 0.025 | 0.265 |
| RU14-01 | 0.000 | 0.025 | 0.000 | 0.004 | 0.000 | 0.018 | 1.207 | 3.196 | 0.127 | 4.676 |
| RU16-01 | 0.000 | 0.032 | 0.000 | 0.002 | 0.000 | 0.004 | 0.068 | 0.170 | 0.030 | 0.305 |

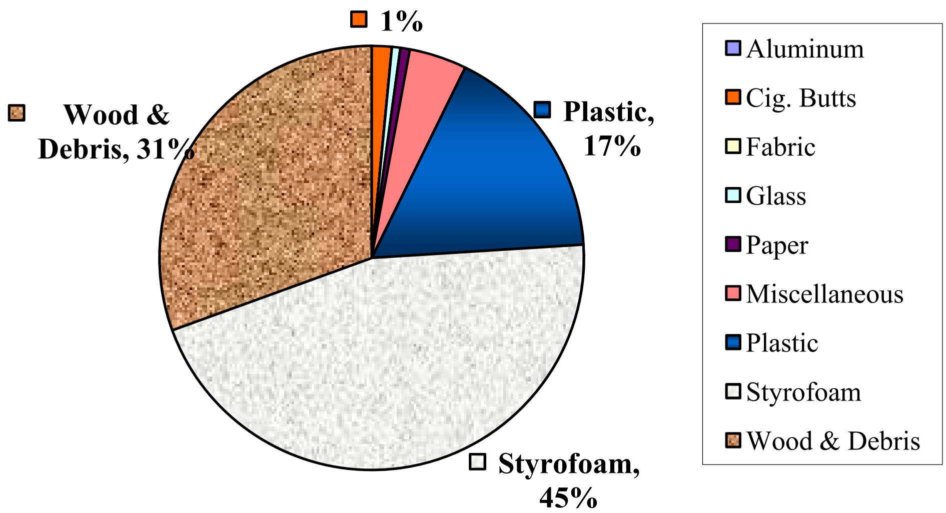
The Weight (lbs)

| ID | Alumin-um | Cig. Butts | Fabric | Glass | Paper | Misc. | Plastic | Styrofo-am | Wood & Debris | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| RU01-01 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 | 0.004 | 0.071 | 0.082 |
| RU01-02 | 0.052 | 0.008 | 0.000 | 0.000 | 0.000 | 0.300 | 0.310 | 0.031 | 0.101 | 0.802 |
| RU01-03 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.050 | 0.006 | 0.690 | 0.758 |
| RU01-04 | 0.074 | 0.039 | 0.000 | 0.108 | 0.013 | 0.510 | 0.310 | 0.081 | 1.321 | 2.456 |
| RU02-01 | 0.052 | 0.024 | 0.000 | 0.000 | 0.000 | 0.122 | 0.412 | 0.131 | 0.628 | 1.369 |
| RU02-02 | 0.000 | 0.022 | 0.000 | 0.000 | 0.000 | 0.214 | 0.575 | 0.192 | 0.521 | 1.524 |
| RU04-02 | 0.011 | 0.029 | 0.000 | 0.042 | 0.010 | 0.280 | 0.167 | 0.021 | 0.085 | 0.645 |
| RU06-01 | 0.010 | 0.001 | 0.000 | 0.048 | 0.000 | 0.121 | 0.100 | 0.019 | 0.001 | 0.300 |
| RU07-01 | 0.000 | 0.009 | 0.000 | 0.042 | 0.018 | 0.340 | 0.123 | 0.056 | 0.400 | 0.988 |
| RU09-01 | 0.000 | 0.056 | 0.000 | 0.028 | 0.000 | 0.272 | 0.777 | 0.090 | 0.051 | 1.274 |
| RU14-01 | 0.000 | 0.037 | 0.000 | 0.110 | 0.000 | 0.411 | 3.801 | 1.151 | 0.387 | 5.897 |
| RU16-01 | 0.000 | 0.042 | 0.000 | 0.028 | 0.000 | 0.080 | 0.213 | 0.041 | 0.056 | 0.460 |

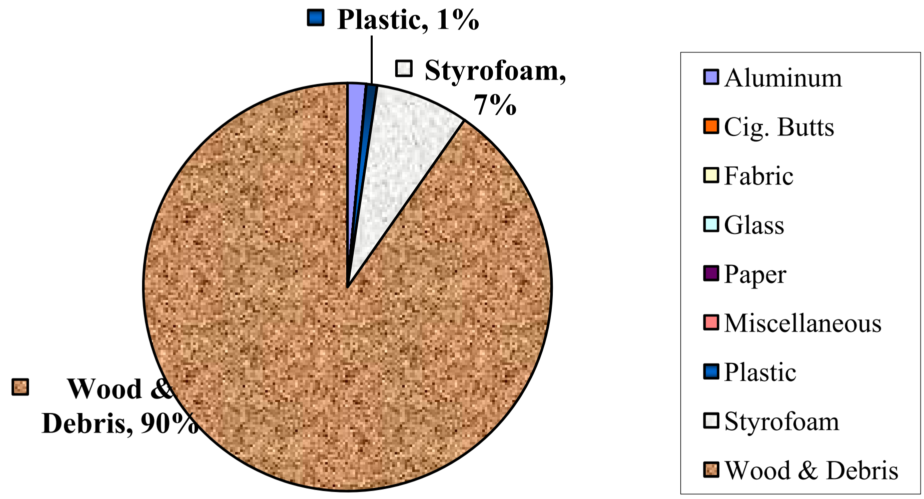
The most common types of floatables found were plastic, Styrofoam, and organic debris. The characterization study showed that Styrofoam constituted over 50 percent by volume while plastics constituted over 40 percent by weight of the floatable litter (Figure 5.7).



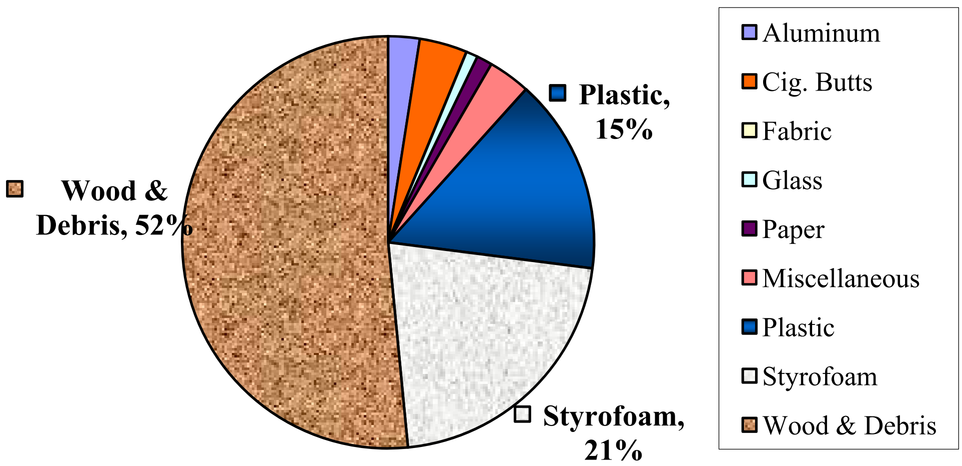
**RU01-02**


1%
Wood & Debris, 31%
Plastic, 17%
Styrofoam, 45%
Aluminum
Cig. Butts
Fabric
Glass
Paper
Miscellaneous
Plastic
Styrofoam
Wood & Debris

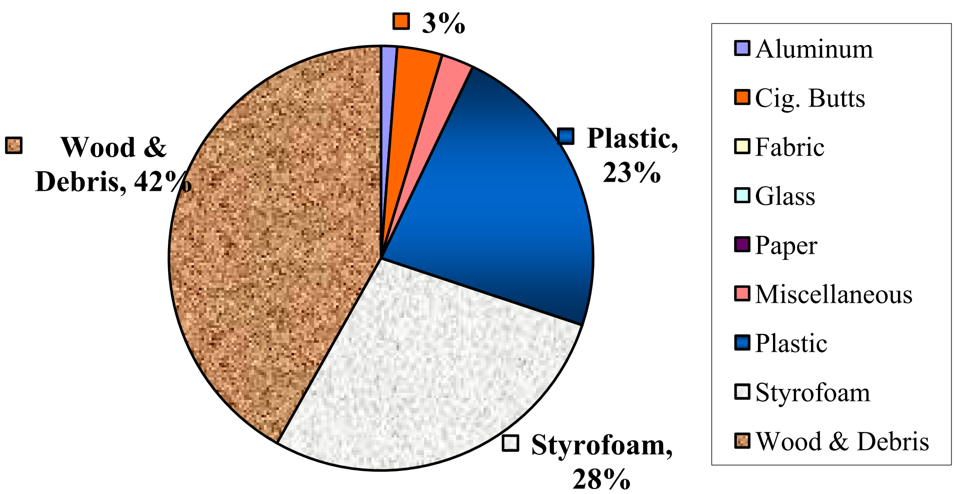
**RU01-03**



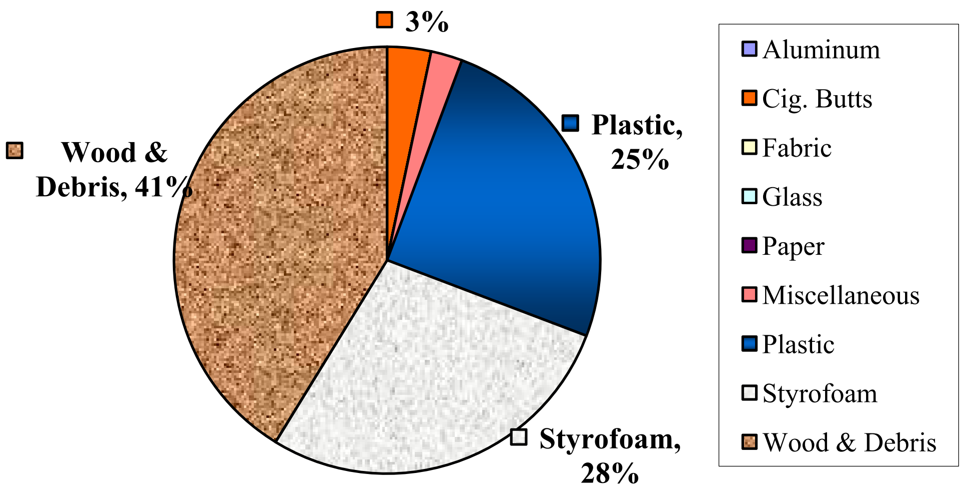

**RU01-04**

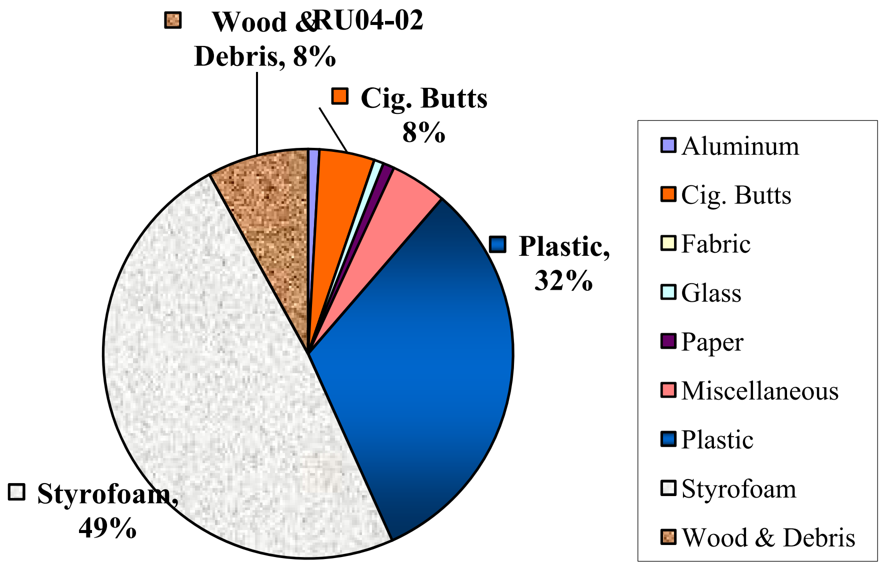


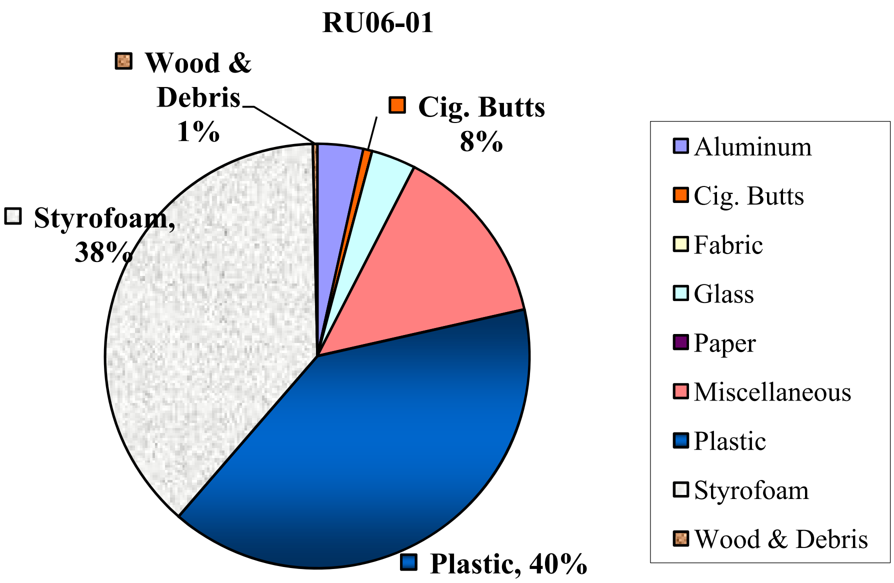
**RU02-01**



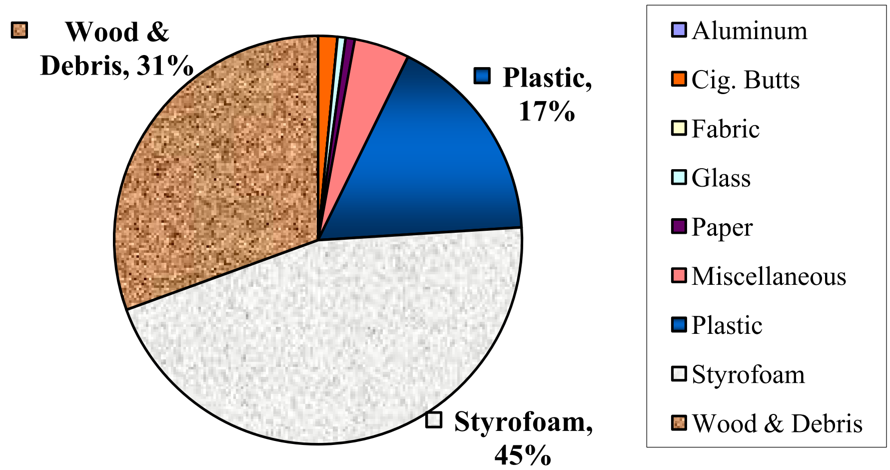

**RU02-02**



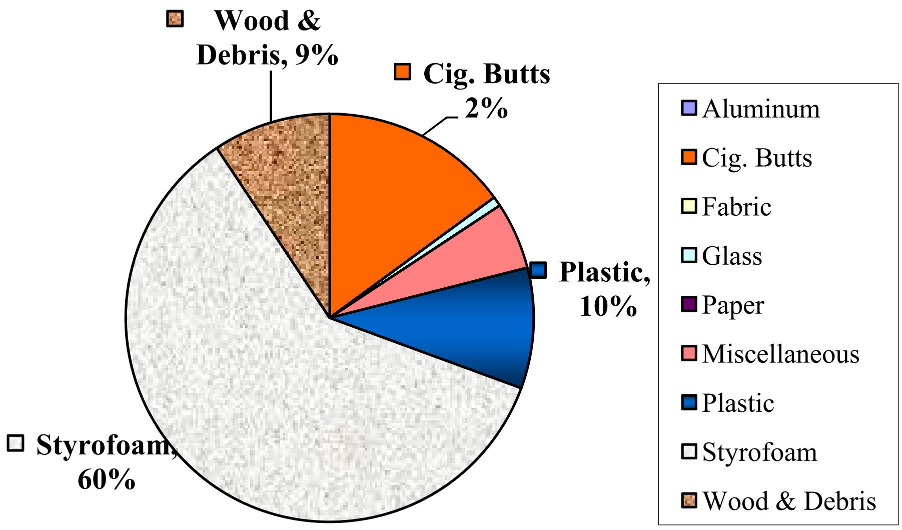

RU04-02
Wood & Debris, 8%
Cig. Butts 8%
Plastic, 32%
Styrofoam, 49%
Aluminum
Cig. Butts
Fabric
Glass
Paper
Miscellaneous
Plastic
Styrofoam
Wood & Debris

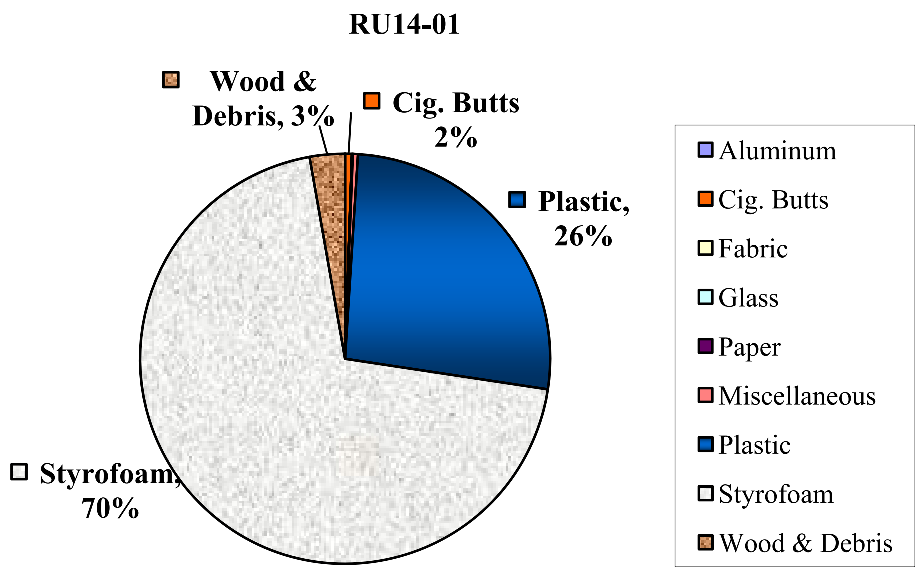

RU06-01
Wood & Debris 1%
Cig. Butts 8%
Styrofoam, 38%
Plastic, 40%
Aluminum
Cig. Butts
Fabric
Glass
Paper
Miscellaneous
Plastic
Styrofoam
Wood & Debris

RU07-01




RU09-01





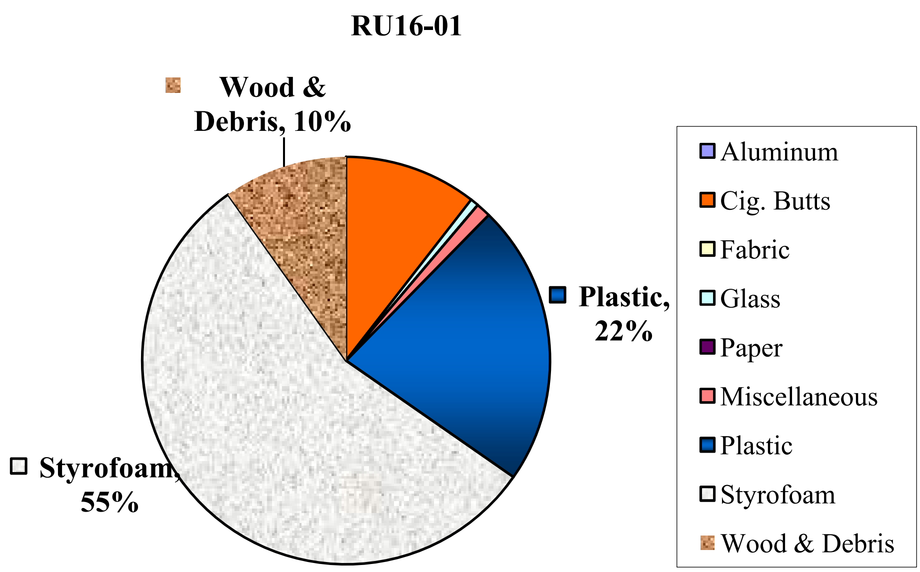
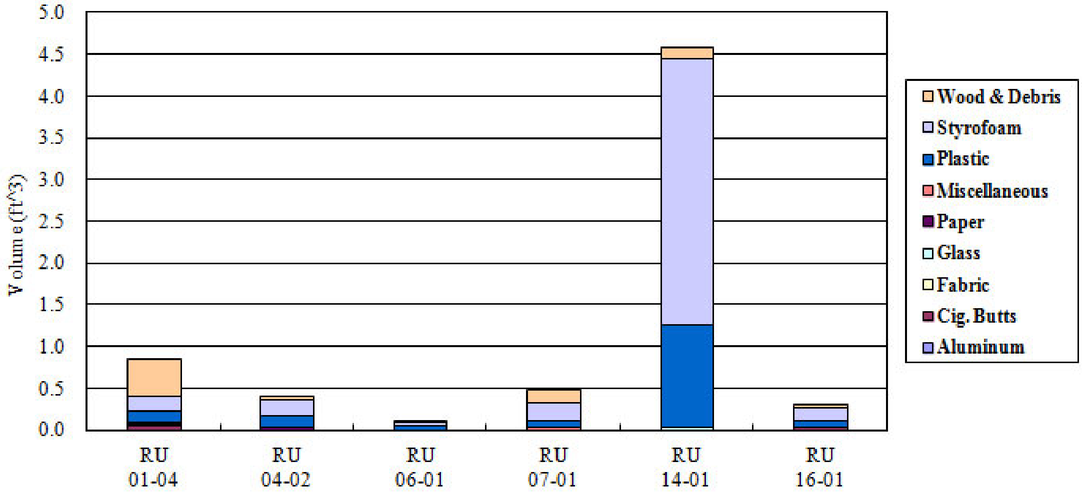



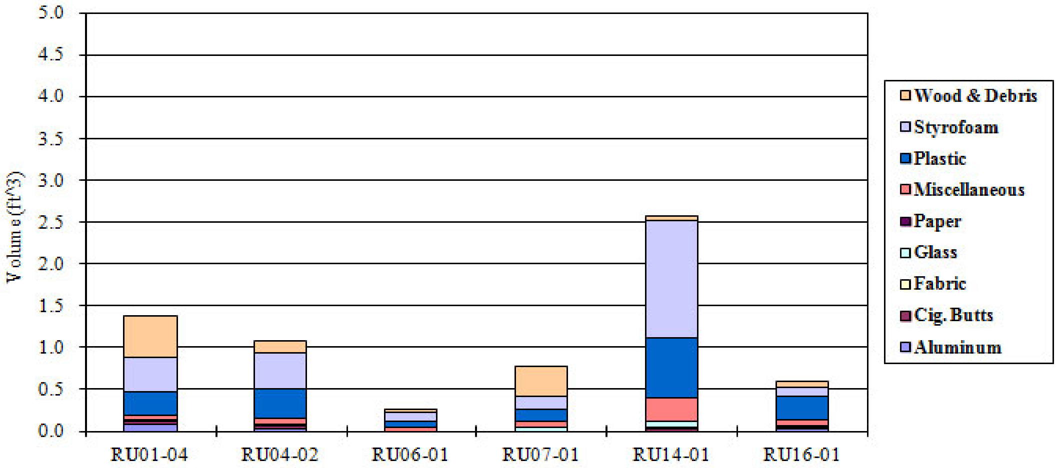

**Figure 5.8 Types and volume proportions of floatables that were trapped and removed**

During the first cleanout in 2008, a large amount of Styrofoam had been found at the device (Figure 5.8a). Most of those floatables were Styrofoam peanuts and Styrofoam boards usually used for packing. It was suspected that those materials had not come from roadway runoff but rather from activities not related to traffic or normal debris carried by storm runoff. During the second cleanout in 2011, however, RU14-01 still contained a large amount of Styrofoam (Figure 5.8b). The Styrofoam litter observed in 2011 consisted mostly of beverage cups, dishes, and packing peanuts, but no large Styrofoam boards were found like in 2008.

A large volume of floatables within an HDS can cause problems such as discharge of litter into receiving waters during large storm events, blockage of inlet or outlet pipes, and reduced volume of water being treated by the device, among others. All of these problems can cause the discharges to receiving waters to violate the NPDES permit limits and lead to fines for the managing agency.




(a) Volume and type of floatables trapped (2008)




(b) Volume and type of floatables trapped (2011)

**Figure 5.9 Comparison and distribution of floatables by volume (2008 vs. 2011)**

**Sediment weight and volume**

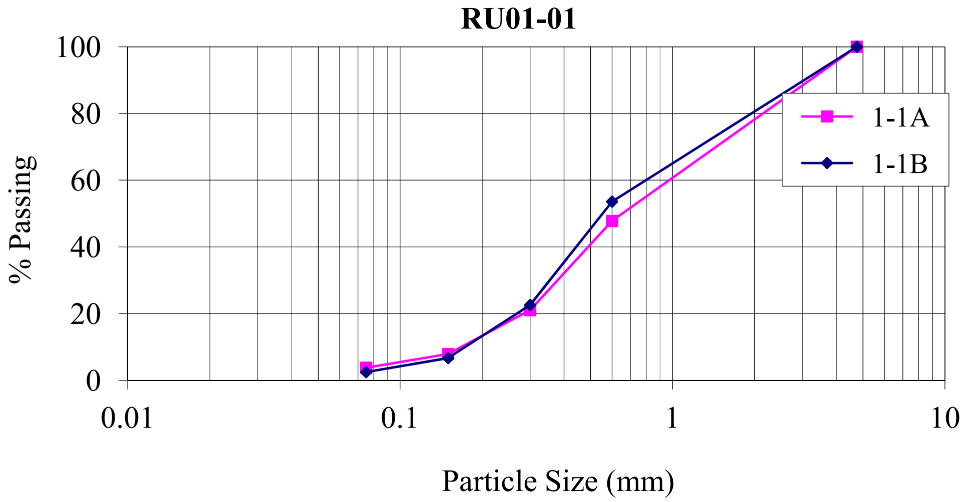
The weight and volume of sediment retained in the HDS are shown in Table 5.3. Volume was calculated from the sediment depth measurements. In the 2011, the weight of sediment was not measured or recorded. The data shows large variations between the amounts of sediment retained by devices of approximately the same size operating for equivalent lengths of time. For example, devices RU01-01 and RU 14-01 are the same size and operated for almost the same length of time before the 2008 clean out, but RU01-01 retained less than 4% of the volume retained by RU 14-01. While part of the difference in sediment retention could be explained by site conditions, it was found upon further investigation that device RU01-01 had been coupled with an incorrectly constructed diversion chamber so runoff was bypassing the HDS. It is expected that similar-sized devices located in areas with similar conditions should have similar sediment accumulation over time. Large discrepancies in sediment accumulation in devices with similar characteristics can indicate problems such as blockage of pipes, incorrectly constructed components, damaged structural components. Regularly scheduled site inspections and comparison of accumulation patterns can help identify problems in installed devices and avoid fines and sanctions from environmental authorities.

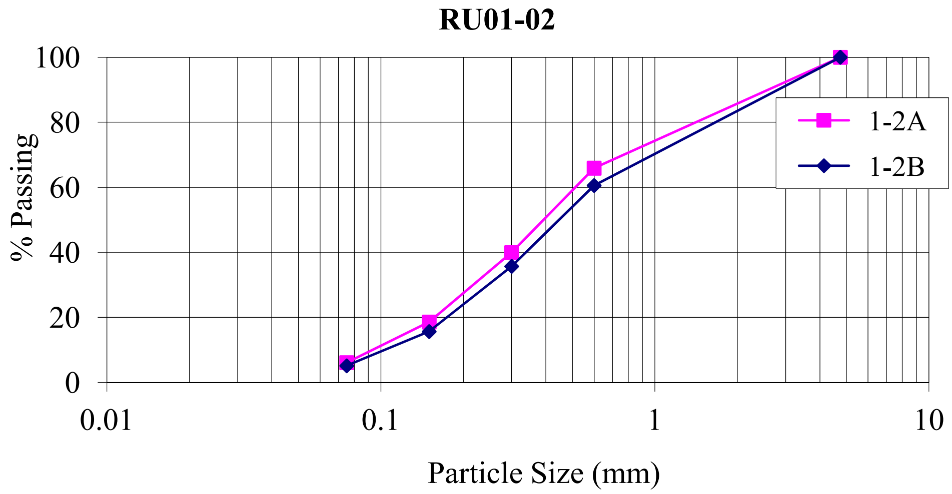
**Table 5.3 Volume and Weight of Bottom Sediment in Each Vortechs® Swirl Chamber (2008)**

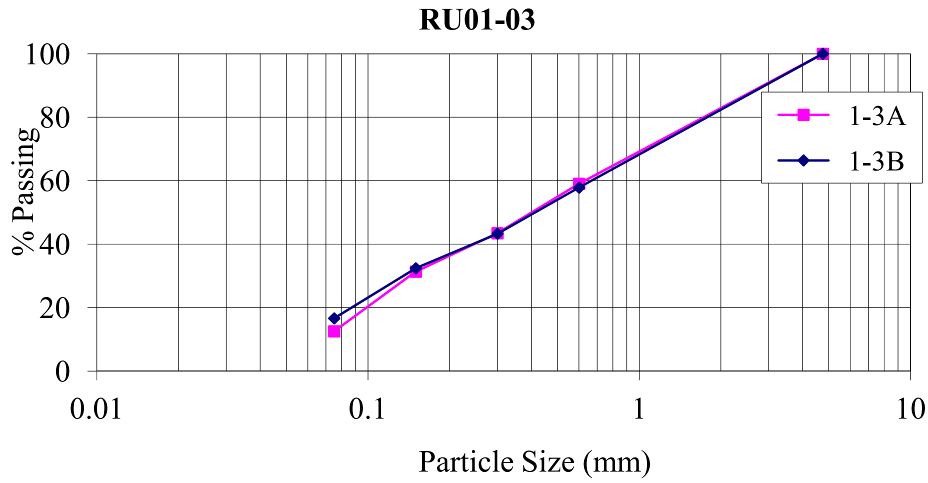
| | Volume ($ft^3$) | Weight (lbs.) |
|---|---|---|
| RU01-01 | 2 | 103 |
| RU01-02 | 48 | 3157 |
| RU01-03 | 56 | 4094 |
| RU01-04 | 70 | 4561 |
| RU02-01 | 30 | 2521 |
| RU02-02 | 18 | 1931 |
| RU04-02 | 10 | 1489 |
| RU06-01 | 9 | 639 |
| RU07-01 | 36 | 2793 |
| RU09-01 | 11 | 490 |
| RU14-01 | 54 | 3553 |
| RU16-01 | 14 | 1101 |
| Total | 358 | 26432 |

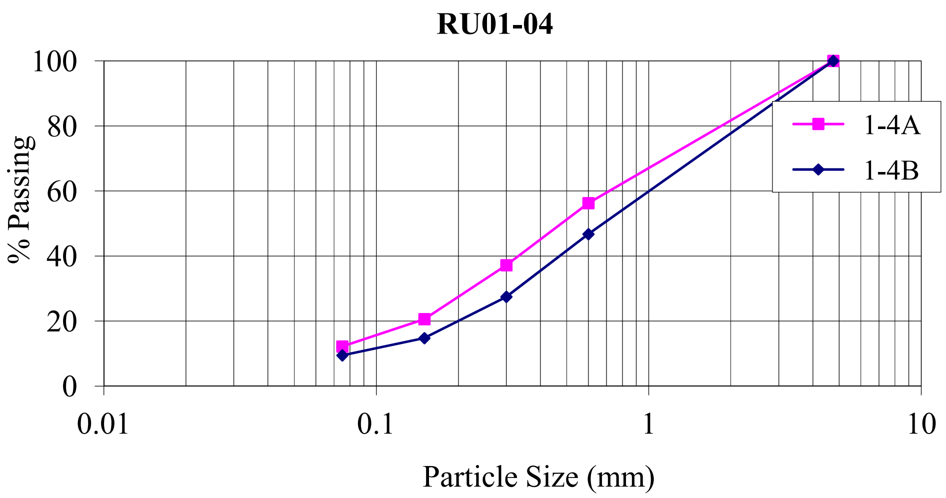
### Sediment particle size distribution

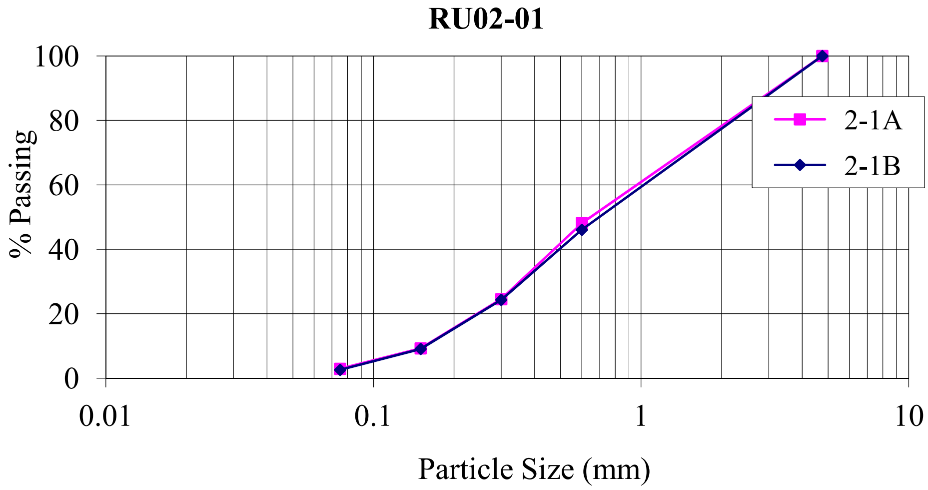
Two samples were taken from each site for particle size distribution (PSD) analysis. In Figure 5.9, particle size distribution curves are represented.

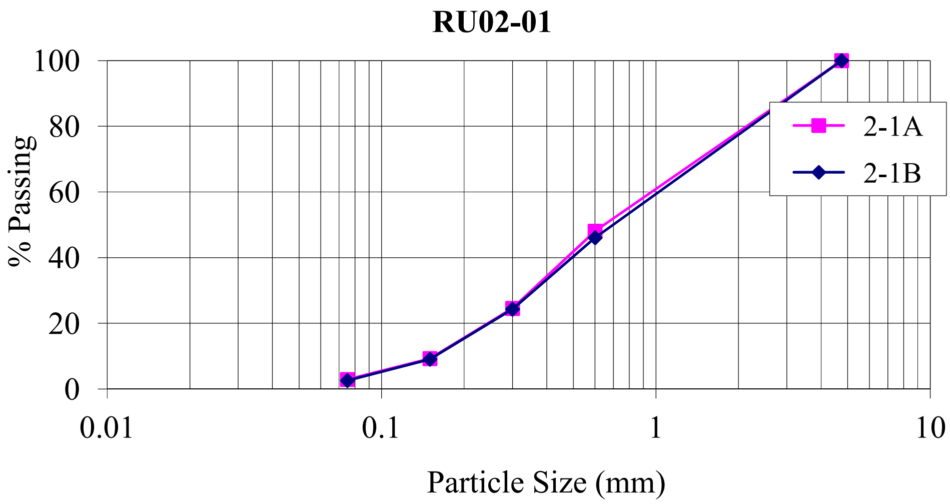

RU01-01
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
1-1A
1-1B

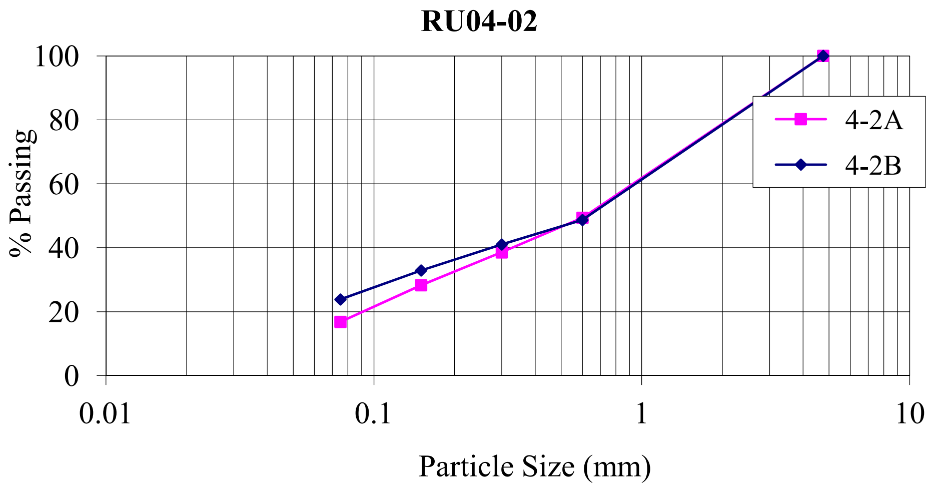

RU01-02
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
1-2A
1-2B

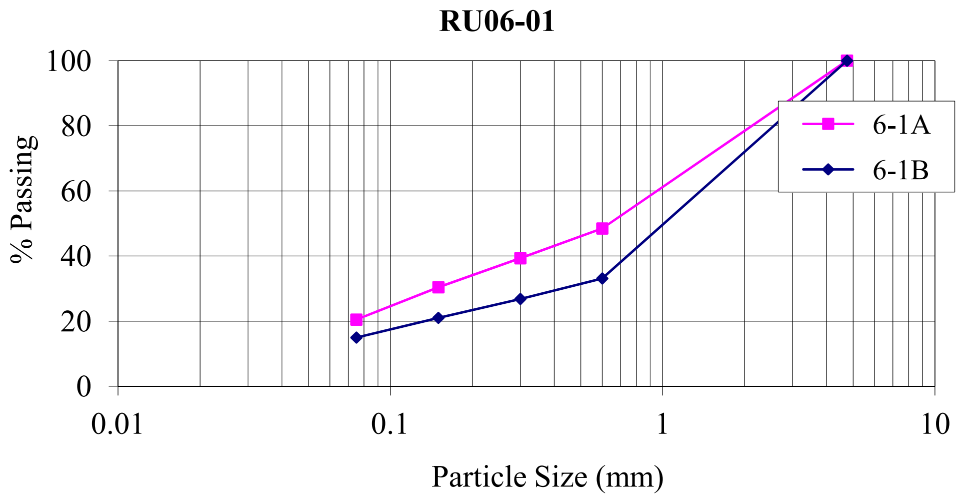

RU01-03
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
1-3A
1-3B

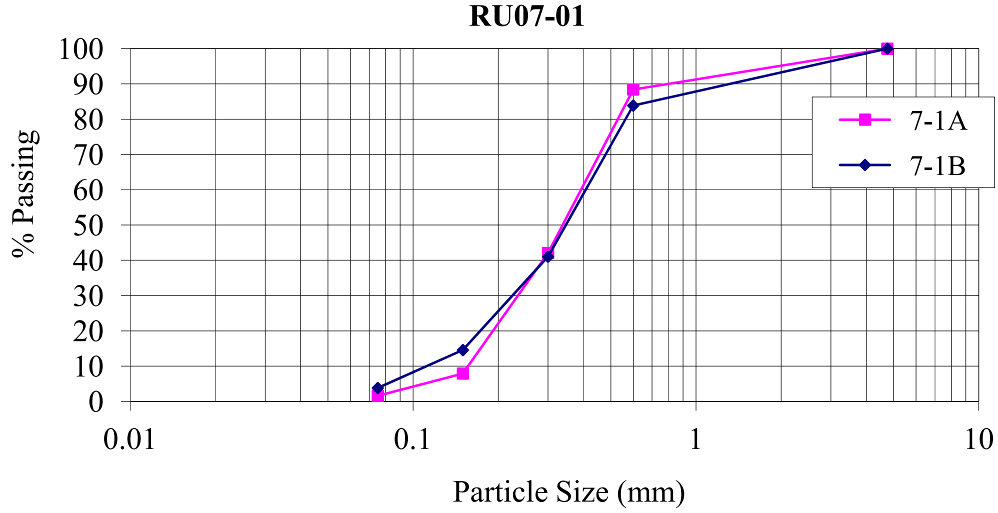

RU01-04
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
1-4A
1-4B

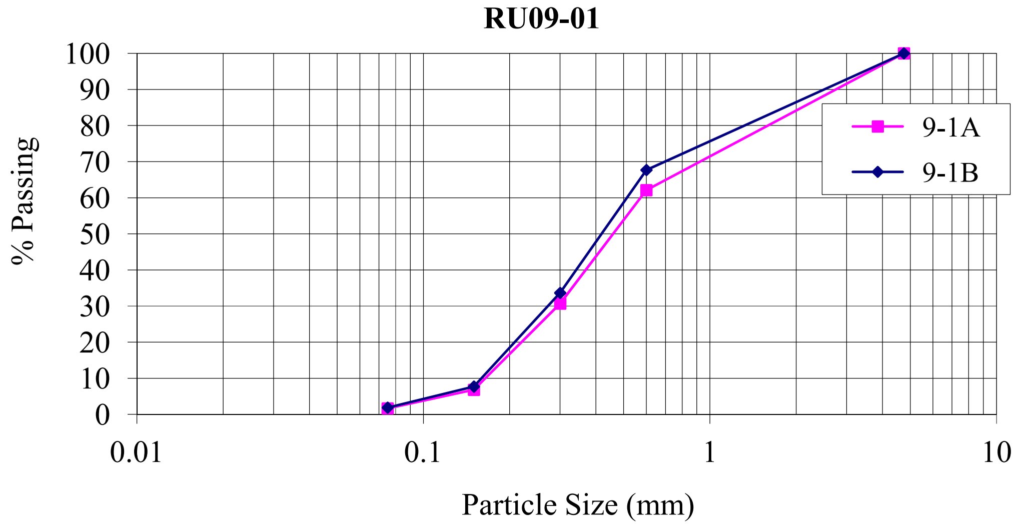

RU02-01
% Passing
100
80
60
40
20
0
0.01
0.1
1
10
Particle Size (mm)
2-1A
2-1B

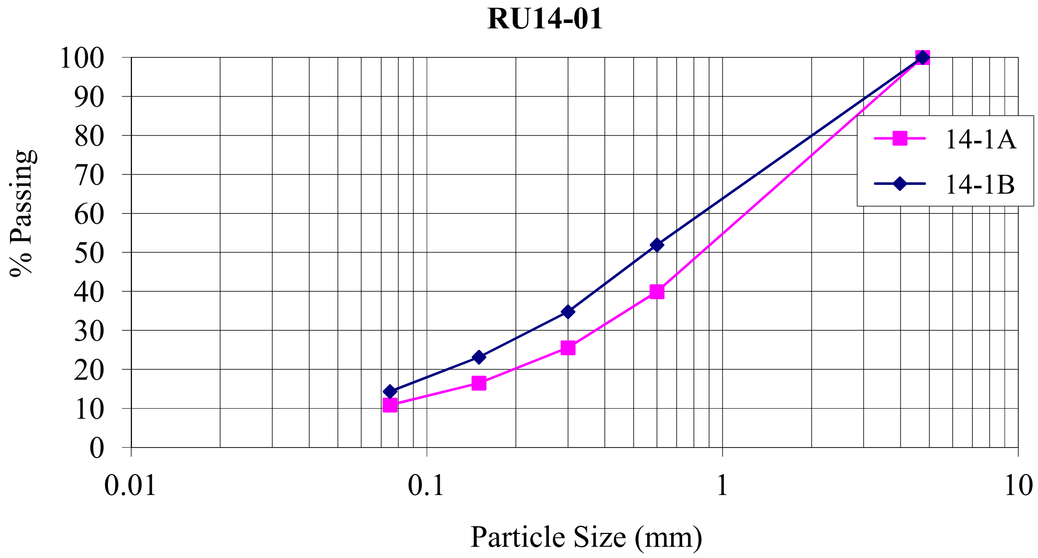

RU02-01
% Passing
100
80
60
40
20
0
0.01
0.1
1
10
Particle Size (mm)
2-1A
2-1B


RU04-02
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
4-2A
4-2B


RU06-01
100
80
60
40
20
0
% Passing
0.01
0.1
1
10
Particle Size (mm)
6-1A
6-1B


RU07-01
% Passing
100
90
80
70
60
50
40
30
20
10
0
0.01
0.1
1
10
Particle Size (mm)
7-1A
7-1B


RU09-01
% Passing
100
90
80
70
60
50
40
30
20
10
0
0.01
0.1
1
10
Particle Size (mm)
9-1A
9-1B



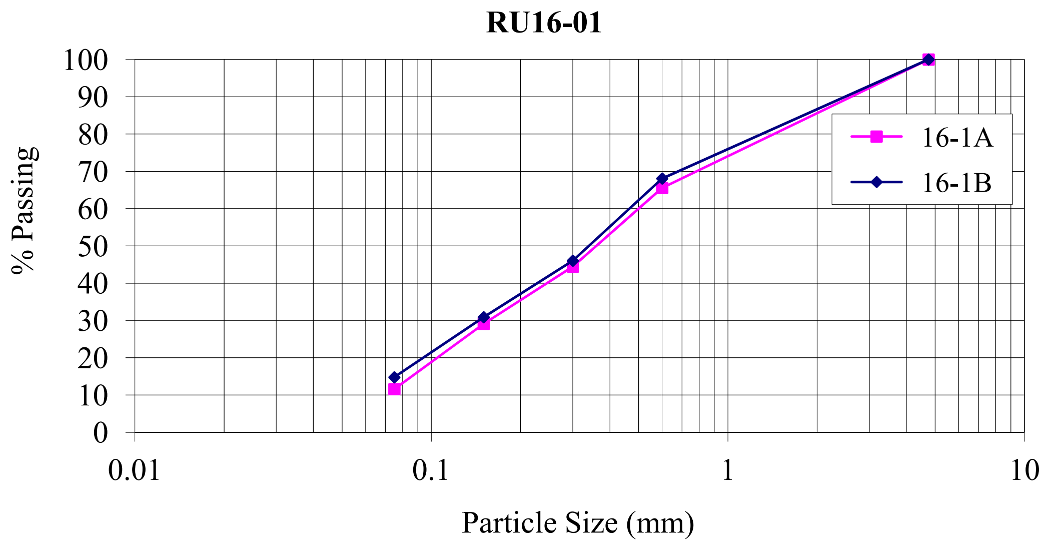




**Figure 5.10 Particle size distribution curves of sediment. Two samples were taken from each device in 2008.**

Larger material such as leaves, litter, and debris retained by the #4 sieve (4.75 mm) was excluded from the PSD analysis. These large materials represented approximately 12% by weight of the total collected sediment. There are large variations from one device to another and no correlation could be found between device size and large material collected. Even devices within the same site presented very large differences. Large debris can cause problems in the inlet and outlet of the device which can cause water to bypass the HDS and be discharged directly into receiving waters. HDS should be sized with enough capacity to accommodate large debris, especially in wooded or rural areas where large quantities of leaves and branches are expected to be carried with runoff. The percentage of particles larger than 4.75 mm in the sediment samples is shown in Figure 5.10.

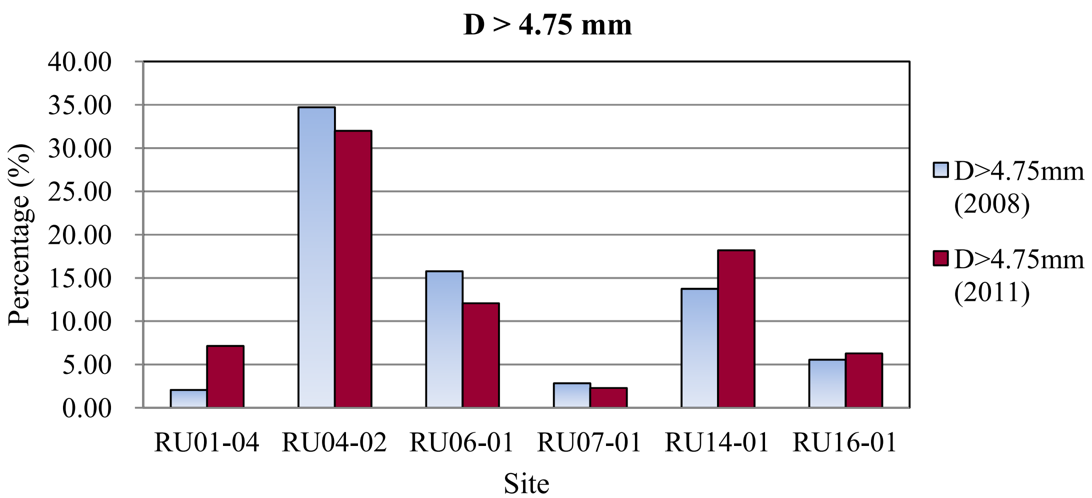



**Figure 5.11 Comparison of particles larger than 4.75 mm**

This monitoring guideline is designed for devices that primarily collect particles larger than 75 microns (0.075 mm). The sediment samples tested in this study contained 13 percent of particles larger than 4.75 mm and 7 percent of particles smaller than 75 microns by weight on average. In the previous study in 2008, 12 percent of particles by weight on average were larger than 4.75 mm and 11 percent was smaller than 75 microns found from the same 6 devices.

**Chemical Analysis of Sediment Samples**

Sample sediment was collected halfway through the cleanout operation. These sediment samples were then sent to a laboratory for analysis. The results were similar to those from the previous study conducted in 2008.

The sediment samples were tested for Arsenic, Cadmium, Copper, Lead and Zinc. All the tested sediments had concentrations below regulated levels of Arsenic, Cadmium, Copper, and Zinc. Lead concentration at the RU06-01 device located in North Bergen, NJ was higher than the residential soil quality. The lead concentration of the sediment at RU06-01 was 419 mg/kg while the residential soil quality standard should be below 400 mg/kg.

Total Kjeldahl Nitrogen and Total Phosphorus concentrations were higher in the tested sediments than the non-residential (pine barren) soil quality. Nitrogen and phosphorus are not considered toxic at these concentrations, but can cause disruptions to aquatic ecosystems. The classification of and analytical methods for the stormwater solids can be found in Roesner et al. (2007), Rushton and England (2006), and Rushton (2006).

Arsenic: The highest concentration of arsenic found was 9.37 mg/kg at RU07-01 (Figure 5.11). Arsenic concentration in all devices was lower than the standard median concentration for residential and non-residential soil quality (20 mg/kg).

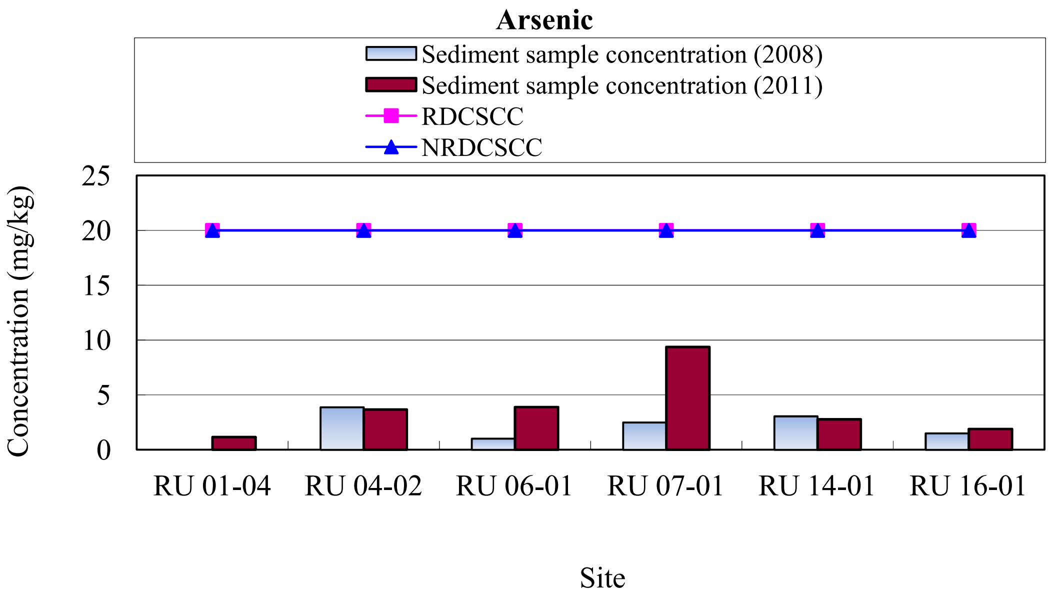



**Figure 5.12 Comparison of arsenic concentration in sediment sample taken in 2008 and 2011. Residential direct contact soil criteria (RDCSCC) and non-residential direct contact soil cleanup criteria (NRDCSCC) are shown as reference.**

Copper: Copper concentration in the six devices sampled for this study ranged from 8.9 to 229 mg/kg (Figure 5.12). Measured copper concentration in all sediments tested was lower than the standard median concentration for residential and non-residential soil quality (600 mg/kg).

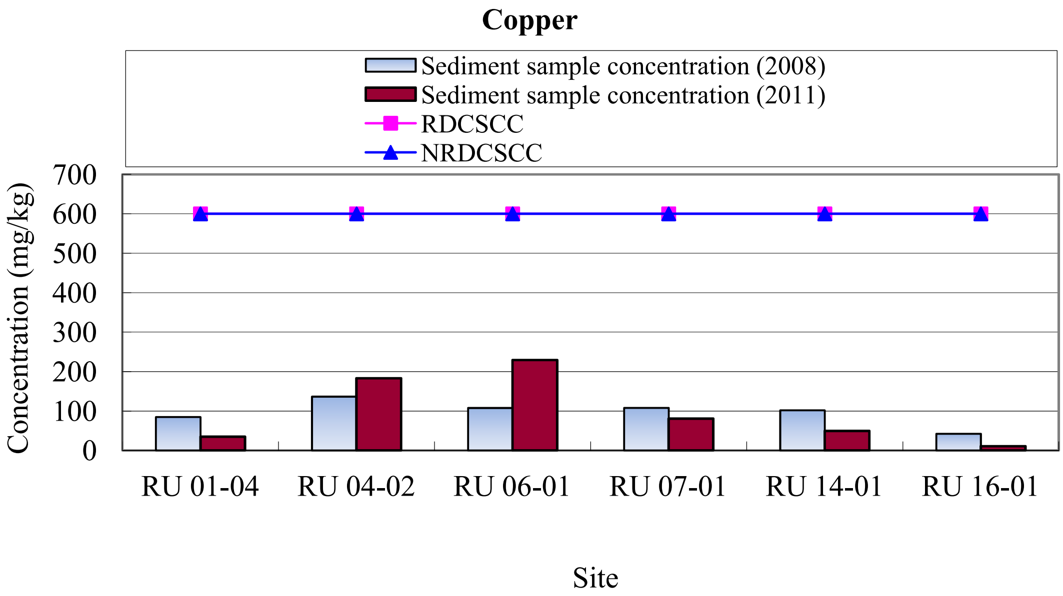



**Figure 5.13 Comparison of copper concentration in sediment sample taken in 2008 and 2011. Residential direct contact soil criteria (RDCSCC) and non-residential direct contact soil cleanup criteria (NRDCSCC) are shown as reference.**

Lead: Lead concentration was lower than the standard median concentration for residential soil quality (400 mg/kg) and non-residential soil quality (600 mg/kg) in all devices except RU06-01 (Figure 5.13). Lead concentration at RU06-01, located in North Bergen, was 419 mg/kg which exceeds the residential soil quality standard.

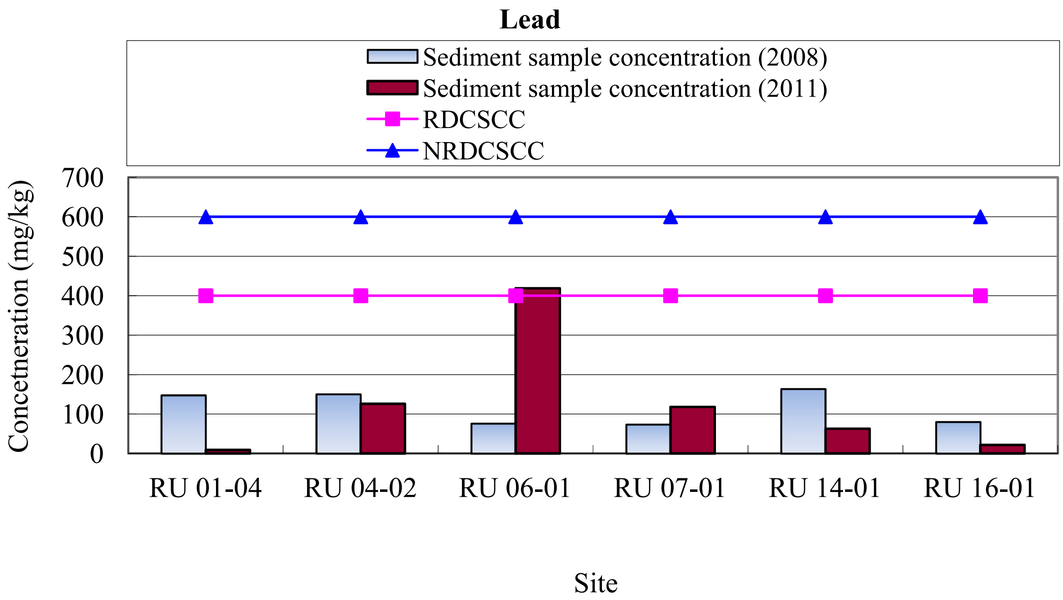



**Figure 5.14 Comparison of lead concentration in sediment sample taken in 2008 and 2011. Residential direct contact soil criteria (RDCSCC) and non-residential direct contact soil cleanup criteria (NRDCSCC) are shown as reference.**

<u>Zinc</u>: Zinc concentration for the six devices ranged from 24.8 to 769 mg/kg for this study (Figure 5.14). Zinc concentration was lower than the median standard concentrations for residential and non-residential soil quality (1500 mg/kg) in all devices.

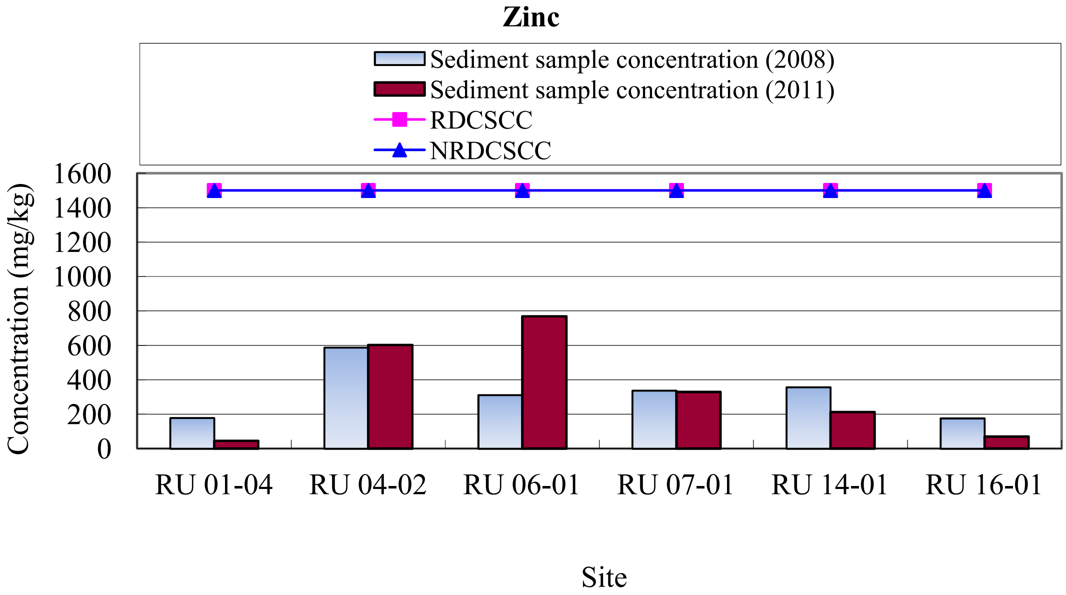



**Figure 5.15 Comparison of zinc concentration in sediment sample taken in 2008 and 2011. Residential direct contact soil criteria (RDCSCC) and non-residential direct contact soil cleanup criteria (NRDCSCC) are shown as reference.**

<u>Cadmium</u>: Small concentrations of Cadmium were detected at three urban sites: RU04-2 (0.263 mg/kg), RU06-1(0.524 mg/kg) and RU14-1(0.105 mg/kg) (Figure 5.15). Cadmium was not detected at the other three sites. In the study conducted in 2008, a small concentration of Cadmium had been detected at these same sites and at the RU01-04 site. However, in all cases, the concentration is well below the acceptable standards.

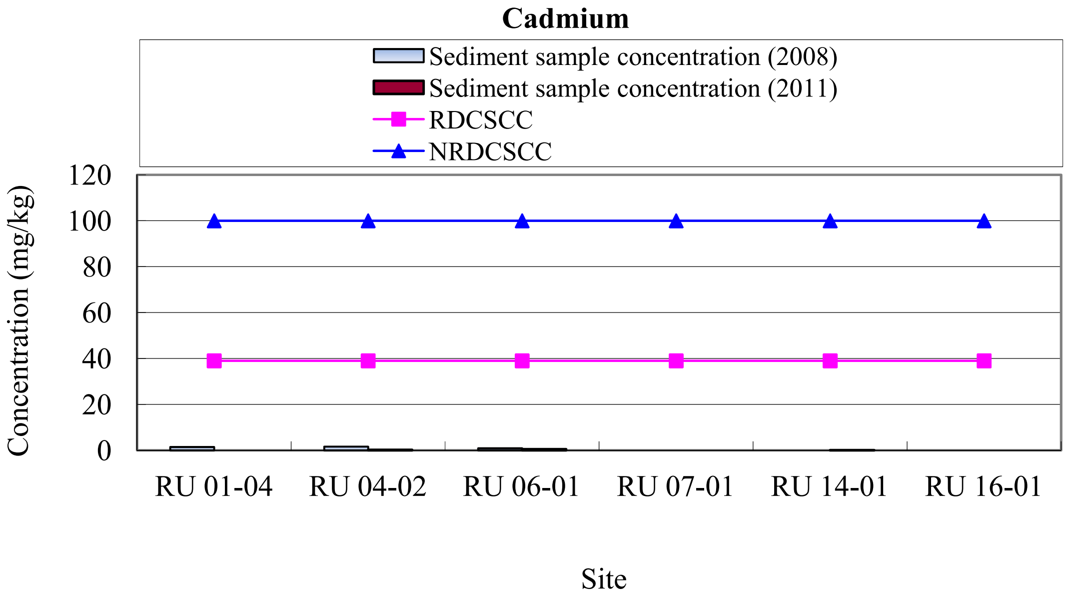



**Figure 5.16 Comparison of cadmium concentration in sediment sample taken in 2008 and 2011. Residential direct contact soil criteria (RDCSCC) and non-residential direct contact soil cleanup criteria (NRDCSCC) are shown as reference.**

Total Phosphorus (TP): Total phosphorus concentration measure for the six devices ranged from 79 to 743 mg/L (Figure 5.16). The highest concentration was detected at RU04-02 located in Elizabeth. Total Phosphorus concentration in all devices exceeded the concentration of pine barren (forest) soil (94 mg/kg) taken from Rutgers pinelands field station.

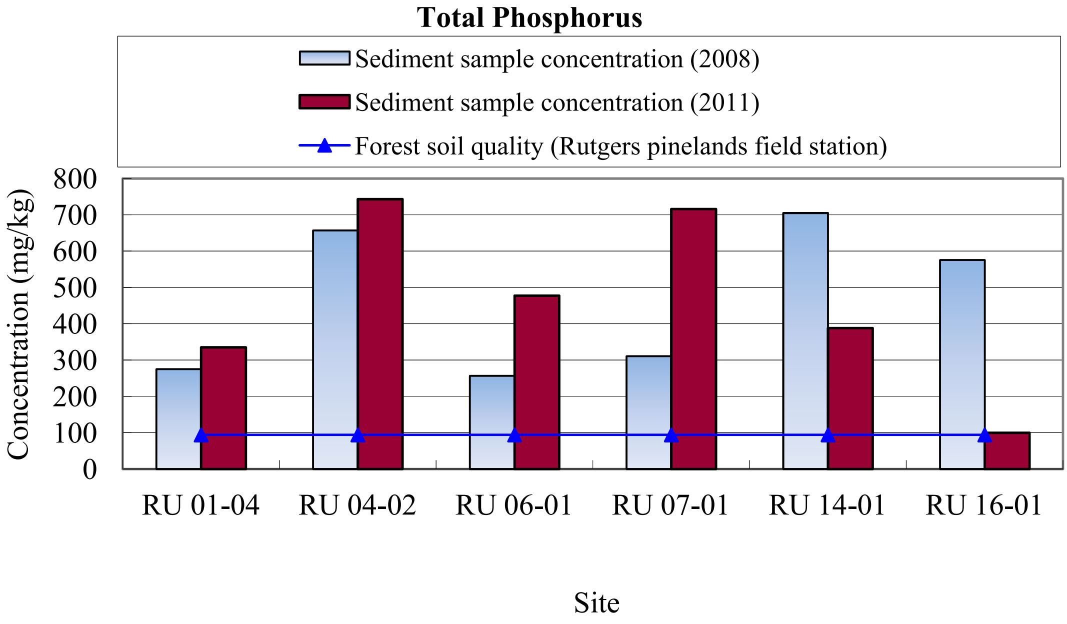



**Figure 5.17 Comparison of total phosphorus concentration in sediment sample taken in 2008 and 2011. Forest (pine barren) soil quality from Rutgers pinelands field station is shown as reference.**

Total Kjeldahl Nitrogen (TKN): TKN concentration for the six devices ranged from 91 to 1340 mg/kg (Figure 5.17). TKN concentration in all devices exceeded the concentration of forest (pine barren) soil (219 mg/kg) taken from Rutgers pinelands field station.

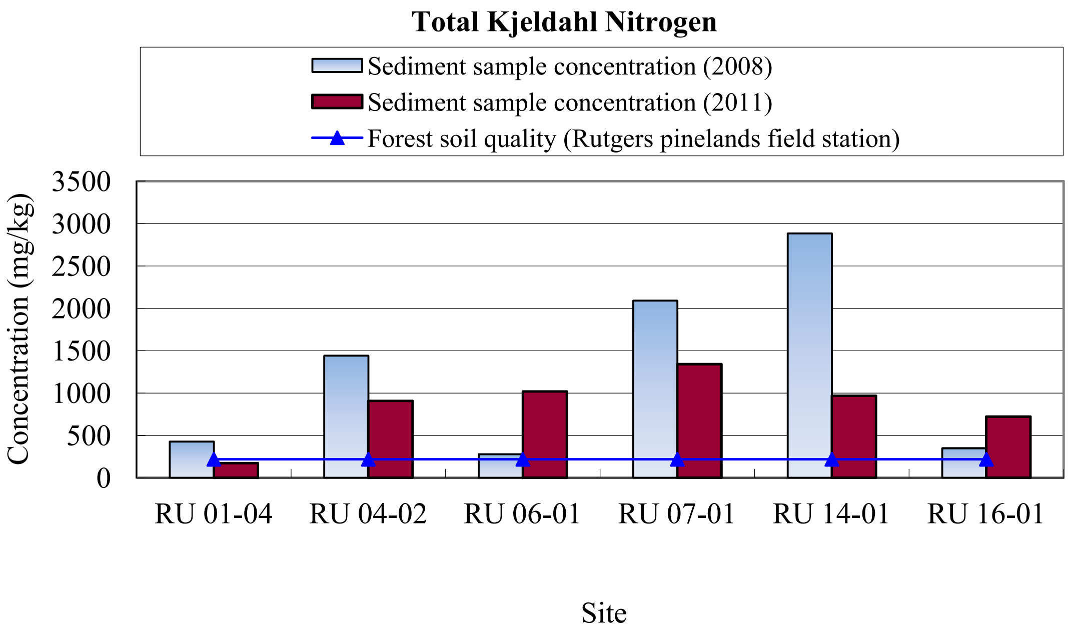



**Figure 5.18 Comparison of total Kjeldahl nitrogen concentration in sediment sample taken in 2008 and 2011. Forest soil quality from Rutgers pinelands field station is shown as reference.**

**Percent Organic Matter of Sediment**

A common organic content analysis method is the loss-on-ignition (LOI) method. The LOI method is carried out at high temperatures. For this study, ASTM D2974 Method C was used. ASTM D2974 uses ash burning at 440 degrees Celsius. A concern with the LOI method is the possibility that inorganic constituents of the soil may lose structural water and carbonate minerals. Additionally, hydrated slats can be decomposed upon heating (Nelson and Sommers, 1996).

The organic content of the sediments ranged from 3.3 % to 28.1 % in 2011. The highest was 28.7% (2011) and 24.3% (2008) from site RU07-01, located in an open/suburban area (Table 5.4 and Figure 5.18).

**Table 5.4 Measurement of Organic Content in Bottom Sediments (2011)**

| Site ID | Weight of aluminum pan (mg) | Weight of residue + pan before ignition (mg) | Weight of residue + pan after ignition (mg) | Organic content(%) |
|---|---|---|---|---|
| RU01-04 | 15.51 | 221.53 | 180.51 | 18.5 |
| RU04-02 | 14.01 | 233.11 | 215.50 | 7.6 |
| RU06-01 | 14.40 | 155.41 | 151.21 | 3.3 |
| RU07-01 | 15.02 | 215.36 | 150.92 | 28.1 |
| RU14-01 | 15.30 | 153.13 | 146.55 | 4.3 |
| RU16-01 | 14.90 | 243.43 | 192.12 | 21.1 |

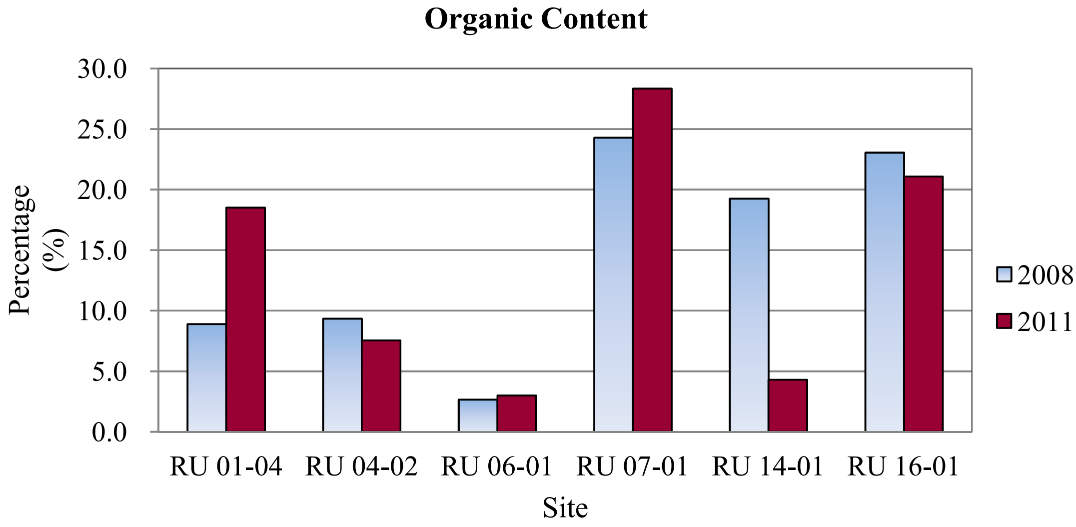



**Figure 5.19 Organic content of bottom sediments**

## 5.4 Conclusion

For the twelve (12) hydrodynamic separators at eight (8) different project sites that were part of the study, the average time between installation and monitoring cleanout was around 5 years. During this period a combined total of 34 lbs. of oil, 26,000 lbs. of sediment, and 16 lbs. of floatables had collected in the HDS. Several sites yielded high levels of oil and grease. Large amounts of floatables were also collected from the sites consisting mostly of plastic, Styrofoam, and organic debris.

After 3 to 4 year from first cleanout, six (6) of the twelve (12) selected and monitored devices reached the cleanout threshold. They were cleaned out and analyzed using the same methodology in 2008.

Testing of the pumped-out sediment indicated low levels of heavy metals (copper, zinc, lead, cadmium, and arsenic) as well as low levels of TKN and TP in both monitoring periods. The particle size distribution analysis showed that an average of 7 percent of samples passed the #200 (75 microns) sieve in the 12 samples analyzed; that is, devices primarily collected particles greater than 75 microns.

Organic content of the bottom sediment ranged from 3 to 34 percent (2008) and 3 to 28 percent (2011). The measured quantity and quality of the trapped solids will continue to be related to highway drainage characteristics such as soil type/erosion, traffic volume, ratio of drainage area to device size, and precipitation.

# Chapter 6

# Monitoring Results of HDS

## 6.1 Introduction

Monitoring for twelve (12) selected devices started in 2007 and 2008. This monitoring program was conducted over four and a half-year period after initial cleanout. In 2011, six (6) devices were found to have reached capacity and had to be cleaned out again. Among those six devices, only four (4) devices in typical site conditions were monitored again after the second cleanout. At four and a half-year period, other four (4) devices in typical site conditions reached cleanout trigger depth. In addition to monitoring for Vortechs® device, another two (2) devices were chosen for cleanout and monitoring in 2010: one Aqua-Swirl and one Downstream Defender.

## 6.2 The measurement procedure

The accumulated sediment depth over the observation period was used as the lead indicator for the time interval between HDS cleanouts. The sediment depths were measured subsequently from the clean state. The depths were measured at a pre-determined time interval, every two months from December 2007 to July 2009 and every three months thereafter.

Sediment depth accumulation was measured using a stadia rod. Personnel trained in safety procedures including confined space entry manually opened the manhole cover atop the swirl chamber of each HDS. Pictures of oil and floatables were taken and proportion of covered area was calculated.

To gather additional data, the sediment depths prior to the cleanout were measured as well. The cleanout materials including bottom sediment, oil, and buoyant debris in the devices were characterized physically and chemically.

### 6.3 Measurement of sediment depth before cleanout

During 2007, sediment depth was measured from thirty four (34) devices installed at seventeen (17) sites before cleanout. All collected sediment depth from thirty four devices is shown in figure 6.1. Regardless of time, sediment depth appears to vary widely from site to site. this non-linear relation makes hard to find the optimum maintenance interval. In some of devices, gross solids might have come from unusual activities rather than simple roadway runoff.

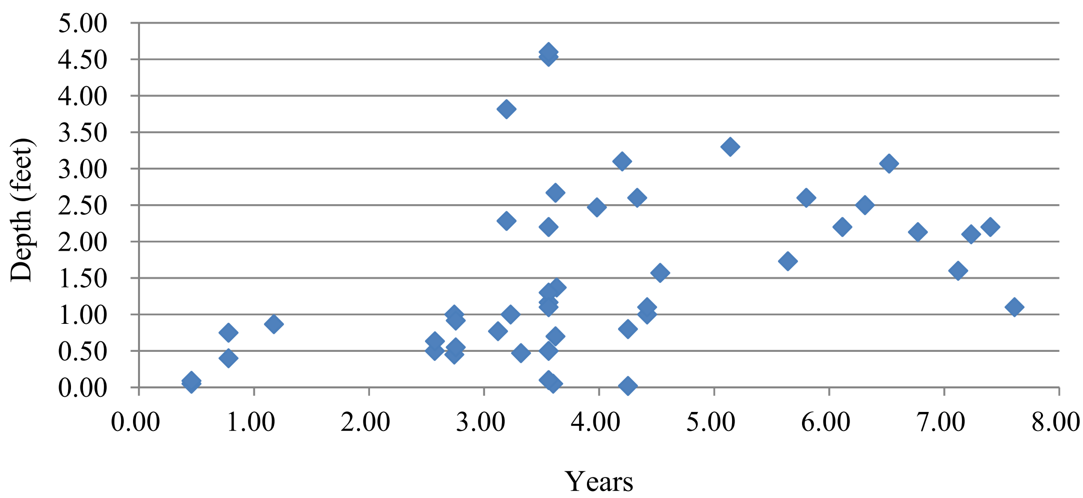



**Figure 6.1 Sediment accumulated depth from 34 devices before cleanout.**

Twelve (12) out of those 34 devices were selected for monitoring and subsequently cleaned out between December 2007 and May 2008. Just before cleanout, the sediment depths were measured. The measured depth of bottom sediment from selected twelve devices is shown in Table 6.1

**Table 6.1 Depth of Sediment Trapped and Inspection before Cleanout (12 Devices)**

| Site ID | Construction Date | 1st Inspection | | Inspection Just before Cleanout | |
|---|---|---|---|---|---|
| | | Inspection Date | Sediment Depth (feet) | Inspection / Cleanout Date | Sediment Depth (feet) |
| RU01-01 | 2003-10-31 | 2007-06-13 | 0.05 | 2008-02-01 | 0.02 |
| RU01-02 | 2003-10-31 | 2007-10-22 | 0.7 | 2008-02-01 | 0.8 |
| RU01-03 | 2003-10-31 | 2007-06-13 | 2.5 | 2008-02-26 | 2.6 |
| RU01-04 | 2003-10-31 | 2007-06-12 | 2.7 | 2008-01-11 | 3.1 |
| RU02-01 | 2004-09-15 | 2007-06-12 | 1.0 | 2007-12-10 | 0.9 |
| RU02-02 | 2004-09-15 | 2007-06-26 | 0.5 | 2008-01-09 | 0.5 |
| RU04-02 | 2004-11-30 | 2007-06-26 | 0.6 | 2008-01-16 | 0.8 |
| RU06-01 | 2001-11-06 | 2007-06-22 | 1.7 | 2008-02-28 | 2.5 |
| RU07-01 | 2000-11-03* | 2007-06-21 | 2.6 | 2008-03-13 | 3.1 |
| RU09-01 | 2000-05-10* | 2007-06-15 | 1.6 | 2007-12-19 | 1.1 |
| RU14-01 | 2003-10-29 | 2007-06-19 | 1.4 | 2008-05-08 | 1.6 |
| RU16-01 | 2000-09-13* | 2007-06-13 | 2.1 | 2008-02-07 | 2.2 |

* Construction plans approval date, not actual construction date.

## 6.4 Second cleanout and monitoring

Monitoring of these twelve devices was conducted over a 3-year period after this initial cleanout. During this 3-year period, six of the twelve devices accumulated enough sediment and had to be cleaned out again. Determining the need for cleanout was based on sediment depth measurements taken at regular intervals as part of the monitoring program. The maximum sediment depth allowed before cleanout had been set at two feet from the manufacturer's specifications. Table 6.2 shows the site ID, model, and location of the six devices chosen for second cleanout and monitoring.

**Table 6.2 Six (6) Devices Selected for Second Cleanout and Monitoring**

| Site ID | Model | Municipality | County | Location |
|---|---|---|---|---|
| RU01-04 | VX7000 | Piscataway | Middlesex | Rt. 18 Extension along River Road |
| RU04-02 | VX11000 | Elizabeth | Union | Pearl Street & Grove Street |
| RU06-01 | VX3000 | North Bergen | Hudson | 36th Street |
| RU07-01 | VX9000 | Deptford | Gloucester | Rt. 47 near Cattle Road |
| RU14-01 | VX16000 | Parsippany | Morris | Rt. 46 & New Road |
| RU16-01 | VX5000 | Frankford | Sussex | Rt.15 & US 206 |

Table 6.3 shows the cleanout dates and sediment depth measured immediately before the second cleanout.

**Table 6.3 Depth of Sediment Trapped and Removed (Six Devices)**

| Site ID | Previous Cleanout Date | Cleanout Date | Sediment Depth in Swirl Chamber |
|---|---|---|---|
| RU01-04 | 2008-01-11 | 2011-05-11 | 2.3 ft |
| RU04-02 | 2008-01-16 | 2011-05-19 | 2.0 ft |
| RU06-01 | 2008-02-28 | 2011-06-13 | 3.0 ft |
| RU07-01 | 2008-03-13 | 2011-06-14 | 3.9 ft |
| RU14-01 | 2008-05-08 | 2011-05-24 | 1.9 ft |
| RU16-01 | 2008-02-07 | 2011-06-03 | 2.2 ft |

After the second cleanout, four (4) devices in general site conditions (RU01-04, RU04-02, RU14-01 and RU16-01) were monitored again from clean state. At the four and a half year period, other four devices in general site conditions (RU01-02, RU01-03, RU02-01 and RU09-01) reached cleanout trigger depth.

In addition to monitoring the Vortechs® device, another two (2) devices were chosen for cleanout and monitoring in 2010: one Aqua-Swirl® and one Downstream Defender® (Table 6.4).

**Table 6.4 Depth of Sediment Trapped and Removed (Other Two Devices)**

| Site ID | Model | Municipality | Construction Date | Inspection Just before Cleanout | |
|---|---|---|---|---|---|
| | | | | Inspection / Cleanout Date | Sediment Depth (feet) |
| RU 15-01 | Downstream Defender (DD 10) | Fair Lawn | 2000-07-11* | 2011-06-01 | 4.5 |
| RU 18-01 | Aqua-Swirl (AS-7) | Robbinsville | 2008-04-07* | 2011-05-11 | 3.8 |

* Construction plans approval date, not actual construction date.

## 6.5 Sediment accumulation results during the monitoring program

The monitoring program began once the device was in a clean state and performed every two months and three month after August 2009 (Figure 6.2). The accumulated sediment depth over the observation period was the lead indicator for the time interval between devices cleanouts.

During monitoring program, sediment was accumulated over the cleanout trigger depth from 8 devices (RU01-04, RU02-01, RU04-02, RU06-01, RU07-01, RU09-01, RU14-01 and RU16-01). Two devices (RU01-02 and RU01-03) almost reached trigger depth (1.8 and 1.9 feet) and other two devices (RU01-01 and RU02-02) accumulated low sediment depth (only 0.1 and 1.3 feet) after four and a half years.

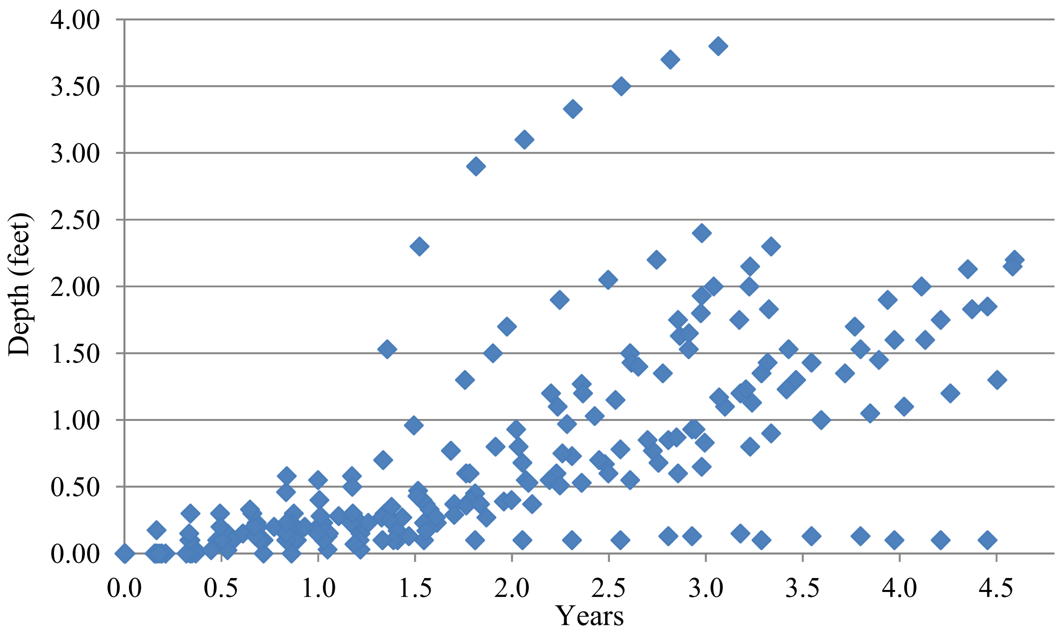



**Figure 6.2 Sediment accumulated depth from twelve selected devices during the monitoring program (December 1, 2007 – September 10, 2012). Time zero is the time of cleanout for each device.**

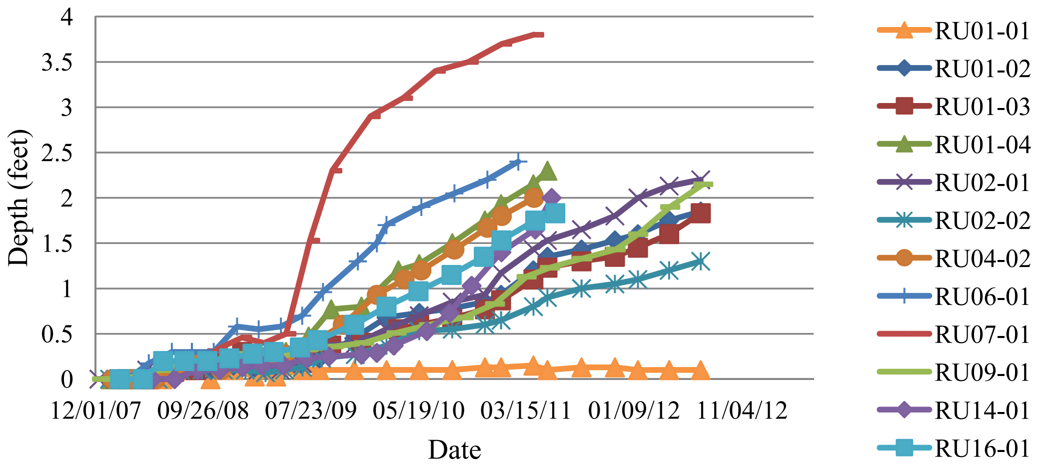



**Figure 6.3 Sediment accumulated depth from twelve selected devices from the monitoring program (December 1, 2007 – September 10, 2012). Note that not all the devices were cleaned out at the same time and the sediment depth measurements were not commenced simultaneously.**

At this point, accumulated sediment depth conforms to an S-curve when plotted. Figure 6.3 shows relatively fast accumulated rate in urban/heavy traffic areas and slow sediment accumulation in non-urban/light traffic areas.

# Chapter 7

# Collecting and Incorporating Factors

More research is required to relate the amount of trapped materials and the variables in combination. This study presents development and integration of the variables such as rainfall intensity and duration, highway drainage area characteristics and traffic volume. Regression analysis has been performed for the relationship among the variables and the amount of trapped materials. As a result, maintenance and interval based on various characteristics of the sites has been obtained and will be presented.

## 7.1 Drainage area assessment

Drainage area data are obtained from the corresponding design companies and information on the device is from the manufacturing company's product manual. Pipe information such as slope, length, diameter, and connected device is obtained from the NJDOT drainage plans.

**Table 7.1 Drainage Area Information**

| Site ID | Model | SS[a] ($yd^3$) | MPV[b] (gal) | MTC[c] (cfs) | DA[d] (acres) | DA/CA[e] ($acre/ft^2$) | Pipe Slope | Design Traffic Data (vpd) |
|---|---|---|---|---|---|---|---|---|
| RU01-01 | 16000 | 7.1 | 2774 | 25.2 | 4.97* | 0.044 | 0.00357 | 37000 |
| RU01-02 | 7000 | 4.0 | 1244 | 11.2 | 1.13* | 0.023 | 0.00758 | |
| RU01-03 | 7000 | 4.0 | 1244 | 11.2 | 0.98* | 0.020 | 0.01471 | |
| RU01-04 | 7000 | 4.0 | 1244 | 11.2 | 1.45* | 0.029 | 0.01562 | |
| RU02-01 | 16000 | 7.1 | 2774 | 25.2 | 0.61* | 0.005 | 0.00909 | 7700 |
| RU02-02 | 9000 | 4.8 | 1582 | 14.2 | 0.61* | 0.010 | 0.00556 | |
| RU04-02 | 11000 | 5.6 | 1947 | 17.5 | 7.70 | 0.097 | 0.00556 | 85380 |
| RU06-01 | 3000 | 1.8 | 506 | 4.4 | 1.18 | 0.059 | 0.00571 | 37205 |
| RU07-01 | 9000 | 4.8 | 1582 | 14.2 | 1.28 | 0.020 | 0.04101 | 17340 |
| RU09-01 | 3000 | 1.8 | 506 | 4.4 | 0.49 | 0.025 | 0.01000 | 33700 |
| RU14-01 | 16000 | 7.1 | 2774 | 25.2 | 2.45* | 0.022 | 0.00152 | 36420 |
| RU16-01 | 5000 | 3.2 | 952 | 8.6 | 1.13* | 0.030 | 0.00730 | 47860 |

* Calculated approximate areas from drainage construction plans.
a. Sediment Storage ($yd^3$)
b. Maintenance "Pump Out" Volume (gallons)
c. Maximum Treatment Capacity (cfs)
d. Drainage Area (acres)
e. Drainage Area / Grit Chamber Area ($acres/ft^2$)

Creation of a Geodatabase and Functional Map

A Geographical Information System (GIS) on the storm drain network related to the device was developed to support analysis of the relationship between the drainage network data and the maintenance interval of the HDS. The GIS data were comprised of location, size, invert elevation, and type of storm sewer structure. The location and visible attributes of the storm drain asset were field-verified during inspection.

Based on the GIS data, the road segments related to drainage network were defined.

Then, the length and traffic volume of the road segment were measured for analysis of the maintenance interval for the HDS.

The following functional maps (Figure 7.1 – Figure 7.8) developed from using the ESRI GIS software shows storm drain network related to the device in the study area. The functional maps are able to help trace water flow throughout the storm drainage system.

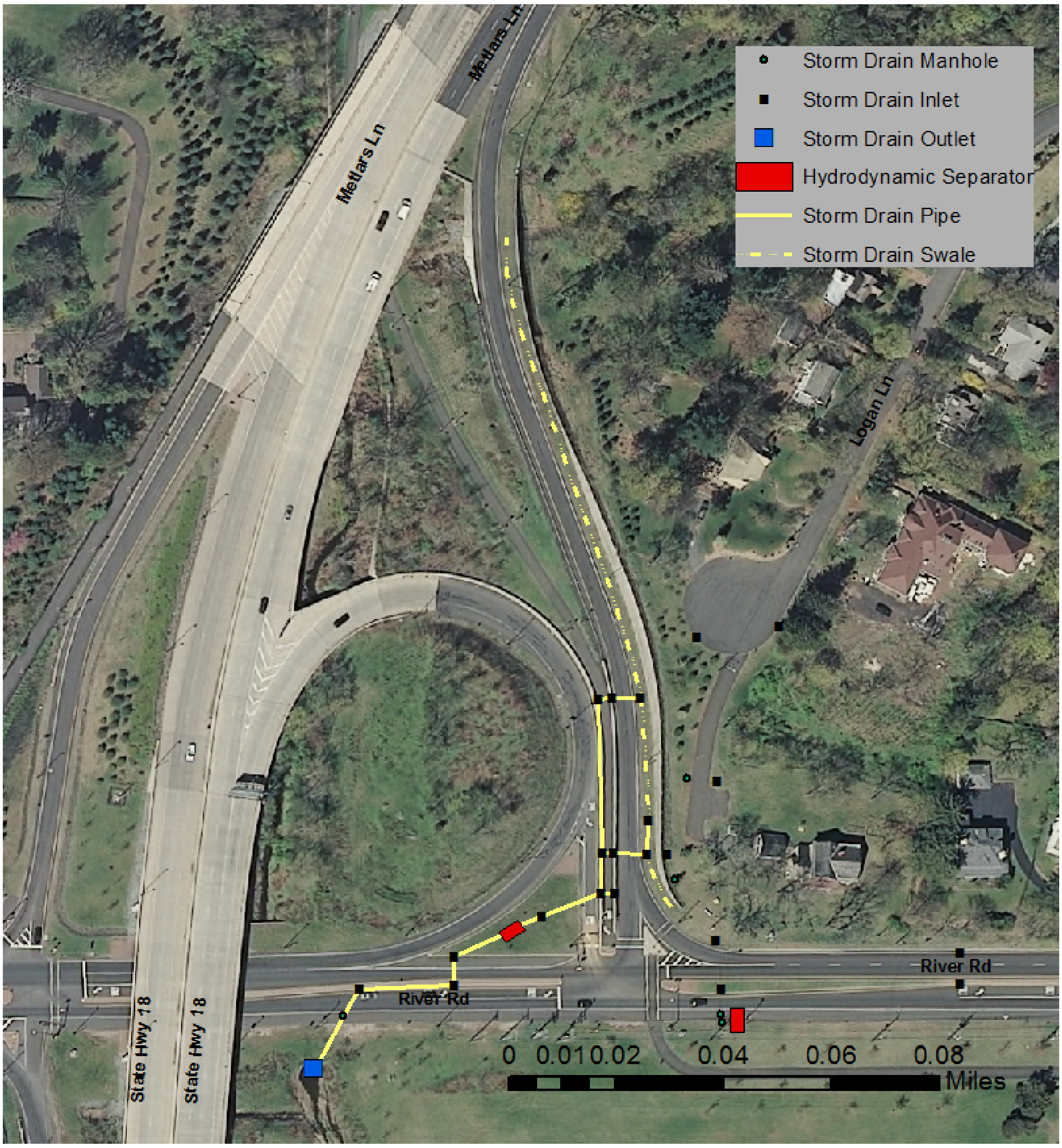



**Figure 7.1 Storm drainage network (RU01-02, Piscataway, NJ)**

The storm drainage network for device RU01-02 contains pipes and swales along the north ramp to Route18. The device captures runoff from the northbound ramp.

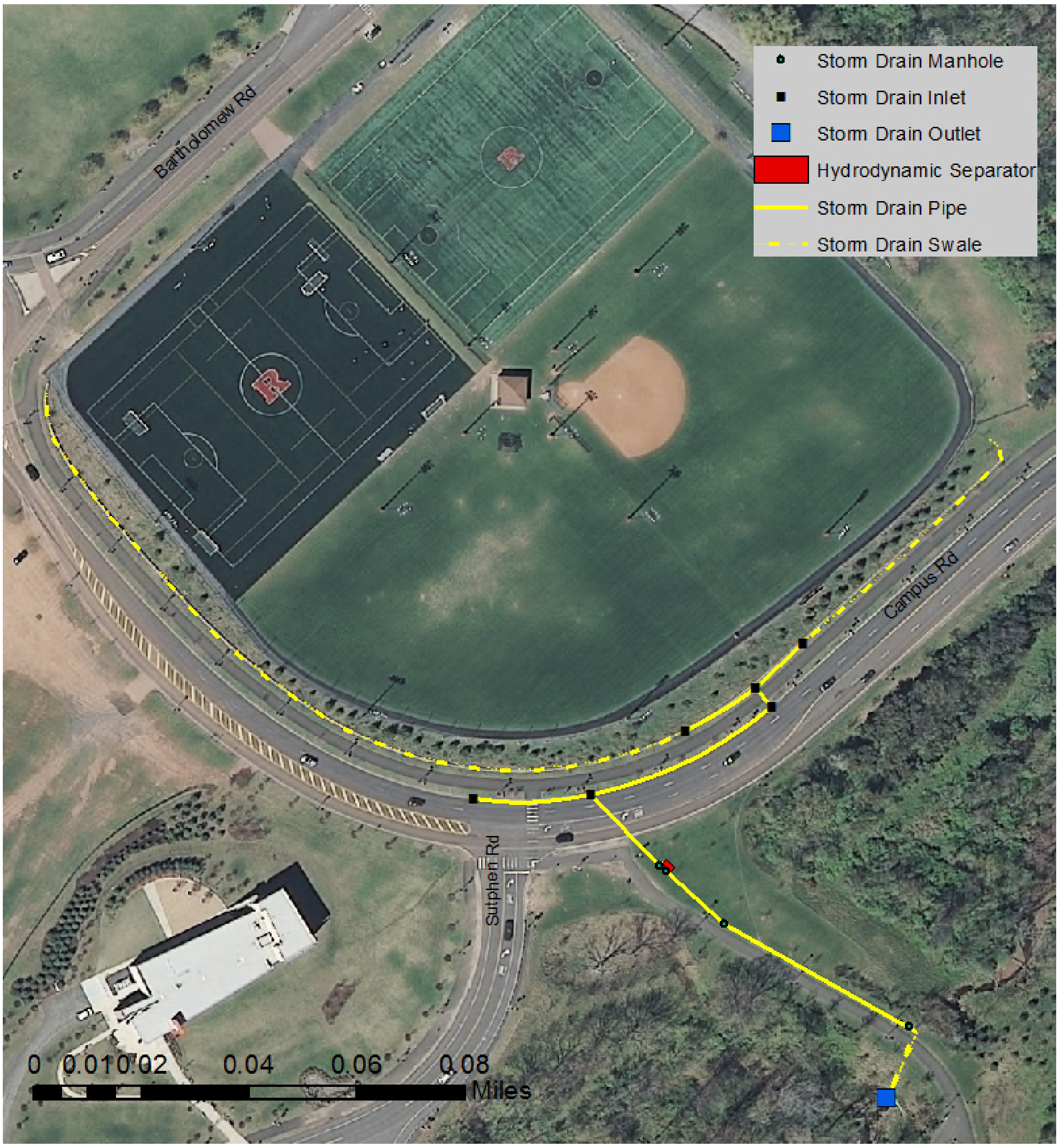



**Figure 7.2 Storm drainage network (RU01-03, Piscataway, NJ)**

The storm drainage network for device RU01-03 contains pipes and swales along Campus Road. The device captures runoff from both eastbound and westbound lanes of Campus Road.

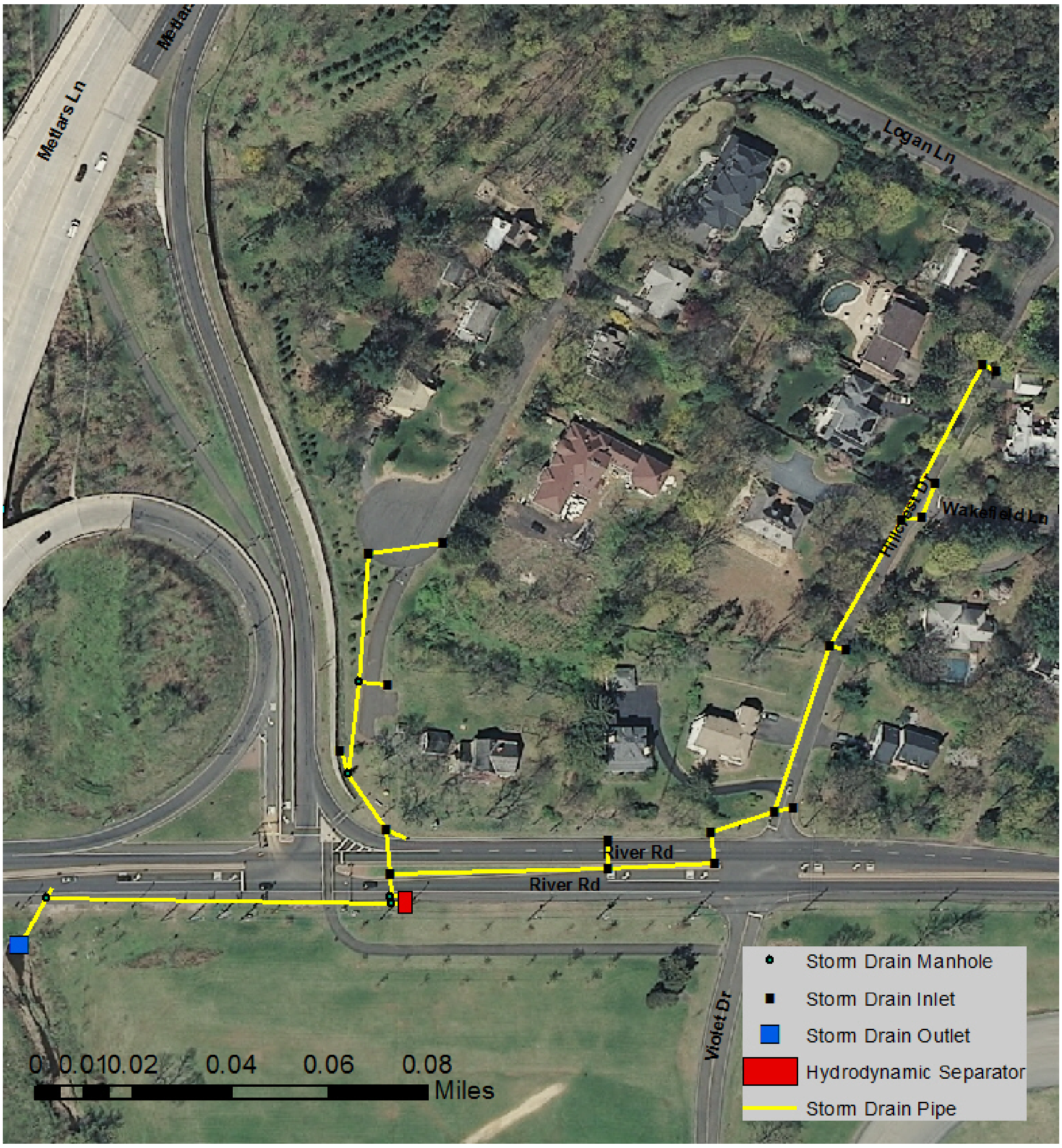



**Figure 7.3 Storm drainage network (RU01-04, Piscataway, NJ)**

The device RU01-04 captures runoff from both directions on River Road and Hillcrest Drive that is a side road of River Road.


**Figure 7.4 Storm drainage network (RU02-01, Edison, NJ)**

The device RU02-01 captures runoff from northbound Route 27 and southbound Evergreen Road that is a side road of Route 27.

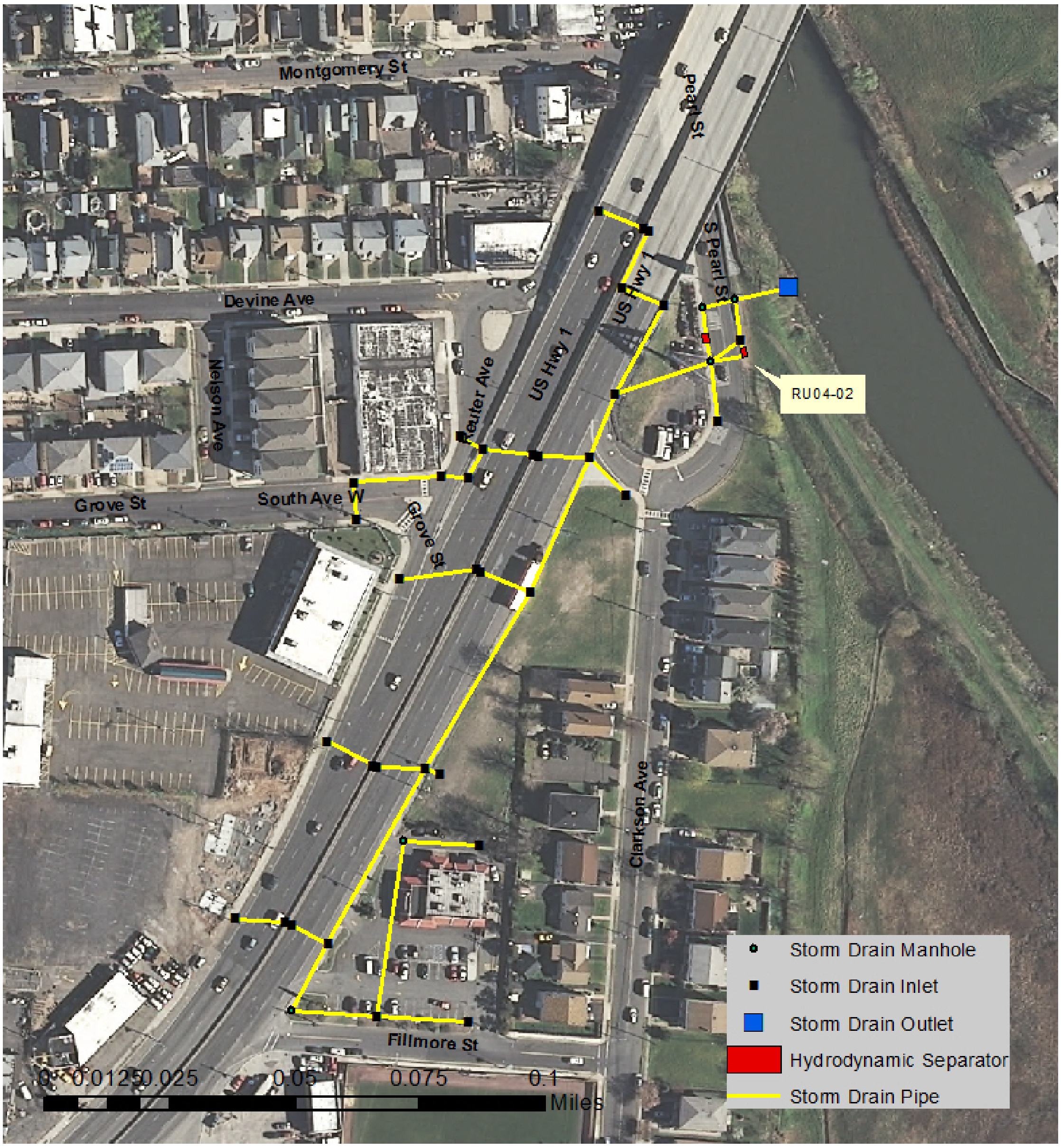



**Figure 7.5 Storm drainage network (RU04-02, Elizabeth, NJ)**

The device RU04-02 captures runoff from both directions on Route 1&9, Southbound Pearl Street, Grove Street and Reuter Avenue.


**Figure 7.6 Storm drainage network (RU09-01, Lakewood, NJ)**

The device RU09-01 captures runoff from both northbound and southbound Route 9.


**Figure 7.7 Storm drainage network (RU14-02, Parsippany, NJ)**

The device RU14-02 captures runoff from both directions on Route 46 and New Road.

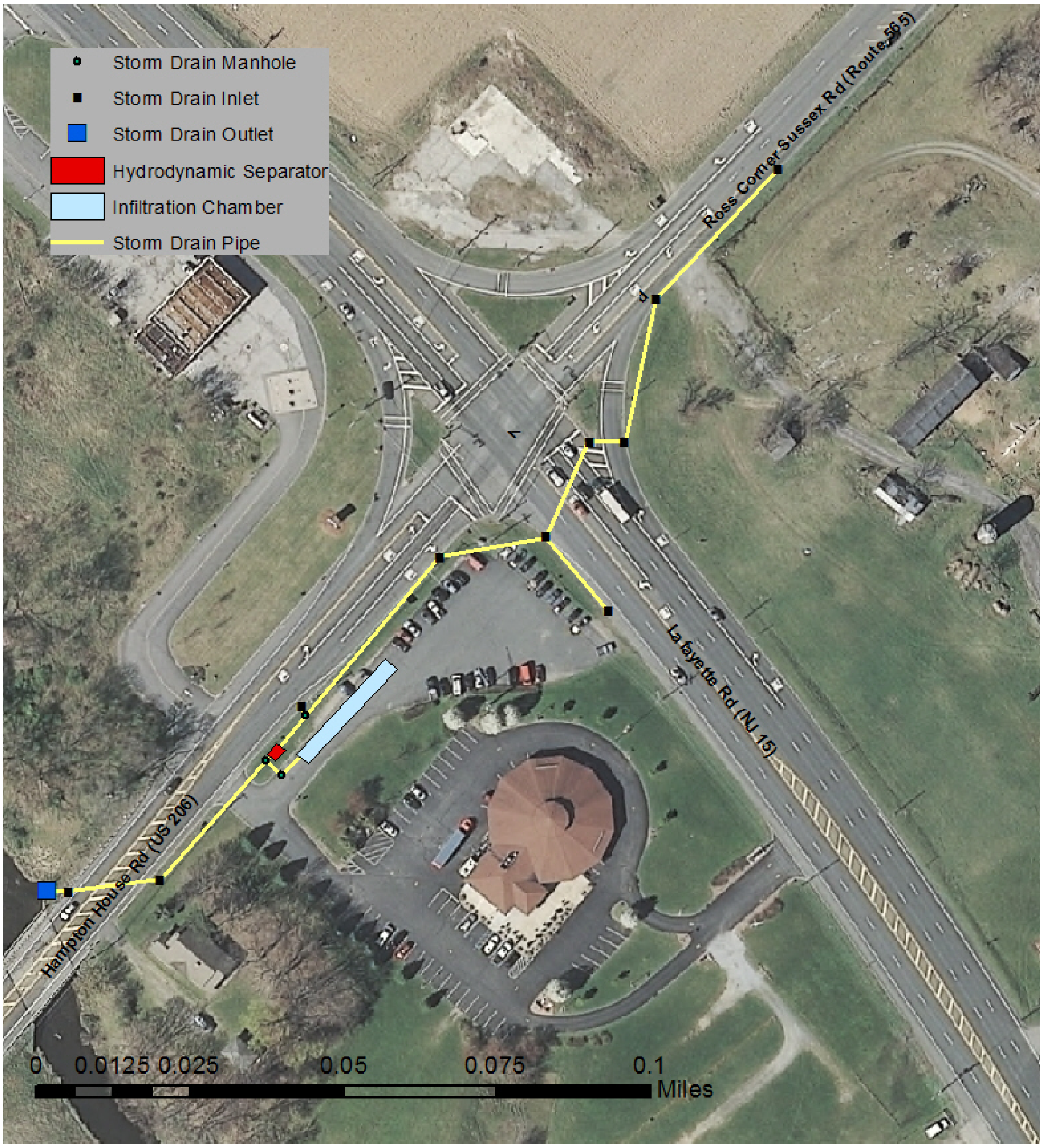



**Figure 7.8 Storm drainage network (RU16-01, Frankford, NJ)**

The device RU16-01 captures runoff from northbound US 206, southbound Route 565, and Southbound NJ 15.

## 7.2 Traffic Volume

The annual average daily traffic (AADT) count is commonly used in transportation planning. The key sheet of construction plan for each device shows the design traffic volume data (Figure 3.1). The NJDOT website (http://www.state.nj.us/transportation/refdata/roadway/traffic_counts/) provides estimates of Annual Average Daily Traffic (AADT), and it includes the traffic data from the major roads statewide (NJDOT, 2014).

However, the traffic volume counts of all the road segments related to the device are required in this study in order to analysis the relationship between the total traffic volume and the amount of sediment trapped in the device. The traffic volume counts were measured from all the road segment from 2009 to 2012, and the average value is shown in Table 7.2. Due to the high cost of a large-scale monitoring, the traffic volume only during the peak hour in the study area was counted for this research.

**Table 7.2 Average Traffic Volume Count for Each Road and Site**

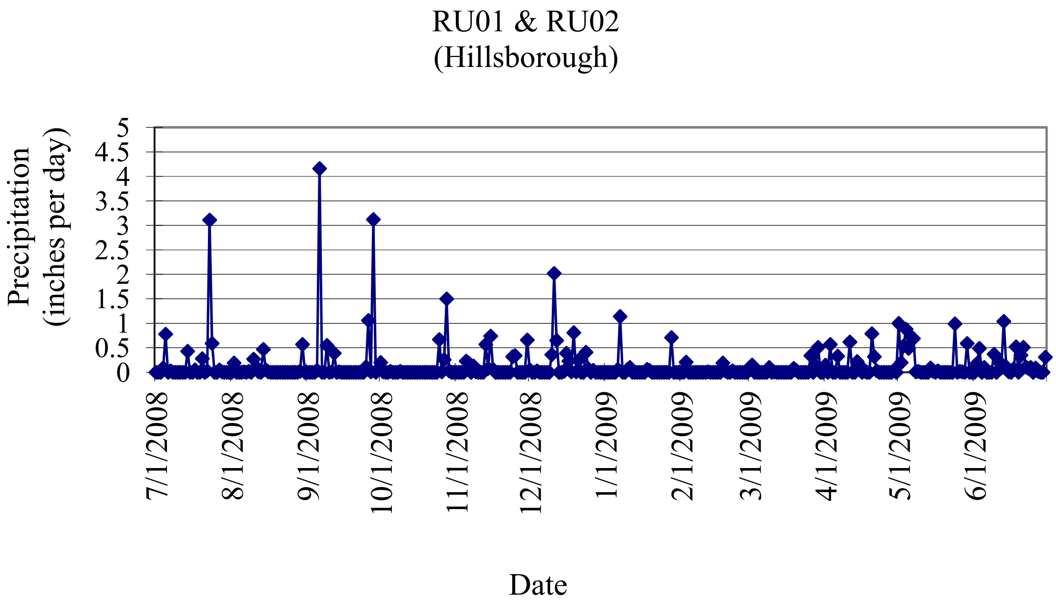
| Site | Road | Average traffic volume of road (vph) | Average traffic volume of site (vph) |
|---|---|---|---|
| RU01-02 | Ramp 18 N | 925 | 925 |
| RU01-03 | Campus Rd E | 273 | 861 |
| | Campus Rd W | 588 | |
| RU01-04 | River Rd E | 1157 | 2360 |
| | River Rd W | 1163 | |
| | Hillcrest Dr | 39 | |
| RU02-01 | Rt. 27 N | 1045 | 1249 |
| | Evergreen Rd S | 204 | |
| RU04-02 | Rt.1&9 S | 1942 | 4485 |
| | Rt.1&9 N | 1687 | |
| | S Pearl St. | 198 | |
| | Grove St. | 368 | |
| | Reuter Ave. | 228 | |
| | McDonald | 64 | |
| RU09-01 | Rt. 9 S | 910 | 1940 |
| | Rt. 9 N | 1031 | |
| RU14-01 | Rt. 46 E | 1930 | 4710 |
| | Rt. 46 W | 1874 | |
| | New Rd S | 500 | |
| | New Rd N | 406 | |
| RU16-01 | US 206 Hampton | 587 | 1672 |
| | RT 565 | 443 | |
| | NJ 15 S | 643 | |

### 7.3 Precipitation

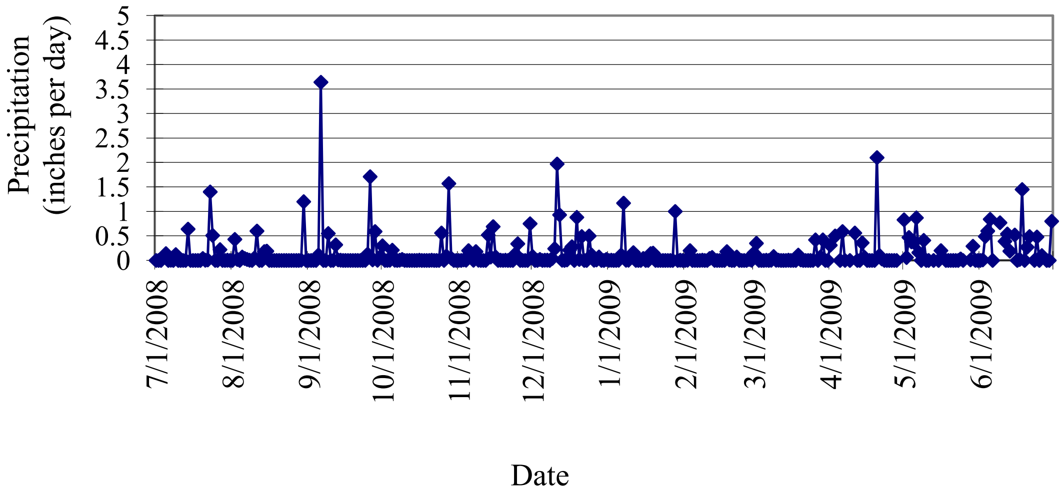
New Jersey Precipitation

The average annual precipitation in New Jersey ranges from about 40 inches along the southeast coast to 51 inches in north-central parts of the state. Many areas average between 43 and 47 inches (ONJSC, 2009).

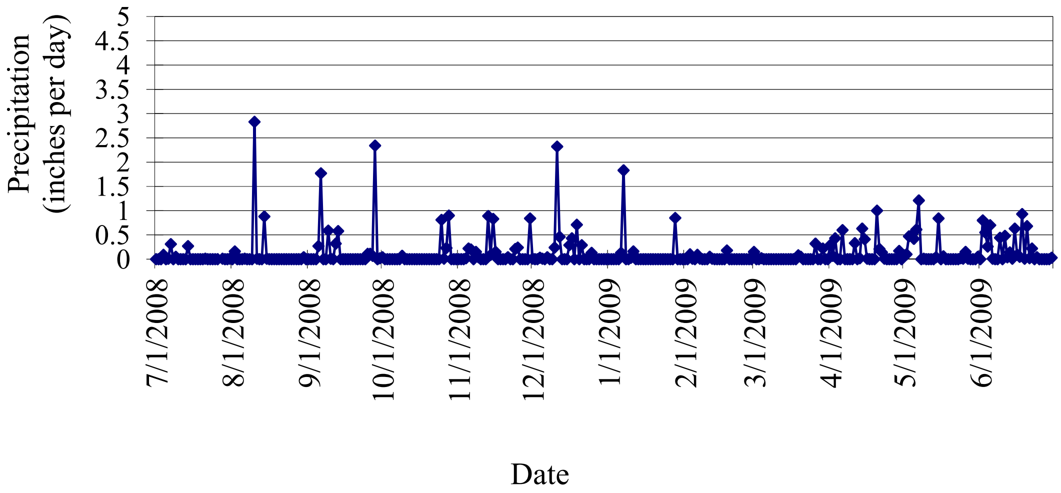
The daily precipitation at each site during the monitoring period was collected (Figure 7.9). Precipitation data were obtained from NJWxnet (New Jersey Weather and Climate Network) and NCDC (National Climatic Data Center).



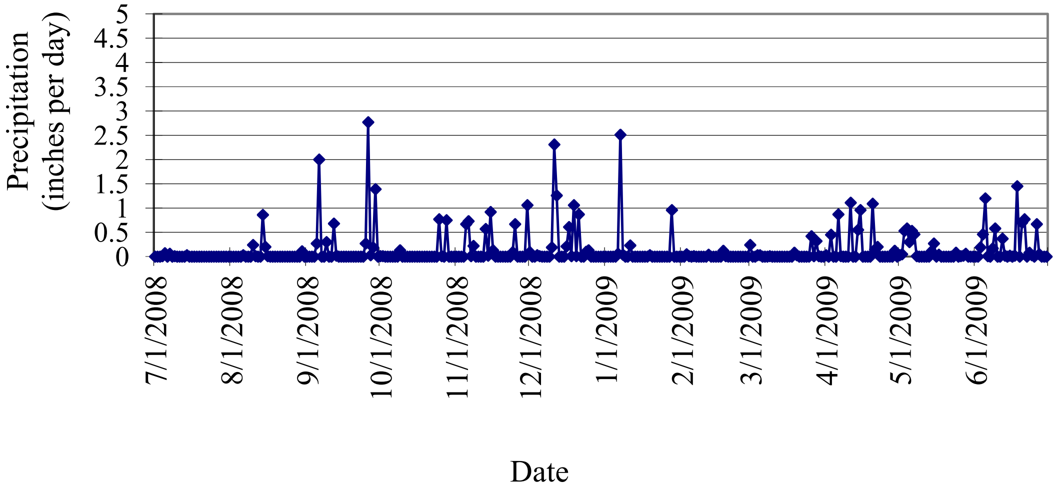
RU04 & RU06
(Newark)



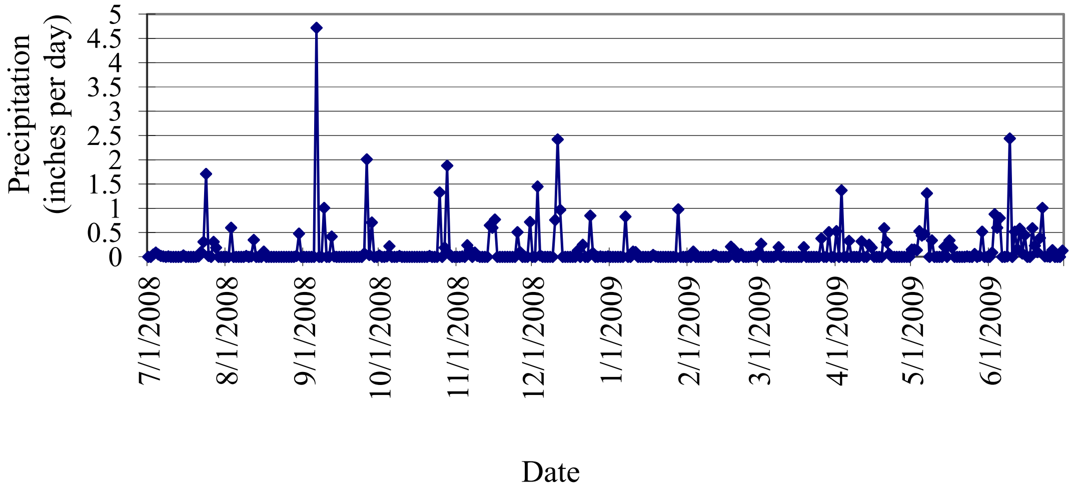

RU07-01
(Bethel Mill Park)



RU09-01
(Wall Twp.)




RU14-01
(Parssipany)



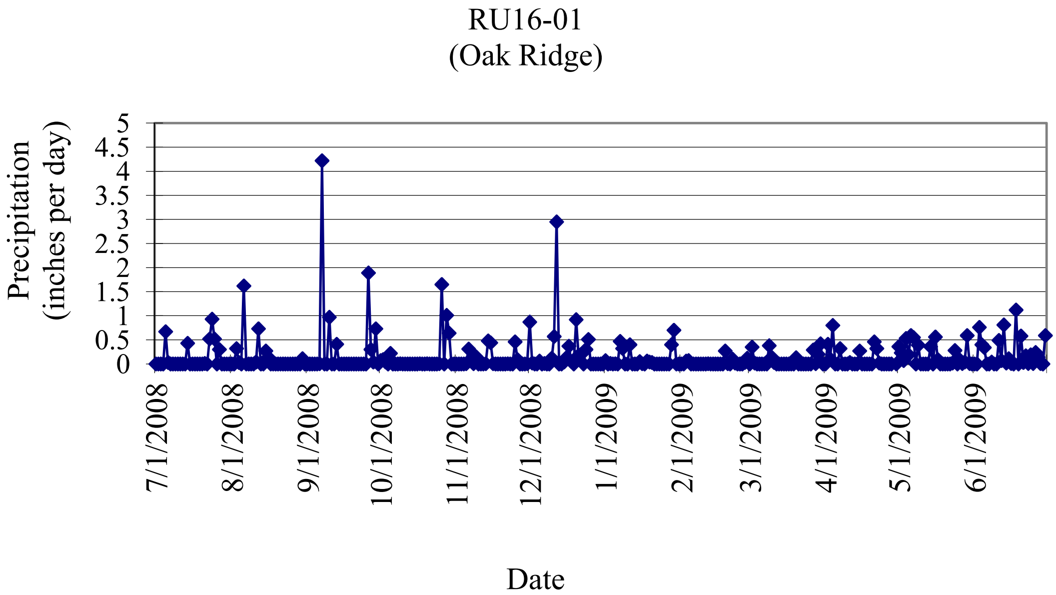



**Figure 7.9 The daily precipitation at station in or near study site**

The annual precipitation from July 2007 to June 2008 at all the monitored sites is shown in Figure 7.10 that demonstrates some but not dramatic spatial variation across the state.

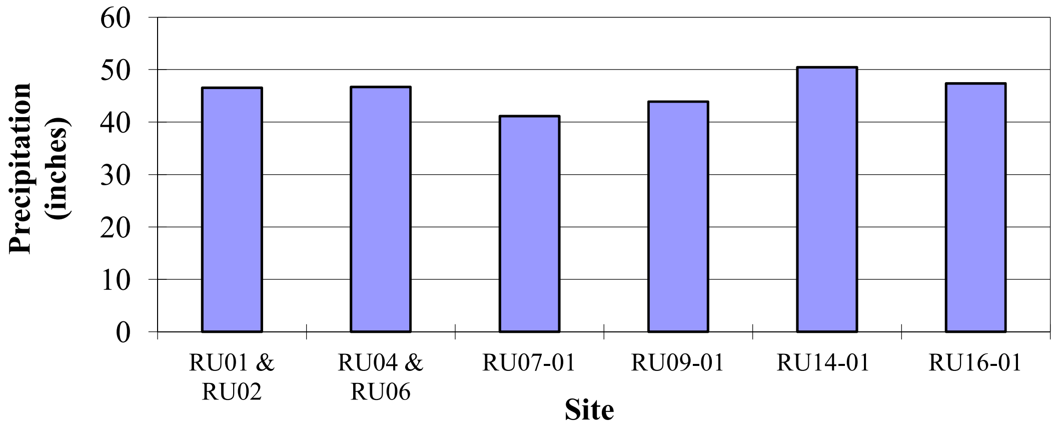
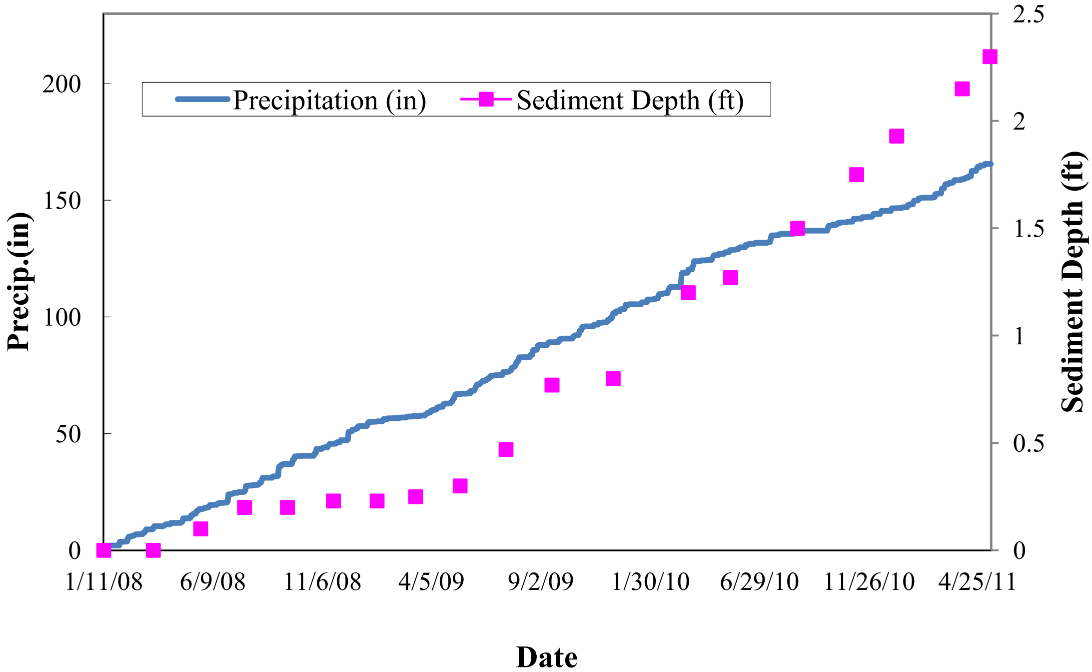
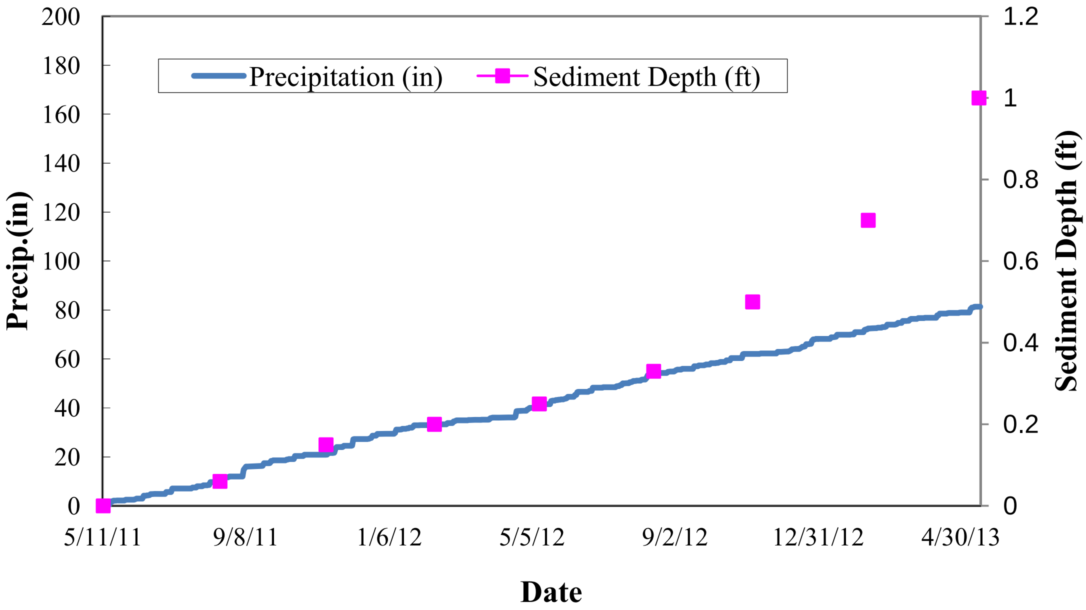



**Figure 7.10 Precipitation in One Year (07.01.2008 ~ 06.30.2009) at each site**

Solids are carried by runoff from surfaces of highways or major roads into the devices. Thus, the precipitation was initially considered as an important variable affecting the sediment accumulation. The accumulated precipitation is plotted against the accumulated sediment depth in Figure 7.11. It is difficult to see the correlation between the precipitation and the sediment depth. Sometimes the HDS collected more sediment during the month with low rainfall but less sediment during the month of heavy rainfall. Therefore, the sediment accumulation may have more to do with the amount of sediment available to be washed into the device rather than the runoff volume available to wash.




(a) The first monitoring period.




(b) The second monitoring period.

**Figure 7.11 Precipitation and sediment accumulations for device RU 01-04**

# Chapter 8

# Maintenance Interval for HDS

## 8.1 Introduction

All HDS require regular inspection and maintenance in order to ensure that the system performs as efficiently as possible. It is imperative to determine the optimum maintenance intervals. To achieve this goal, twelve (12) installed devices were selected for monitoring, analysis, and development of maintenance intervals.

The accumulated sediment depth over the observation period (Chapter 6) was used as the lead indicator for the time interval between HDS cleanouts. There are three types of sediment accumulation patterns so this study categorized sites into three (3) conditions based on variables such as land use, source control, drainage area, traffic counts, and impervious area. In general site conditions, the equation to determine the optimum maintenance intervals is developed based on the most effective variables identified.

## 8.2 Analysis and Evaluation

**Recommended inspection and maintenance intervals of selected devices**

The accumulated sediment depth over the observation period was used as the lead indicator for the time interval between HDS cleanouts. There are large variations in sediment accumulation among the devices due to variables that affect it such as rainfall intensity and duration, drainage area size, traffic count, land use, source control, seasonality and deicing practices. Based on the most effective variables identified, this research divided the sites into four (4) categories of conditions to determine the optimum maintenance intervals.

**Site Condition 1: Inadequate Flow in the Drainage Network**

During the regular inspection, it was observed that various problems caused insufficient flow to the devices. These problems included an incorrectly constructed device, misaligned pipes, and blockage by debris or solids. In the case of RU01-01 for example, the depth of accumulated sediment varied between 0 and 0.1 feet over a period of three years after the initial cleanout (Figure 8.1). The large difference between the expected and observed results was found to be due to an incorrectly constructed diversion chamber. The stormwater runoff was not being diverted to the device, thus it was not receiving treatment. In the case of RU02-02, a blockage was detected in a pipe of the drainage network. That might have caused the low accumulated sediment depth (only 0.6 feet over three years) observed in the device (Figure 8.1). These problems need to be corrected.

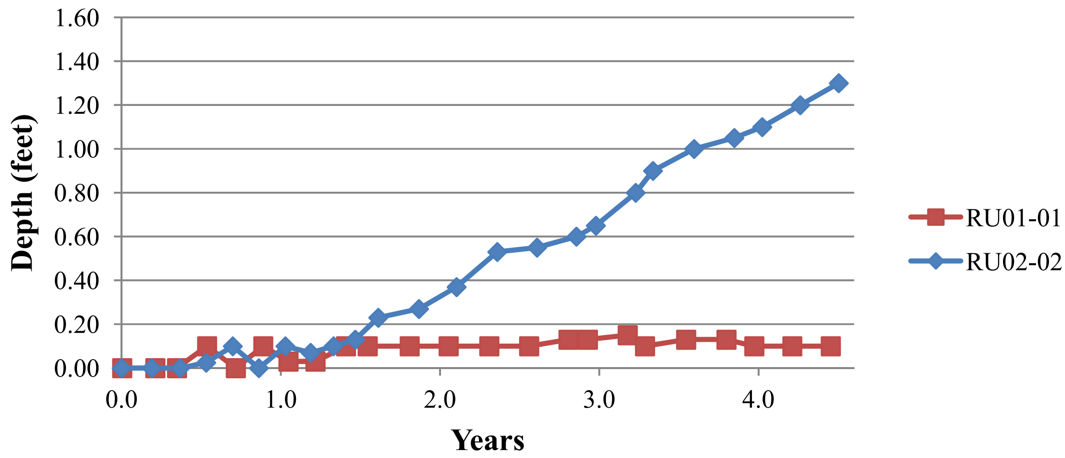



**Figure 8.1 Sediment accumulated depth (Condition 1: inadequate flow in the drainage network)**

**Site Condition 2: Poor Source Control**

Poor source control can cause severe erosion or deposition. Variation of sediment accumulation depth conforms to an S-shape curve when plotted (Figure 8.2). Due to the severe land surface erosion problems, devices require a maintenance interval of one and a half years.

At the site of RU06-01, construction activities (beneath the overpass) observed near Tonnelle Avenue contributed unusual amounts of sand to be washed into the storm sewers. Additionally, there was a significant amount of mush sediment on the roadway directly in front of the bridge scupper. This mush sediment was washing directly into the catch basin nearest the device and was settled in the swirl/grit chamber.

At the site of RU07-01, it was noticed that driveways from a farm comprised mostly of sand were eroding and the sand was being washed into the network. Large amounts of deposited sand were also observed on the driveways of a nearby construction area. The combination of eroded sand from the farm, deposited sand from construction activity, heavy rain events (51.16 inches between September 25th 2008 and September 24th 2009), and steep roads were responsible for an unusual increase in the amount of accumulated sediment.

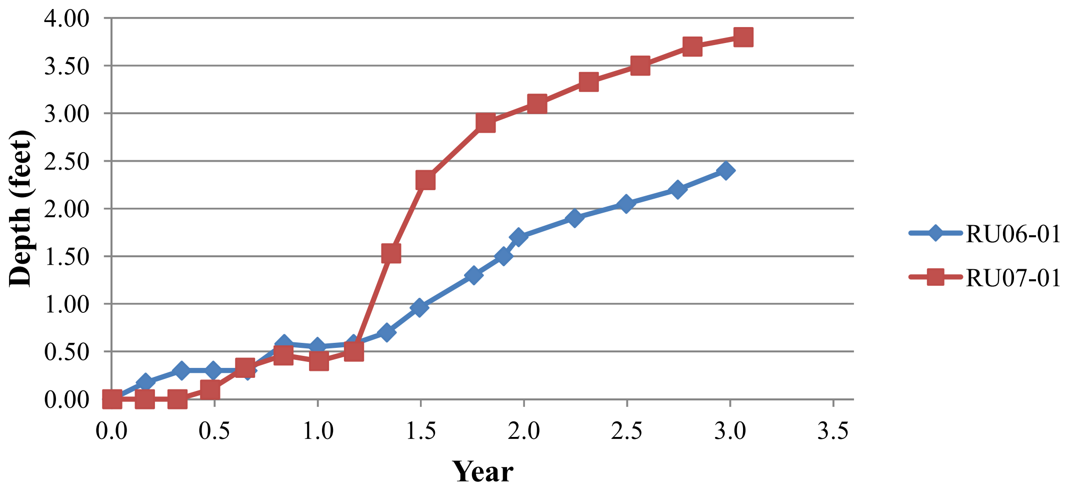



**Figure 8.2 Sediment accumulated depth (Condition 2: Poor source control)**

**Site Condition 3: Sites Under General Conditions**

By the time of May to June, 2011, four devices (RU01-04, RU04-02, RU14-01 and RU16-01) had reached or almost reached the cleanout trigger sediment depth (2 feet), they were cleaned out. These four devices are generally located in more urban and high traffic areas. The sediment depths in four other devices (RU01-02, RU01-03, RU02-01 and RU09-01) had not reached the trigger sediment depth and were continued to be monitored. They are located generally in rural and low traffic areas. The time variation of bottom sediment depths for all the eight devices under the general site conditions are plotted in Figure 8.3.

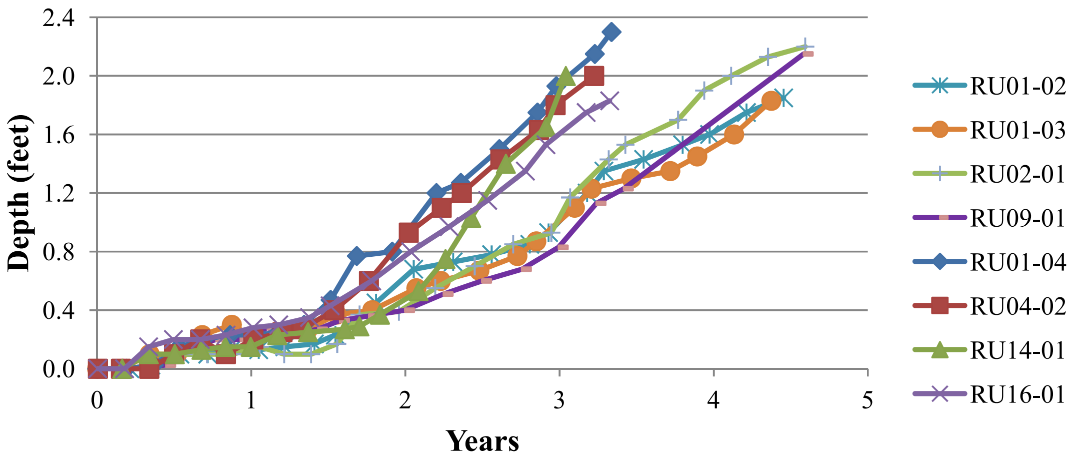



**Figure 8.3 Sediment accumulated depth (Condition 3: General condition).**

It is expected that both the traffic volume (a direct source of the solids deposit) and the impervious surface area (a collector of the atmospheric solids deposition) would have primary influences on the amount of sediment available to be washed into the device and consequently, the device bottom sediment accumulation and the cleanout interval. From Figure 8.3, it appears there are two clusters of sediment accumulation curves and cleanout intervals. The devices in the higher cluster are generally located in the urban and high traffic area and appear needed to be cleaned out every three years. The devices in the lower cluster are generally located in the non-urban low traffic area and appear needed to be cleaned out every four and one half years.

An effort was made in this research to combine the influences of both traffic volume and the impervious area and to predict the cleanout interval based on these two primary influencing factors.

The cleanout interval should be inversely and nonlinearly related to the rate of the sediment load into the device. And, the rate of the sediment load could be assumed to be linearly related to the traffic volume and the impervious drainage area.

The sediment/solids load to the device per hour ($S_t$) is assumed to be linearly related to the rate of solids deposition from vehicle ($w_1$) and the rate of solids load from impervious drainage area ($w_2$) as follows:

$$S_t = w_1 N_v + w_2 A_i \qquad (7.1)$$

Where:

$S_t$ = Sediment/solids load to the device per hour (g/hr)

$w_1$ = Solids load from a vehicle per hour (g/vehicle/hr)

$w_2$ = Solid load from drainage area per hour (g/acre/hr)

$N_v$ = Number of vehicles on the road(s) related with the device

$A_i$ = Impervious drainage area for the device (acre)

The number of the vehicles on the road(s) across the drainage area of the device ($N_v$) can be related to the length of the road(s) (miles), the vehicle speed limit (miles per hour), and the traffic count (the number of vehicles per hour) and calculated as follows:

$$\mathrm{Nv} = \frac{\text{Length of road (miles)}}{\text{Speed Limit}\left(\frac{\text{miles}}{\text{hr}}\right)} \times \mathrm{vph}\left(\frac{\text{vehicles}}{\text{hr}}\right) \tag{7.2}$$

Table 8.1 below shows data on the actual traffic count, the speed limit, the length of road(s), the impervious drainage area, the cleanout interval, and the total sediment mass accumulated at the time of cleanout for each of the eight devices at normal sites.

Note that the traffic counts actually conducted for the road(s) related to the particular device. The mass of sediment in Table 8.1 (the last column on the right) was calculated by multiplying the calculated volume of the bottom sediment at the cleanout (the bottom surface area times the two-feet trigger depth) by the average sediment bulk density (1.26 g/cm$^3$) based on the actual measurements. The sediment loading rate ($S_t$) is calculated from dividing the mass of sediment trapped in the device by the cleanout interval.

Among the eight devices, drainage areas (Table 8.1) for the two devices RU04-02 and RU9-01 were directly obtained from the design reports rather than estimated from the maps and thus they are most accurate. Coincidently, the drainages areas for these two devices (7.7 and 0.49 acres, respectively) also happened to be the largest and the smallest among the eight, and they are the two most impervious (92% and 97% impervious, respectively) as well. The data from these two devices were used to solve simultaneously for $w_1$ and $w_2$. The solved values of $w_1$ and $w_2$ are 2.2 (g/vehicle/hr) and 53 (g/acre/hr), respectively. The values of $w_1$ and $w_{2,}$ in more commonly used units, are 42 pounds per vehicle per year and 1,000 pounds per acre per year, respectively.

**Table 8.1 Information on Traffic Count, Drainage Area, Cleanout Interval, and Sediment Accumulation**

| Site ID | Traffic Count (number per hour) | Road Length (miles) | Speed Limit (miles per hour) | Impervious Drainage Area (acres) | Cleanout Interval (yrs) | Device Diameter (ft) | Mass of Sediment Trapped in Device (kg) |
|---|---|---|---|---|---|---|---|
| RU 01-02 | 925 | 0.16 | 35 | 0.61 | 4.48 | 8 | 3,580 |
| RU 01-03 | 861 | 0.16 | 25 | 0.60 | 4.55 | 8 | 3,580 |
| RU 01-04 | 2,360 | 0.10 | 25-45 | 1.66 | 3.06 | 8 | 3,580 |
| RU 02-01 | 1,249 | 0.07 | 35-45 | 1.02 | 4.16 | 12 | 8,090 |
| RU 04-02 | 2,243 | 0.16 | 25-40 | 3.54 | 3.15 | 10 | 5,650 |
| RU 09-01 | 1,940 | 0.11 | 40 | 0.48 | 4.49 | 5 | 1,430 |
| RU 14-01 | 4,710 | 0.25 | 35-50 | 2.18 | 3.04 | 12 | 8,090 |
| RU 16-01 | 1,672 | 0.13 | 35-55 | 1.47 | 3.46 | 7 | 2,720 |

With the values of $w_1$ and $w_2$, the sediment/solids load to the device per hour ($S_t$) can be estimated using the given number of vehicles on the road related with the device and the impervious drainage area for the device (acre). The number of the vehicles on the road can be calculated from the traffic count, the road length, and the speed limit as indicated above or from counting all the vehicles on the road(s) from an aerial photograph.

Assuming a nonlinear logarithmic relationship between the cleanout interval and the sediment load, the data from all the eight devices (Table 4) were used to determine the coefficients that would offer the best fit. The fitted relationship is as follows:

$$y = - 0.99 \ln (S_t) + 8.1 \tag{7.3}$$

where,

$y$ = Device cleanout interval (yr)

$S_t$ = Sediment/solids load to the device per hour (g/hr)

The fitted curve along with the data from all the eight devices are shown in Figure 10. It is a very good fit with the R2 (the coefficient of determination) value of 0.87.

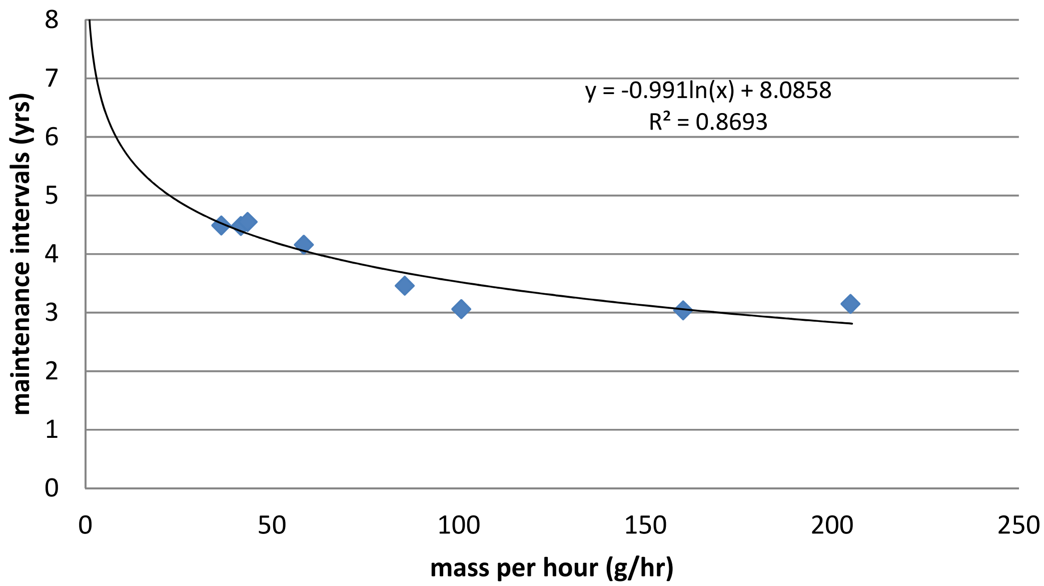



**Figure 8.4 Relation between maintenance interval and sediment load to device.**

The above fitted model based on the traffic volume and the impervious area can be used to predict the cleanout/maintenance interval. This will be more accurate than the four-year interval roughly extrapolated during the previous research project.

All the devices monitored were sized based on NJDEP's previous water quality design storm (WQDS) with 1.25 inches of rainfall depth uniformly distributed over two hours. The updated design storm still has 1.25 inches of rainfall depth but non-uniformly distributed (NJDEP, 2004). This updated WQDS may lead to the use of a larger device for the same drainage area. The maintenance interval for the device sized based on the updated WQDS may be longer than the one predicted using the relationship established in this study, and it can be increased proportionally to the increase in the bottom surface area.

For other types of hydrodynamic separators, the maintenance interval can be adjusted based on the proportion of the maximum allowable sediment storage volume.

## 8.3 Conclusions

For the maintenance interval, the measured variation of sediment depths over time can be used to estimate the device inspection interval. If half the maximum allowable sediment depth is used to determine the device inspection interval, devices installed at sites with serious erosion (condition 2) should be inspected every three months, devices installed in general areas (condition 3) should be inspected six months.
If there are any structural problems that prevent trapping pollutants, an immediate structural correction will be recommended.

If there is a poor source control and/or construction activities are ongoing within the drainage area, the devices will require a maintenance interval of one and a half years due to land surface erosion problems.

For the sites of general conditions, the maintenance intervals were measured to be from three to four and one half years. For planning future maintenance/cleanout activities, it is recommended that the predictive model be used with the number of vehicles on the road(s) and the impervious drainage area as inputs.

The above maintenance/cleanout and inspection/measurement interval estimates are based on monitoring depth measurement and the maximum sediment depth of two feet. The installed devices were sized based on uniform-intensity design storm in New Jersey. According to the new rule for non-uniform storm (NJDEP, 2004), newer devices are larger in size than the ones currently used in the study.

# Chapter 9

# Recommendation and Guideline for Maintenance

Before recommendation and guideline, It is imperative to know problems related to maintenance. While forty one (41) HDS devices have been inspected, some problems are found.

- Incorrectly constructed structures such as flow control wall, diversion chamber, and a pipe. (3 devices)
- Inaccessible chambers due to no manhole cover or covers located on the road. (10 devices)
- Blocked pipe, chamber or inlet due to poor source control (5 devices)
- Constructional debris in the device (8 devices): Construction debris is found in 3 devices after cleanout activities and 5 devices under construction.
- Damaged structures: damaged the coupler, concrete wall and bottom are found in 3 devices after cleanout activities.

The device must be essentially inspected and clean after installation. It is the responsibility of the installer or contractor to leave the device in a clean state.

## 9.1 Design and construction for maintenance

Design and construction is usually done on the basis of function, but rarely considers the maintenance activities that will take place during the useful life of the device. Further research on design and construction for maintenance is warranted. For example, there should be easy access to all chambers of a device for cleaning, inspections, and repairs. Also, determining whether the responsibility of factors such as accessibility, location, should correspond to the vendor or to the contractor could be analyzed.

The Stormwater Best Management Practices manual by the NJDEP offered useful insights on several aspects of Stormwater Management. Chapter 2 of the BMP, Low Impact Development Techniques refers to the importance of Source control in preventing and reducing the amount of pollutants, floatables, and other contaminants entering the stormwater network.

## 9.2 Measures to reduce maintenance costs

At the 12 sites that were part of the study, the time between the installation and cleanout was around 4.8 years. During this period a combined total of 33.95 lbs of oil, 26431.5 lbs of sediment and 16.45 lbs of floatables had collected in the HDS. The total volume of trapped solid in the devices was 378.06 $ft^3$, which is estimated from the sediment depth and swirl chamber area. The cleanout at each site cost \$3,500 with an approximately additional charge of \$59 /ton for the disposal. If the oil is to be separately disposed, 1.8 gallons oil booms costing 150\$ / 12 booms would have to be used. If a facility can handle both water and solids, transportation between the site and each facility can be reduced.

Considering that the number of HDS could increase in the near future to thousands, the total cost for cleanout comes into the low millions. Optimizing maintenance intervals instead of simply cleaning out the devices yearly could substantially reduce maintenance costs over the life of the device.

## 9.3 Maintenance interval

Twelve (12) hydrodynamic separators (HDSs), a type of stormwater manufactured treatment device (MTD), were continuously monitored after the end of the previous research project to gain confidence in the previously projected device maintenance intervals.

The sites for the twelve devices were divided into three different categories: (1) sites with inadequate inflow to the device, (2) sites with the poor source control, and (3) sites under general conditions. For the sites with inadequate inflow, the installation problems should be corrected and/or the inlet pipes should be cleared. For the sites with poor source control, a maintenance interval of one and one half years is recommended, but, it is preferably recommended that they are made stable, to reduce the degree of erosion, and then put on a maintenance interval for the general sites. For the general sites, the maintenance intervals were measured to be from three to four and one half years. For planning future maintenance/cleanout activities, it is recommended that the predictive model be used with the number of vehicles on the road(s) and the impervious drainage area as inputs.

For the same type of devices or other types of devices, the maintenance interval can be predicted first using the same relationship obtained from this study and then adjusted proportionally based on the ratio of the maximum allowable bottom sediment storage volumes.

# Chapter 10

# Summary and Conclusion

To improve the quality of runoff and meet the new stormwater management requirements, numerous prefabricated stormwater treatment systems have been installed throughout the State of New Jersey and the United States. The use of such systems, known as Stormwater Hydrodynamic Separators (HDS), is expected to continue in the foreseeable future. Therefore, the goal of this study is to develop effective maintenance procedures and quantify maintenance schedules for HDS. The main achievements and findings obtained from this research are summarized and concluded, based on the monitoring, evaluation and modeling, as follow:

**Information for Selecting, Inspecting, and Maintaining HDS**

Information for properly selecting, inspecting, and maintaining HDS was identified and collected, and this research contributed to the database forms development. Three types of information form were developed: asset data from, inspection form and maintenance form.

This development will be very helpful for leveling the playing field, properly track the devices, and inspect and maintain the devices in a timely fashion and in a cost-effective way.

**Quantity and Quality of Materials Trapped by HDS**

Measured quantity and quality of the trapped stormwater solids varied widely from site to site. Before the first cleanout, total depth of the bottom sediment ranged from 2.7 feet (exceeding the maintenance limit of 2 feet) to 0.5 feet (well within the maintenance limit). Twenty months after cleanout, the highest sediment bottom depth was 2.3 feet and the lowest was 0.23 feet, excluding a device with an incorrectly installed diversion structure.

Several sites yielded high levels of oil and grease. Large amounts of floatables were also collected from the sites consisting mostly of plastic, Styrofoam, and organic debris. Testing of the pumped-out sediment indicated low levels of heavy metals (copper, zinc, lead, cadmium, and arsenic). Concentrations of all the measured heavy metals were much lower than the New Jersey residential soil contamination limits indicating that the bottom solids could be disposed of at standard sanitary landfills. Concentrations of phosphorus and nitrogen in the bottom sediment were much lower than those in typical sewage sludge.

The particle size distribution analysis showed that an average of 10 percent of the samples passed the #200 (75 microns) sieve: coarse sediment. Organic content of the bottom sediment ranged from 3 to 34 percent.

From the measured results, it is recommended that vacuum truck be used to pump out both water and solids and they be disposed together at a pre-treatment facility.

**Effective Maintenance Procedures and Guideline**

This research provided a useful guideline for treatment and maintenance for HDS. From the results of the monitoring and evaluation an ideal and efficient maintenance procedure and interval was proposed to provide environmental improvements and help reduce the overall maintenance cost.

**Optimum Maintenance Intervals**

The accumulated sediment depth over the observation period was used as the lead indicator for the time interval between HDS cleanouts. The research identified traffic volume and impervious drainage area as the most effective variables. Using these two variables, the equation of optimum maintenance intervals was derived.

There are three types of sediment accumulation patterns based on characteristics of drainage area, and three separate recommendations were given.

- If there are any structural problems that prevent trapping pollutants, an immediate structural correction is recommended.

- If there is a poor source control and/or construction activities are ongoing within the drainage area, the devices will require a maintenance interval of one and a half years. Also, inspection is recommended every three months.

- If sites are in general conditions, maintenance intervals of devices are recommended using the equation of optimum maintenance intervals. Also, inspection is recommended every six months.

Efficient cleanout procedure, appropriate design, correct construction, proper source control, and optimized maintenance interval could substantially reduce maintenance costs over the life of the device.

# Appendices

## Appendix A: Stormwater HDS asset data form

**HDS Location Info (*common for all types of devices*)**

| HDS ID | Device Name | Model | Serial No. |
|---|---|---|---|
| | | | |

| Nearest Road | [NB,SB,EB,WB] |
|---|---|
| | ▼ |

| Municipality | County | Region |
|---|---|---|
| | | |
| GPS Latitude | GPS Longitude | Elevation (ft) |
| | | |
| State   lane Coordinate X | State Plane Co  rdinate | |
| | | |
| Nearest Cross Road | Nearest Landmark | |
| | | |

| Nearest Milepost | Distance from  Milepost (ft) | Depth from Ground Surfac   to Device Bottom (ft) |
|---|---|---|
| | | |

| Distance from Roadway Centerline (ft) | Physical Location | Is Device in Vehicle Traffic? |
|---|---|---|
| | ▼ | ▼ |

Location Map


(sample image: background image from Google street map)

**NJDOT Project Info (*common for all types of devices*)**

| Project Name | Project No. | Plan Approval Date | Project Completion Date |
|---|---|---|---|
| | | | |

| Project Description | |
|---|---|

| NJDOT Project Manager | Designer Company/Organization | Designer Name |
|---|---|---|
| | | |

| NJDOT Environment Person | Contractor Company/Organization | Contractor Name | NJDOT Construction Field Manager |
|---|---|---|---|
| | | | |

| Env. Permit Issuer | Permit No. | Permit Date | Design Traffic Data (A.D.T) | | |
|---|---|---|---|---|---|
| | | | Road | Present (vpd) | Future (vpd) |
| | | | | | |

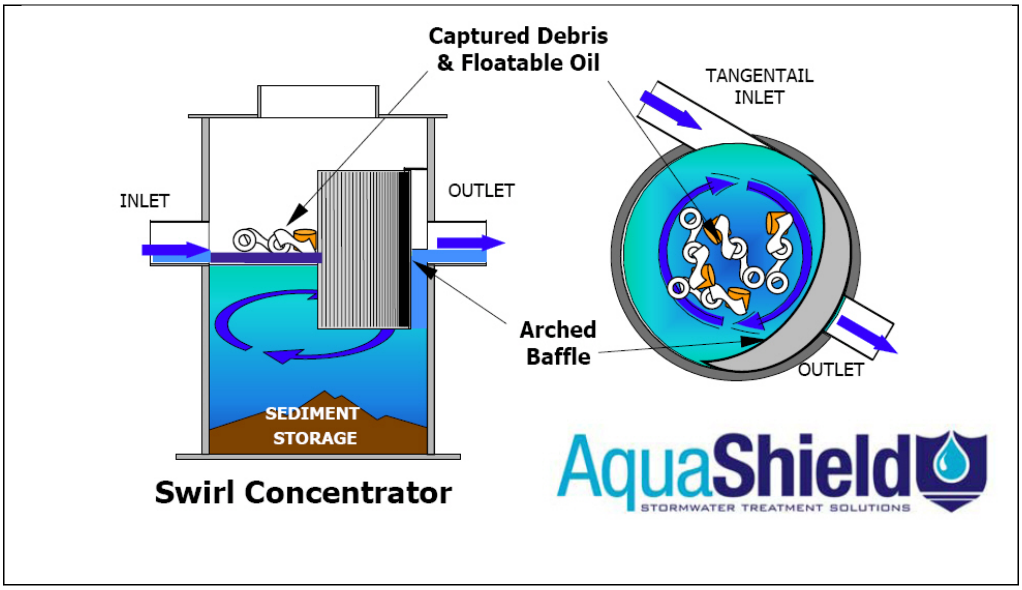
| Water Quality Design Storm | Flood Control Design Storm (Maximum) | Groundwater Recharge Design Storm |
|---|---|---|
| ▼ | ▼ | ▼ |

| NJDOT UPC | NJDOT Job Number | Route No. | Milepost | Federal Project No. |
|---|---|---|---|---|
| | | | | |
| Municipality 1 | Municipality 2 | Municipality 3 | County 1 | County 2 |
| | | | | |

| Bid Date | BD Number | |
|---|---|---|
| | | |

**Device Characteristics Info (*select a form below to fill based on type of the device*)**

Schematic of Device: Aqua-Swirl®



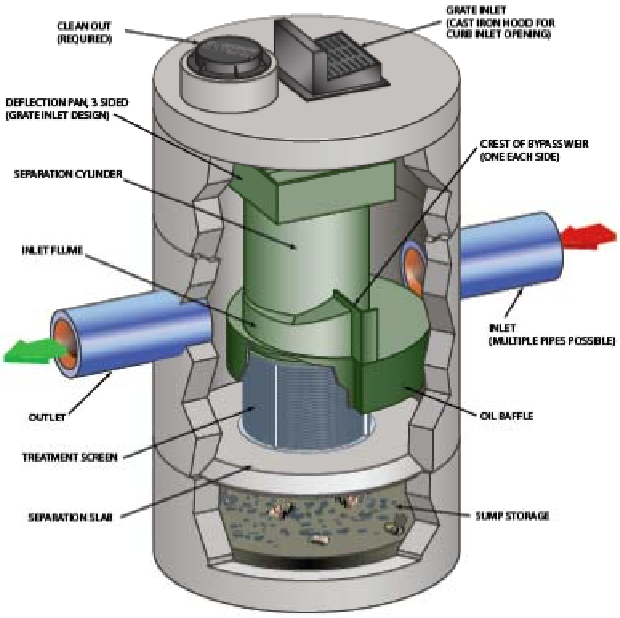

| Device Height (ft) | Device Diameter (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|
| | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Swirl Chamber Diameter (ft) | Swirl Chamber Area (sq. ft) | Sediment Storage Capacity (ft3) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Trash/Debris /Oil Storage Capacity (ft3) | Trash/Debris/ Oil Storage Depth (ft) | Trash/Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

Schematic of Device: CDS®



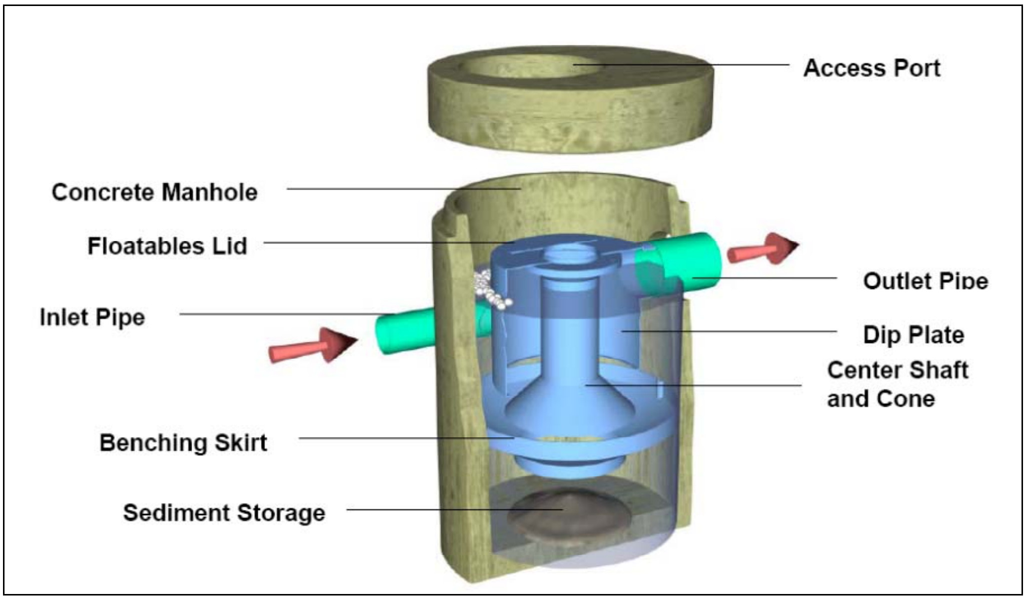

| Device Height (ft) | Device Diameter (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|
| | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Chamber Diameter (ft) | Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Trash/Debris /Oil Storage Capacity ($ft^3$) | Trash/Debris/ Oil Storage Depth (ft) | Trash/Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

Schematic of Device Downstream Defender®



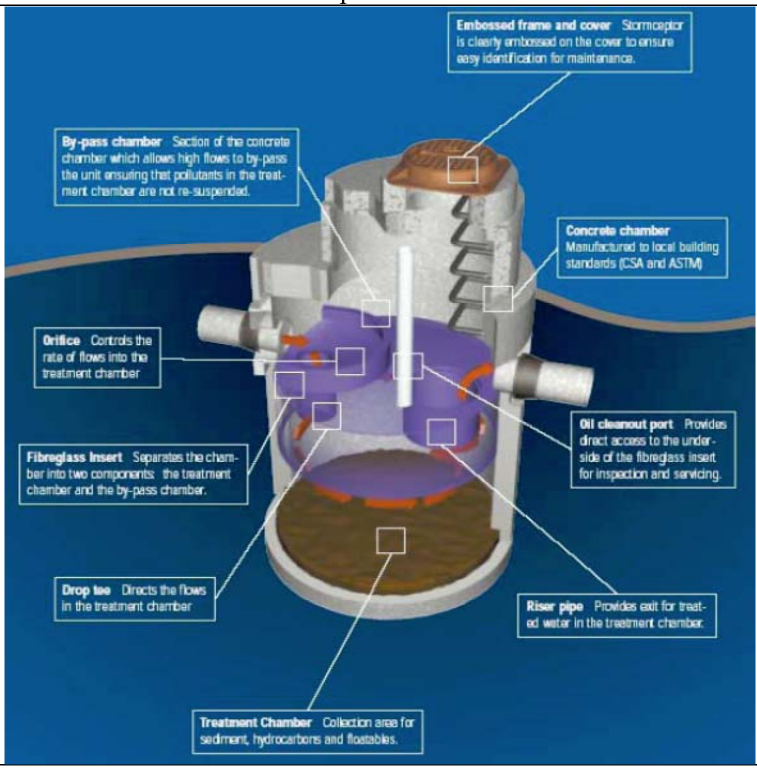

| Device Height (ft) | Device Diameter (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|
| | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Chamber Diameter (ft) | Chamber Area (sq. ft) | Sediment Storage Capacity (ft3) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Trash/Debris /Oil Storage Capacity (ft3) | Trash/Debris/ Oil Storage Depth (ft) | Trash/Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

Schematic of Device: Stormceptor® STC



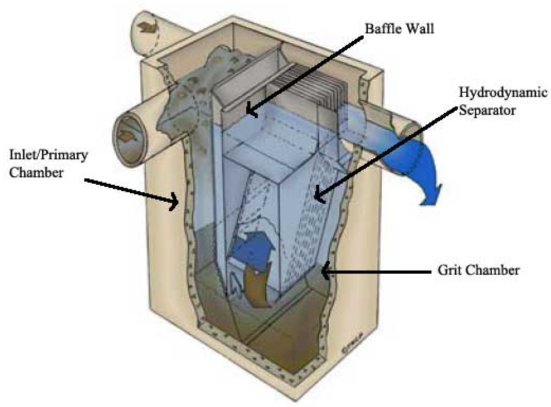

| Device Height (ft) | Device Diameter (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|
| | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Chamber Diameter (ft) | Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Trash/Debris/ Oil Storage Capacity ($ft^3$) | Trash/Debris/ Oil Storage Depth (ft) | Trash/Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

Schematic of Device: Terre Kleen®




| Device Height (ft) | Device Width (ft) | Device Length (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|---|
| | | | | |

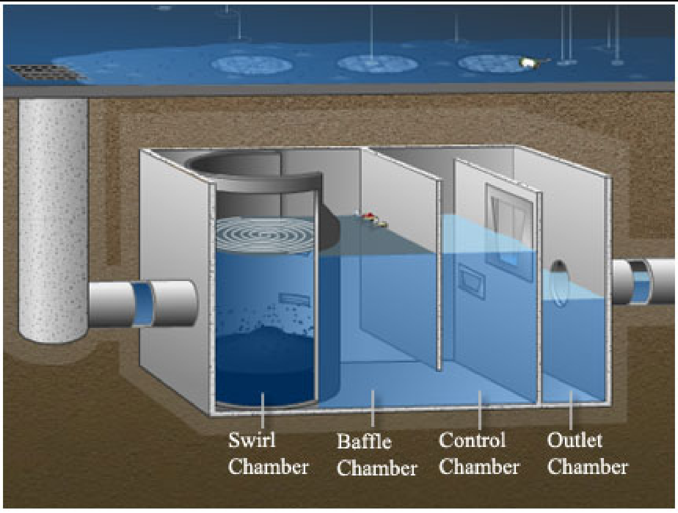
| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Primary Chamber | | | | | |
|---|---|---|---|---|---|
| Length (ft) | Width (ft) | Primary Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
| | | | | | |

| Trash/Debris/Oil Storage Capacity ($ft^3$) | Trash/Debris/Oil Storage Depth (ft) | Trash/ Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

| Grit Chamber | | | | | | |
|---|---|---|---|---|---|---|
| Length (ft) | Width (ft) | Grit Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) | Sediment Storage Capacity ($ft^3$) |
| | | | | | | |

Schematic of Device: Vortechs®




| Device Height (ft) | Device Width (ft) | Device Length (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|---|
| | | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Swirl Chamber Diameter (ft) | Swirl Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Baffle Chamber Dimensions (approx.) | | Baffle Cham-ber Area (sq. ft) | Trash/ Debris/ Oil Storage Capacity ($ft^3$) | Trash/ Debris/ Oil Storage Depth (ft) | Trash/ Debris Cleanout Thickness Thres-hold (ft) | Trash/ Debris Cleanout Area Thres-hold (%) | Oil Cleanout Thick-ness Thres-hold (ft) | Oil Cleanout Area Thres-hold (%) |
|---|---|---|---|---|---|---|---|---|
| L (ft) | W (ft) | | | | | | | |
| | | | | | | | | |

Schematic of Device: VortSentry®


| Device Height (ft) | Device Diameter (ft) | Device Footprint Area (sq. ft) | Materials Used for Manufacturing the Device |
|---|---|---|---|
| | | | |

| No. of Manhole Covers | All Components Visible from Ground? | If Not, Name Component(s) Invisible from Ground | All Compartments Accessible by Vacuum Hose? | If Not, Name Compartment(s) Inaccessible by Vacuum Hose |
|---|---|---|---|---|
| | ▼ | | ▼ | |

| Swirl Chamber Diameter (ft) | Swirl Chamber Area (sq. ft) | Sediment Storage Capacity ($ft^3$) | Sediment Storage Depth (ft) | Sediment Cleanout Depth Threshold (ft) |
|---|---|---|---|---|
| | | | | |

| Trash/Debris/Oil Storage Capacity ($ft^3$) | Trash/Debris/Oil Storage Depth (ft) | Trash/Debris Cleanout Thickness Threshold (ft) | Trash/ Debris Cleanout Area Threshold (%) | Oil Cleanout Thickness Threshold (ft) | Oil Cleanout Area Threshold (%) |
|---|---|---|---|---|---|
| | | | | | |

(***Common for all types of devices***)

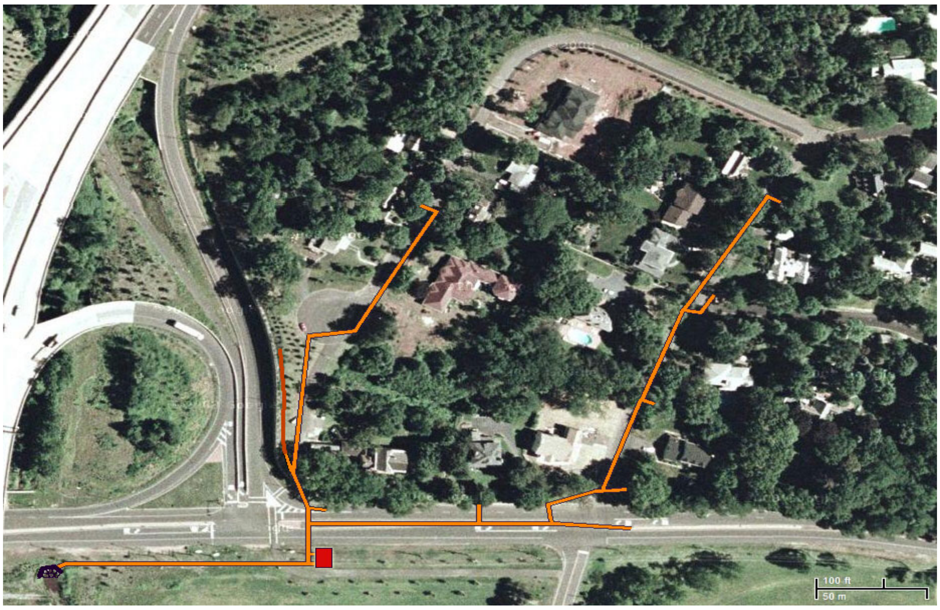
| TSS Removal Rate Certified by NJDEP (%) | Maximum Treatment Flow Rate (cfs) | Maximum Hydraulic Flow Rate (cfs) | Head Loss at Maximum Treatment Flow (ft) | Head Loss at Maximum Hydraulic Flow (ft) |
|---|---|---|---|---|
| | | | | |

| Device Vendor | Invoice Date | Delivery Date | Installation Date | Device Cost (includes S&H) | Installation Cost |
|---|---|---|---|---|---|
| | | | | | |

| Item Sequence No. on Plan | Item No. on Plan | Item Name on Plan | Plan Sheet No. | Special Provisions Page No. |
|---|---|---|---|---|
| | | | | |

**Device Watershed Info (*common for all types of devices*)**

Aerial Satellite Image and Drainage Network



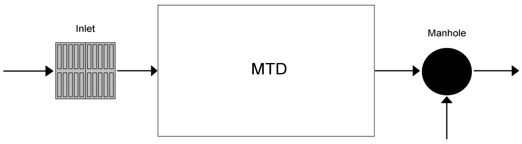
(sample image: satellite image from Google map)

| Drainage Area (acre) | Watershed Land Use | Watershed Soil Type | Percentage of Impervious Area (%) |
|---|---|---|---|
| | ▼ | ▼ | |
| Longest Flow Path Length (ft) | Slope along Flow Path | Manning's Roughness Coefficient along Flow Path | Time of Concentration (minutes) |
| | | | |

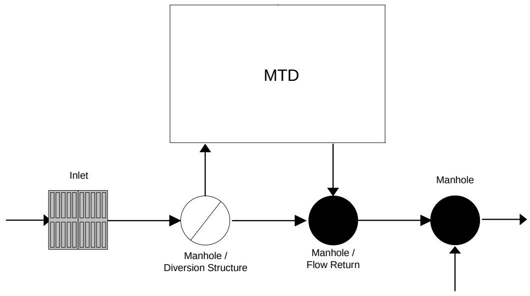
| Runoff Coefficient | NRCS Curve Number |
|---|---|
| | |

**Device Spatial Relation Info (*common for all types of devices*)**

Online System




Offline System




| | |
|---|---|
| Is Device Offline? | ▼ |

**For both Offline and Online Device**

| ID of Upstream Inlet, Catch Basin or Manhole | Dimensions (Length x Width) of Upstream Inlet or Catch Basin, or Diameter of Upstream Manhole | Invert Elevation of Upstream Inlet, Catch Basin, or Manhole | Ground Elevation of Upstream Inlet, Catch Basin, or Manhole |
|---|---|---|---|
| | | | |

| ID of Downstream Manhole or Catch Basin | Diameter of Downstream Manhole or Dimensions (Length x Width) of Catch Basin | Invert Elevation of Downstream Manhole or Catch Basin | Ground Elevation of Downstream Manhole or Catch Basin |
|---|---|---|---|
| | | | |

| ID of Upstream Pipe | Diameter of Upstream Storm Sewer Pipe (ft) | Invert Elevation of Upstream Storm Sewer Pipe (ft) | Slope of Upstream Storm Sewer Pipe (ft) | Material of Upstream Storm Sewer Pipe (ft) |
|---|---|---|---|---|
| | | | | |

| ID of Downstream Pipe | Diameter of Downstream Storm Sewer Pipe (ft) | Invert Elevation of Downstream Storm Sewer Pipe (ft) | Slope of Downstream Storm Sewer Pipe (ft) | Material of Downstream Storm Sewer Pipe (ft) |
|---|---|---|---|---|
| | | | | |

**For Offline Device Only**

| Diameter of Upstream Diversion Manhole | Invert Elevation of Upstream Diversion Manhole | Ground Elevation of Upstream Diversion Manhole |
|---|---|---|
| | | |

| Diameter of Downstream Return Manhole | Invert Elevation of Downstream Return Manhole | Ground Elevation of Downstream Return Manhole |
|---|---|---|
| | | |

| ID of Upstream Diversion Pipe | Diameter of Upstream Diversion Pipe | Invert Elevation of Upstream Diversion Pipe | Slope of Upstream Diversion | Material of Upstream Diversion |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| | (ft) | (ft) | (ft) | Pipe (ft) | Pipe (ft) |
| | | | | | |
| | ID of Downstream Diversion Pipe (ft) | Diameter of Downstream Return Pipe (ft) | Invert Elevation of Downstream Return Pipe (ft) | Slope of Downstream Return Pipe (ft) | Material of Downstream Return Pipe (ft) |
| | | | | | |

| | | |
|---|---|---|
| Device Outlet Drains to | Direction of Downstream Drain | |
| ▼ | ▼ | |
| Outfall ID | Outfall Drains to Waterway | Waterway ties into |
| | ▼ | ▼ |
| Name of Waterway | | |
| | | |

Additional Comments (common for all types of devices)

| |
|---|
| |

**Drop-down Menu Contents: (*common for all types of devices*)**

[NB,SB,EB,WB] ▼ : NB,SB,EB,WB

Physical Location ▼ : On the Median, On Road, On Shoulder, On Sidewalk, On Mild-Slope Bank, On Steep-Slope Bank, On Large Traffic Island, On Small Traffic Island, On Parking Lot, on Flat Large Area Open Space, Other

Is Device in Vehicle Traffic? ▼ : Yes, No

Water Quality Design Storm▼ : NJDEP Uniform WQ Design Storm, Non-uniform WQ Design Storm

Flood Control Design Storm (Maximum) ▼ : 100-Year Storm, 50-Year Storm, 25-Year, 10-Year Storm, 5-Year Storm, 2-Year Storm

Groundwater Recharge Design Storm▼ : Average Annual Storm, 2-Year Storm

All Components Visible from Ground? ▼ : Yes, No

All Compartments Accessible by Vacuum Hose? ▼ : Yes, No

Watershed Land Use▼ : Commercial, Residential, Mixed(Commercial & Residential), Industrial, Rural, Open Space (Park, Woodland, Golf course, etc.)

Watershed Soil Type ▼ : Sand, Silt, Clay

Is the Device Offline? ▼ : Yes, No

Device Outlet Drains to ▼ : Other Types of Stormwater BMPs, Outfall

Direction of Downstream Drain (Other Types of Stormwater BMPs or Outfall) ▼ : N, NE, E, SE, S, SW, W, NW

Outfall Drains to Waterway ▼ : Ocean, River, Stream, Lake, Pond, Ditch, Wetland, Detention/Retention Area

Waterway ties into ▼ : State System, County System, Municipal System, Private Property, Unknown

## Appendix B: Stormwater HDS inspection form

(***Common for all types of devices***)

| HDS ID | HDS_Inspection_RecID | Weather* | Air Temp. ($^{o}$F) |
|---|---|---|---|
| | | | |

| Inspection Date | Inspection Time | | Purpose of Inspection | Inspector |
|---|---|---|---|---|
| MM-DD-YYYY | Start | End | Routine Inspection ( )<br>Inspection Immediately before Cleanout ( )<br>Inspection Immediately after Cleanout ( )<br>Other ( ) | |
| | HH:MM | HH:MM | | |

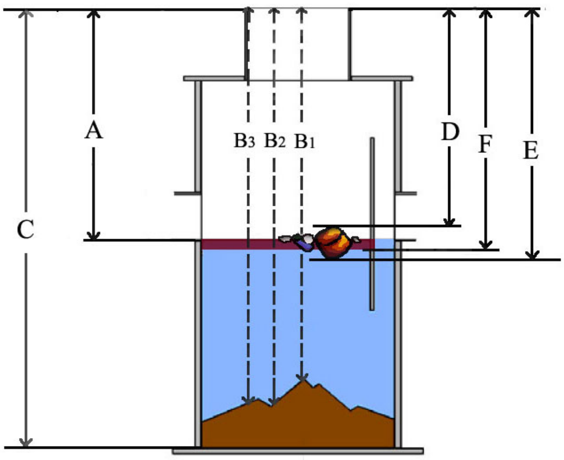
| Inspection Cost | Last Inspection Date | Inspection Interval (months) | Projected Next Inspection Date | Recent Precipitation Event | |
|---|---|---|---|---|---|
| | | | | Date | Depth (in) |
| | (Function) | | (Function) | MM-DD-YYYY | |

* Weather: Sunny, Windy, Cloudy, Rainy, Stormy, Blizzard

**Measurements from Ground above the Device (Routine Inspection or Inspection Immediately before Cleanout)**

(***Select a form below to fill based on type of the device***)

Schematic for Measurements:  Aqua-Swirl®




A: Distance from Water / Oil Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim

C: Distance from Bottom to Top of Manhole Rim

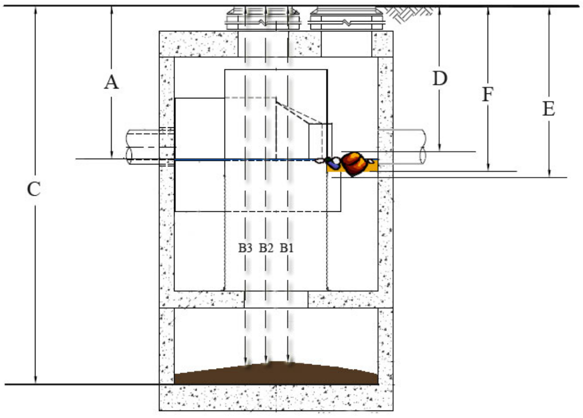
D: Distance from Trash/Debris Surface to Top of Manhole Rim

E: Distance from Trash/Debris Bottom to Top of Manhole Rim

F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| | | | |
|---|---|---|---|
| A (ft) | | Trash/Debris Areal Coverage (%) | |
| B1 (ft) | | D (ft) | |
| B2 (ft) | | E (ft) | |
| B3 (ft) | | Oil Areal Coverage (%) | |
| C (ft) | | F (ft) | |

Schematic for Measurements: CDS®




A: Distance from Water / Oil Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim

C: Distance from Bottom to Top of Manhole Rim

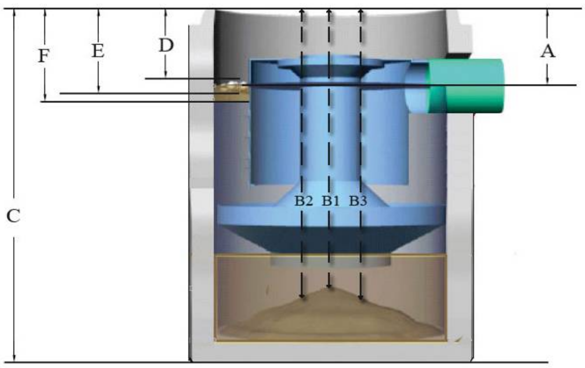
D: Distance from Trash/Debris Surface to Top of Manhole Rim

E: Distance from Trash/Debris Bottom to Top of Manhole Rim

F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| | | | |
|---|---|---|---|
| A (ft) | | Trash/Debris Areal Coverage (%) | |
| B1 (ft) | | D (ft) | |
| B2 (ft) | | E (ft) | |
| B3 (ft) | | Oil Areal Coverage (%) | |
| C (ft) | | F (ft) | |

Schematic for Measurements: Downstream Defender®




A: Distance from Water / Oil Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

C: Distance from Bottom to Top of Manhole Rim

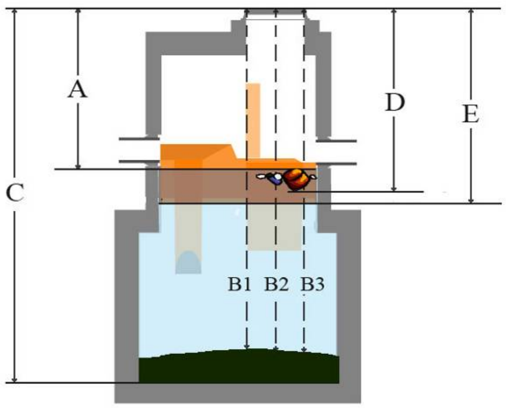
D: Distance from Trash/Debris Surface to Top of Manhole Rim

E: Distance from Trash/Debris Bottom to Top of Manhole Rim

F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| | | | |
|---|---|---|---|
| A (ft) | | Trash/Debris Areal Coverage (%) | |
| B1 (ft) | | D (ft) | |
| B2 (ft) | | E (ft) | |
| B3 (ft) | | Oil Areal Coverage (%) | |
| C (ft) | | F (ft) | |

Schematic for Measurements: Stormceptor® STC




A: Distance from Water / Oil / Trash /Debris Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim

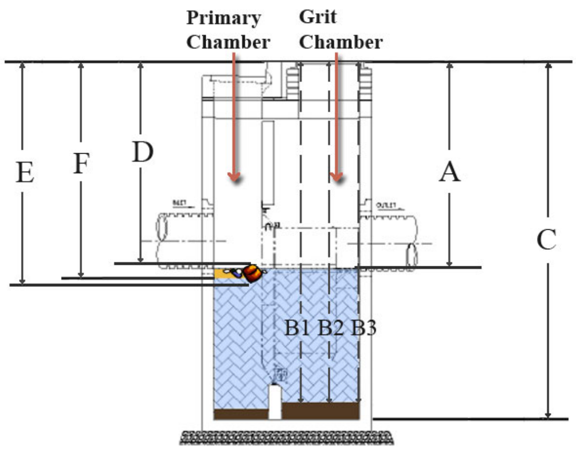
C: Distance from Bottom to Top of Manhole Rim

D: Distance from Trash/Debris Bottom to Top of Manhole Rim

E: Distance from Bottom of Oil Layer to Top of Manhole Rim

| | | | |
|---|---|---|---|
| A (ft) | | Trash/Debris Areal Coverage (%) | |
| B1 (ft) | | D (ft) | |
| B2 (ft) | | E (ft) | |
| B3 (ft) | | Oil Areal Coverage (%) | |
| C (ft) | | | |

Schematic for Measurements: Terre Kleen®




A: Distance from Water / Oil Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim

C: Distance from Bottom to Top of Manhole Rim

D: Distance from Trash/Debris Surface to Top of Manhole Rim

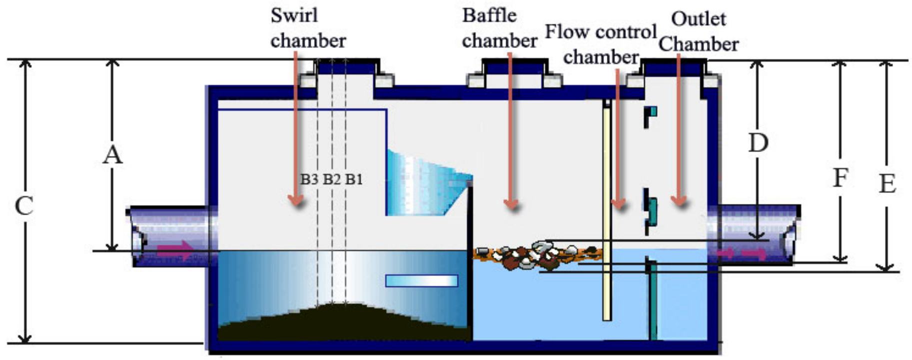
E: Distance from Trash/Debris Bottom to Top of Manhole Rim

F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| Primary Chamber | | | |
|---|---|---|---|
| Ap (ft) | | Trash/Debris Areal Coverage (%) | |
| Bp1 (ft) | | Dp (ft) | |
| Bp2 (ft) | | Ep (ft) | |
| Bp3 (ft) | | Oil Areal Coverage (%) | |
| Cp (ft) | | Fp (ft) | |

| Grit Chamber | | | |
|---|---|---|---|
| Ag (ft) | | Trash/Debris Areal Coverage (%) | |
| Bg1 (ft) | | Dg (ft) | |
| Bg2 (ft) | | Eg (ft) | |
| Bg3 (ft) | | Oil Areal Coverage (%) | |
| Cg (ft) | | Fg (ft) | |

Schematic for Measurements: Vortechs®



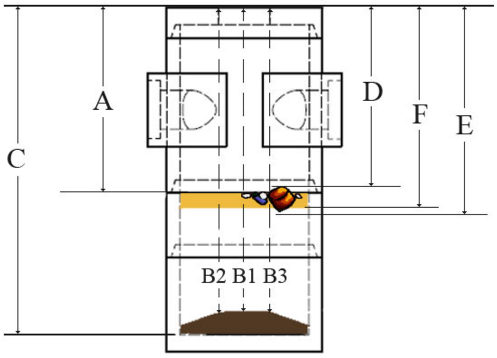

A: Distance from Water / Oil Surface to Top of Manhole Rim
B1: Distance from Center of Sediment Surface to Top of Manhole Rim
B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim
B3: Distance from Far Side of Sediment Surface to Top of Manhole Rim
C: Distance from Bottom to Top of Manhole Rim
D: Distance from Trash/Debris Surface to Top of Manhole Rim
E: Distance from Trash/Debris Bottom to Top of Manhole Rim
F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| Swirl Chamber | | | |
|---|---|---|---|
| As (ft) | | Trash/Debris Areal Coverage (%) | |
| Bs1 (ft) | | Ds (ft) | |
| Bs2 (ft) | | Es (ft) | |
| Bs3 (ft) | | Oil Areal Coverage (%) | |
| Cs (ft) | | Fs (ft) | |

| Baffle Chamber | | | |
|---|---|---|---|
| Ab (ft) | | Trash/Debris Areal Coverage (%) | |
| Bb1 (ft) | | Db (ft) | |
| Bb2 (ft) | | Eb (ft) | |
| Bb3 (ft) | | Oil Areal Coverage (%) | |
| Cb (ft) | | Fb (ft) | |

| Outlet Chamber | | | |
|---|---|---|---|
| Ao (ft) | | Trash/Debris Areal Coverage (%) | |
| Bo1 (ft) | | Do (ft) | |
| Bo2 (ft) | | Eo (ft) | |
| Bo3 (ft) | | Oil Areal Coverage (%) | |
| Co (ft) | | Fo (ft) | |

Schematic for Measurements: VortSentry®




A: Distance from Water / Oil Surface to Top of Manhole Rim

B1: Distance from Center of Sediment Surface to Top of Manhole Rim

B2: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

B3: Distance from Intermediate Location of Sediment Surface to Top of Manhole Rim

C: Distance from Bottom to Top of Manhole Rim

D: Distance from Trash/Debris Surface to Top of Manhole Rim

E: Distance from Trash/Debris Bottom to Top of Manhole Rim

F: Distance from Bottom of Oil Layer to Top of Manhole Rim

| | | | |
|---|---|---|---|
| A (ft) | | Trash/Debris Areal Coverage (%) | |
| B1 (ft) | | D (ft) | |
| B2 (ft) | | E (ft) | |
| B3 (ft) | | Oil Areal Coverage (%) | |
| C (ft) | | F (ft) | |

Observations of Device and Surrounding Drainage Area Characteristics (Routine Inspection or Inspection Immediately before Cleanout)

(Common for all types of devices)

| Traffic Density | Gross Solids - Litter | Gross Solids – Debris | Gross Solids – Coarse Sediment |
|---|---|---|---|
| (Low, Medium, Heavy) | (Small, Medium, Large) | (Small, Medium, Large) | (Small, Medium, Large) |

| Any Soil Erosion and Sediment Deposition in Watershed? | If Severe, Location(s) of Erosion and Deposition in Watershed |
|---|---|
| (Low, Moderate, Severe) | |

| Construction Activities in Watershed? | If Yes, Condition of Source Control Management Practices | If Poor, Location of Source Control Management Practices | If Poor, Describe Condition of Source Control Management Practices |
|---|---|---|---|
| (Yes / No) | (Good, Moderate, Poor) | | |

| Winter Sanding Operation? | Space Available for Cleanout Activities without Traffic Blockage? |
|---|---|
| (Yes / No) | (Yes / No) |

| Insects (Mosquitoes, Larvae, etc…) in HDS? | Vegetation Growth in HDS? | Any Blockage to Flow Path in HDS? | If Yes, Name Location of the Blockage |
|---|---|---|---|
| (Yes / No) | (Yes / No) | (Yes / No) | |

| Any Blockage in Inlet, Manhole, Catch Basin, or Pipe Upstream and Downstream of the Device? | Location of Blockage | Type of Solids in Inlet, Manhole, Catch Basin or Pipe |
|---|---|---|
| (Yes / No) | | (Gravel, Sand, Silt, Clay, Mud, Debris, Litter) |
| Dry Weather Flow in inlet pipe and outlet Pipe? | Backwater to outlet pipe from downstream? | Blockage at Outfall? |
| (Yes / No) | (Yes / No) | (Yes / No) |

| Outfall Structure | | | | | |
|---|---|---|---|---|---|
| Sediment discharged from HDS? | (Yes / No) | Trash/Debris discharged from HDS? | (Yes / No) | Oil Spill Out from HDS? | (Yes / No) |

Device Structural Inspection - Visual Observation from Ground above the Device (Routine Inspection or Inspection Immediately before Cleanout)

(Common for all types of devices)

| | | | |
|---|---|---|---|
| Damage to Manhole Cover(s) | (No, Minor, Serious) | Description of Damage | |
| Damage to Side Walls | (No, Minor, Serious) | Description of Damage | |
| Damage to Inlet Pipe | (No, Minor, Serious) | Description of Damage | |
| Damage to Outlet Pipe | (No, Minor, Serious) | Description of Damage | |

(Select a form below to fill based on type of the device)

Aqua-Swirl®

| | | | |
|---|---|---|---|
| Damage to Arched Baffle | (No, Minor, Serious) | Description of Damage | |

CDS®

| | | | |
|---|---|---|---|
| Damage to Deflection Pan, Separation Cylinder, Crest of Bypass Weir, Oil Baffle, Treatment Screen or Separation Slab | (No, Minor, Serious) | Description of Damage | |

Downstream Defender®

| | | | |
|---|---|---|---|
| Damage to Dip Plate, Floatables Lid, Center Shaft and Cone or Benching Skirt | (No, Minor, Serious) | Description of Damage | |

Stormceptor® STC

| | | | |
|---|---|---|---|
| Damage to Weir, Oil Port, Orifice, Insert, Drop Tee or Riser Pipe | (No, Minor, Serious) | Description of Damage | |

Terre Kleen®

| | | | |
|---|---|---|---|
| Damage to Hydrodynamic Separator or Baffle Wall | (No, Minor, Serious) | Description of Damage | |

Vortechs®

| | | | |
|---|---|---|---|
| Damage to Swirl Chamber Aluminum Wall, Baffle Wall, Flow Control Wall or Orifice Plates | (No, Minor, Serious) | Description of Damage | |

VortSentry®

| | | | |
|---|---|---|---|
| Damage to Inlet Aperture, Flow Partition, Treatment Chamber Baffle, Head Equalizing Baffle or Outlet Flow Control Orifice | (No, Minor, Serious) | Description of Damage | |

Photos Taken during Routine Inspection or Inspection Immediately before Cleanout (common for all types of devices)

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments from Routine Inspection or Inspection Immediately before Cleanout (common for all types of devices)

| |
|---|
| |

Device Structural Inspection – Visual Observation and Physical Testing from Inside of the Device (Inspection Immediately after Cleanout)

(Common for all types of devices)

| | | | |
|---|---|---|---|
| Damage to Side Walls, Ceiling or Bottom | (No, Minor, Serious) | Description of Damage | |
| Damage to Inlet Pipe | (No, Minor, Serious) | Description of Damage | |
| Damage to Outlet Pipe | (No, Minor, Serious) | Description of Damage | |

(Select a form below to fill based on type of the device)

Aqua-Swirl®

| | | | |
|---|---|---|---|
| Damage to Arched Baffle | (No, Minor, Serious) | Description of Damage | |

CDS®

| | | | |
|---|---|---|---|
| Damage to Deflection Pan, Separation Cylinder, Crest of Bypass Weir, Oil Baffle, Treatment Screen or Separation Slab | (No, Minor, Serious) | Description of Damage | |

Downstream Defender®

| | | | |
|---|---|---|---|
| Damage to Dip Plate, Floatables Lid, Center Shaft and Cone or Benching Skirt | (No, Minor, Serious) | Description of Damage | |

Stormceptor® STC

| | | | |
|---|---|---|---|
| Damage to Weir, Oil Port, Orifice, Insert, Drop Tee or Riser Pipe | (No, Minor, Serious) | Description of Damage | |

Terre Kleen®

| | | | |
|---|---|---|---|
| Damage to Hydrodynamic Separator or Baffle Wall | (No, Minor, Serious) | Description of Damage | |

Vortechs®

| | | | |
|---|---|---|---|
| Damage to Swirl Chamber Aluminum Wall, Baffle Wall, Flow Control Wall or Orifice Plates | (No, Minor, Serious) | Description of Damage | |

VortSentry®

| | | | |
|---|---|---|---|
| Damage to Inlet Aperture, Flow Partition, Treatment Chamber Baffle, Head Equalizing Baffle or Outlet Flow Control Orifice | (No, Minor, Serious) | Description of Damage | |

Photo Taken During Structural Inspection Immediately after Cleanout (Common for all types of devices)

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments from Structural Inspection Immediately after Cleanout (Common for all types of devices)

| |
|---|
| |

Calculation and Decision for Cleanout based on Measurements

| Water Depth (ft) | | Sediment Depth (ft) | |
|---|---|---|---|
| | | | |
| Device Cleanout Trigger: Sediment Depth (ft) | | Cleanout Necessary Based on the Measured Sediment Depth? | Yes or No |
| Device Cleanout Trigger: Trash/Debris Thickness (ft) | | Cleanout Necessary Based on the Measured Trash/Debris Thickness? | Yes or No |
| Device Cleanout Trigger: Trash/Debris Areal Coverage (%) | | Cleanout Necessary Based on the Measured Trash/Debris Areal Coverage? | Yes or No |
| Device Cleanout Trigger: Oil Thickness (ft) | | Cleanout Necessary Based on the Measured Oil Thickness? | Yes or No |
| Device Cleanout Trigger: Oil Areal Coverage (%) | | Cleanout Necessary Based on the Measured Oil Areal Coverage? | Yes or No |

**AUTO Functions:**

1. [Last Inspection Date]: From the Previous Inspection Record

2. [Projected Next Inspection Date] = [Last Inspection Date] + [Inspection Interval]

3. [Water Depth] and [Sediment Depth] are calculated automatically from measured [Distance from Water Surface to Top of Manhole Rim], [Distance from Sediment Surface to Top of Manhole Rim] and [Distance from Bottom to Top of Manhole Rim].

   [Water Depth] = (The Average [Distance from Sediment Surface to Top of Manhole Rim] of [Center], [In Between], and [Side]) – [Distance from Water Surface to Top of Manhole Rim]

   [Sediment Depth] = [Distance from Bottom to Top of Manhole Rim] – (The Average [Distance from Sediment Surface to Top of Manhole Rim] of [Center], [In Between], and [Side])

4. Cleanout Necessary Based on Sediment Depth?

   Yes, if [Sediment Depth] is equal or larger than [Device Cleanout Trigger: Sediment Depth], No otherwise.

5. [Trash/Debris Thickness] = [E (Distance from Bottom of Trash/Debris to Top of

Manhole Rim)] - [D (Distance from Trash/Debris Surface to Top of Manhole m)]

6. Cleanout Necessary Based on Trash/Debris Thickness?

   Yes, if [Trash/Debris Thickness] is equal or larger than [Device Cleanout Trigger: Trash/Debris Thickness], No otherwise.

7. Cleanout Necessary Based on Trash/Debris Areal Coverage?

   Yes, if [Trash/Debris Areal Coverage] is equal or larger than [Device Cleanout Trigger: Trash/Debris Areal Coverage], No otherwise.

8. [Oil Thickness] = [F (Distance from Bottom of Oil to Top of Manhole Rim)] - [A (Distance from Oil Surface to Top of Manhole Rim)]

9. Cleanout Necessary Based on Oil Thickness?

   Yes, if [Oil Thickness] is equal or larger than [Device Cleanout Trigger: Oil Thickness], No otherwise.

10. Cleanout Necessary Based on Oil Areal Coverage?

    Yes, if [Oil Areal Coverage] is equal or larger than [Device Cleanout Trigger: Oil Areal Coverage], No otherwise.

## Appendix C: Stormwater HDS maintenance form

### General Information (*common for all types of devices*)

| HDS ID | HDS_Inspection_Rec_ID | HDS_ Maintenance _Rec_ID | Weather | Air Temp. (oF) |
|---|---|---|---|---|
| (Link to Asset Data Form) | (Link to Inspection Data Form) | | ▼ | |

| Maintenance Date | Maintenance Time | | Purpose of Maintenance | Maintenance Company | Number of HDS Maintenance Persons | Inspector |
|---|---|---|---|---|---|---|
| MM-DD-YYYY | Start<br>HH:MM | End<br>HH:MM | ▼ | | | |

| Maintenance Cost | Last Maintenance Date | Maintenance Interval (months) | Projected Maintenance Date |
|---|---|---|---|
| | (Auto) | | (Auto) |

Info for Cleanout Planning (common for all types of devices)

| Need Blockage to Traffic? | Check Weather Forecast for Dry Day? |
|---|---|
| ▼ | ▼ |

| Estimated Volume of Sediment (cubic feet) | Estimated Volume of Water (cubic feet) | Estimated Volume of Trash/Debris (cubic feet) | Estimated Volume of Oil (cubic feet) | Vacuum Truck Storage Capacity (cubic feet) |
|---|---|---|---|---|
| (Auto) | (Auto) | (Auto) | (Auto) | |

| Any Other Device to be Cleaned out during the Same Trip? | | | | | ▼ | |
|---|---|---|---|---|---|---|
| (If Yes) Number of HDS for Cleanout | (If Two MTDs total ) | | (If Three MTDs total) | | (If Four MTDs total) | |
| | The 2nd HDS_ Maintenance _Rec_ID | Distance (miles) | The 3rd HDS_ Maintenance _Rec_ID | Distance (miles) | The 4th HDS_ Maintenance _Rec_ID | Distance (miles) |
| | | | | | | |

Sediment Disposal

| Name of Sediment Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|
| | | |

Water Disposal

| Possible to Dispose Water into the Downstream Drainage Network? | (If No) Name of Water Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|

| | | | |
|---|---|---|---|
| ▼ | | | |

Trash/Debris Disposal

| Need to Remove Trash/Debris before Cleanout? | (If Yes) Name of Trash/Debris Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Oil Disposal

| Need to Remove Oil before Cleanout? | (If Yes) Name of Oil Disposal Facility | Distance from HDS Location to Facility (miles) | Estimated Disposal Cost |
|---|---|---|---|
| ▼ | | | |

| Need to Clean out Sediment/Trash/Debris/Oil Adjacent to HDS? | ▼ | | | | |
|---|---|---|---|---|---|
| Inlet Pipe? | Outlet Pipe? | Inlet? | Manhole? | Catch Basin? | Outfall Structure? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

| Need to Block Inlet or Outlet Pipe by Pipe Plugs during Operation? | ▼ |
|---|---|

Records of Cleanout (common for all types of devices)

Sediment Disposal

| Name of Sediment Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|
| | | |

Water Disposal

| Was Water Disposed into the downstream Drainage Network? | (If No) Name of Water Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Trash/Debris Disposal

| Were Trash/Debris Removed before Cleanout? | (If Yes) Name of Trash/Debris Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|---|
| ▼ | | | |

Oil Disposal

| Was Oil Removed before Cleanout? | (If Yes) Name of Oil Disposal Facility | Distance from HDS Location to Facility (miles) | Disposal Cost |
|---|---|---|---|
| ▼ | | | |

| Was Traffic Blocked? | ▼ | Was Inlet or Outlet Pipe Blocked by Pipe Plugs during Operation? | ▼ |
|---|---|---|---|
| Is Further Cleaning of HDS by Water Jet Necessary? | ▼ | (If Yes) Was HDS Further Cleaned Using Water Jet? | ▼ |

| Was Sediment/Trash/Debris/Oil Adjacent to HDS Cleaned out? | ▼ |
|---|---|

| Inlet Pipe? | Outlet Pipe? | Inlet? | Manhole? | Catch Basin? | Outfall Structure? |
|---|---|---|---|---|---|
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Photos Taken Immediately after Cleanout (common for all types of devices)

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

Additional Comments on Cleanout (common for all types of devices)

| |
|---|
| |

(Select a form below to fill based on type of the device)

Records of Repair: Aqua-Swirl®

| Were Any Components Repaired? | | | ▼ | | | |
|---|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Arched Baffle? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Records of Repair: CDS®

| Were Any Components Repaired? | | | ▼ | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Deflection Pan? | Separation Cylinder? | Crest of Bypass Weir? | Oil Baffle? | Treatment Screen? | Separation Slab? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Records of Repair: Downstream Defender®

| Were Any Components Repaired? | | | ▼ | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Floatables Lid? | Dip Plate? | Benching Skirt? | Center Shaft and | | |

| | | | |
|---|---|---|---|
| | | | Core? |
| ▼ | ▼ | ▼ | ▼ |

Records of Repair: Stormceptor® STC

| Were Any Components Repaired? | | | ▼ | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Weir? | Oil Port? | Orifice? | Insert? | Drop Tee? | Riser Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Records of Repair: Terre Kleen®

| Were Any Components Repaired? | | | | ▼ | | | |
|---|---|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Hydrodynamic Separator? | Baffle Wall? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Records of Repair: Vortechs®

| Were Any Components Repaired? | | | ▼ | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | C ili g? | Bottom? | | |
| ▼ | ▼ | ▼ | ▼ | | |
| Swirl Chamber Aluminum Wall? | Baffle Wall? | Flow Control Wall? | Orifice Plates? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |

Records of Repair: VortSentry®

| Were Any Components Repaired? | | | ▼ | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Inlet Aperture? | Flow Partition? | Treatment Chamber Baffle? | Head Equalizing Baffle? | Outlet Flow Control Orifice? | |
| ▼ | ▼ | ▼ | ▼ | ▼ | |

Photos Taken Immediately after Repair (common for all types of devices)

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

| | | |
|---|---|---|
| | | |

Additional Comments on Repair (common for all types of devices)

| |
|---|
| |

(Select a form below to fill based on type of the device)

Records of Replacement: Aqua-Swirl®

| Were Any Components Replaced? | ▼ | | | | | |
|---|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling | Bottom? | Arched Baffle? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Was Entire Device Replaced? | ▼ | | | | | |

Records of Replacement: CDS®

| Were Any Components Replaced? | ▼ | | | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Deflection Pan? | Separation Cylinder? | Crest of Bypass Weir? | Oil Baffle? | Treatment Screen? | Separation Slab? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Was Entire Device Replaced? | ▼ | | | | |

Records of Replacement: Downstream Defender®

| Were Any Components Replaced? | ▼ | | | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls | Ce ling? | Bottom? | nlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Floatables Lid? | Dip Plate? | Benching Skirt? | Center Shaft and Core? | | |
| ▼ | ▼ | ▼ | ▼ | | |
| Was Entire Device Replaced? | ▼ | | | | |

Records of Replacement: Stormceptor® STC

| Were Any Components Replaced? | ▼ | | | | |
|---|---|---|---|---|---|
| Manhole Cover s ? | Side Walls? | C iling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Weir? | Oil Port? | Orifice? | Insert? | Drop Tee? | Riser Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Was Entire Device Replaced? | ▼ | | | | |

Records of Replacement: Terre Kleen®

| Were Any Components Replaced? | ▼ | | | | | | |
|---|---|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling? | Bottom? | Hydrodynamic Separator? | Baffle Wall? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Was Entire Device Replaced? | ▼ | | | | | | |

Records of Replacement: Vortechs®

| Were Any Components Replaced? | ▼ | | | | |
|---|---|---|---|---|---|
| Manhole Cover(s)? | Side Walls? | Ceiling ? | Bottom? | | |
| ▼ | ▼ | ▼ | ▼ | | |
| Swirl Chamber Aluminum Wall? | Baffle Wall? | Flow Control Wall? | Orifice Plates? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Was Entire Device Replaced? | ▼ | | | | |

Records of Replacement: VortSentry®

| Were Any Components Replaced? | ▼ | | | | |
|---|---|---|---|---|---|
| Manhole Cover(s ? | Side Walls? | Ceiling? | Bottom? | Inlet Pipe? | Outlet Pipe? |
| ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
| Inlet Aperture? | Flow Partition? | Treatment Chamber Baffle? | Head Equalizing Baffle? | Outlet Flow Control Orifice? | |
| ▼ | ▼ | ▼ | ▼ | ▼ | |
| Was Entire Device Replaced? | ▼ | | | | |

Photos Taken Immediately after Replacement (common for all types of devices)

| Photo 1 | Photo 2 | Photo 3 |
|---|---|---|
| | | |

| | | |
|---|---|---|
| | | |

Additional Comments on Replacement (common for all types of devices)

| |
|---|
| |

**Notes:**

HDS_ Maintenance _Rec_ID: Unique Maintenance id to indentify each maintenance record related to the same HDS ID

**Drop-down Menu Contents:**

General Information

Weather: Sunny, Windy, Cloudy, Rainy, Stormy, Blizzard

Purpose of Maintenance ▼ : Cleanout, Repair, Replacement

Need Blockage to Traffic? ▼ : Yes, No

Check Weather Forecast for Dry Day? ▼ :Yes, No

Any Other Device to be Cleaned out during the Same Trip? ▼ : Yes, No

Info for Cleanout Planning

Possible to Dispose Water into the Downstream Drainage Network? ▼ :Yes, No

Need to Remove Oil before Cleanout? ▼ :Yes, No

Need to Remove Trash/Debris before Cleanout? ▼ :Yes, No

Need to Clean out Sediment/Trash/Debris/Oil Adjacent to HDS? ▼ :Yes, No

Inlet Pipe? ▼ :Yes, No

Outlet Pipe? ▼ :Yes, No

Inlet? ▼ :Yes, No

Manhole? ▼ :Yes, No

Catch Basin? ▼ :Yes, No

Outfall Structure? ▼ :Yes, No

Need Blockage to Inlet or Outlet pipe by Pipe Plugs during Operation?▼ :Yes, No

Records after Cleanout

Was water disposed into the downstream drainage network? ▼ :Yes, No

Was Oil Removed before Cleanout? ▼ :Yes, No

Were Trash/Debris Removed before Cleanout? ▼ :Yes, No

Was Sediment/Trash/Debris/Oil Adjacent to HDS Cleaned out? ▼ :Yes, No

Inlet Pipe? ▼ :Yes, No

Outlet Pipe? ▼ :Yes, No

Inlet? ▼ :Yes, No

Manhole? ▼ :Yes, No

Catch Basin? ▼ :Yes, No

Outfall Structure? ▼ :Yes, No

Was Traffic Blocked? ▼ :Yes, No

Was Inlet or Outlet Pipe Blocked by Pipe Plugs during Operation? ▼ :Yes, No

Is Further Cleaning of HDS by Water Jet Necessary? ▼ : Yes, No

(If Yes) Was HDS Further Cleaned Using Water Jet? ▼ : Yes, No

**(*Select drop-down menus below based on type of the device*)**

Records after Repair: Aqua-Swirl®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Arched Baffle?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Records after Replacement: Aqua-Swirl®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Arched Baffle?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: CDS®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Deflection Pan? ▼ : Yes, No

Separation Cylinder? ▼ : Yes, No

Crest of Bypass Weir? ▼ : Yes, No

Oil Baffle? ▼ : Yes, No

Treatment Screen? ▼ : Yes, No

Separation Slab? ▼ : Yes, No

Records after Replacement: CDS®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Deflection Pan? ▼ : Yes, No

Separation Cylinder? ▼ : Yes, No

Crest of Bypass Weir? ▼ : Yes, No

Oil Baffle? ▼ : Yes, No

Treatment Screen? ▼ : Yes, No

Separation Slab? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: Downstream Defender®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Floatables Lid? ▼ : Yes, No

Dip Plate? ▼ : Yes, No

Benching Skirt? ▼ : Yes, No

Center Shaft and Core? ▼ : Yes, No

Records after Replacement: Downstream Defender®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Floatables Lid? ▼ : Yes, No

Dip Plate? ▼ : Yes, No

Benching Skirt? ▼ : Yes, No

Center Shaft and Core? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: Stormceptor® STC

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Weir? ▼ : Yes, No

Oil Port? ▼ : Yes, No

Orifice? ▼ : Yes, No

Insert? ▼ : Yes, No

Drop Tee? ▼ : Yes, No

Riser Pipe? ▼ : Yes, No

Records after Replacement: Stormceptor® STC

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Weir? ▼ : Yes, No

Oil Port? ▼ : Yes, No

Orifice? ▼ : Yes, No

Insert? ▼ : Yes, No

Drop Tee? ▼ : Yes, No

Riser Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: Terre Kleen®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Hydrodynamic Separator?▼ : Yes, No

Baffle Wall?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Records after Replacement: Terre Kleen®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Hydrodynamic Separator?▼ : Yes, No

Baffle Wall?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: Vortechs®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ▼ : Yes, No

Bottom? ▼ : Yes, No

Swirl Chamber Aluminum Wall? ▼ : Yes, No

Baffle Wall? ▼ : Yes, No

Flow Control Wall? ?▼ : Yes, No

Orifice Plates? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Records after Replacement: Vortechs®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ▼ : Yes, No

Bottom? ▼ : Yes, No

Swirl Chamber Aluminum Wall? ▼ : Yes, No

Baffle Wall? ?▼ : Yes, No

Flow Control Wall? ▼ : Yes, No

Orifice Plates? ▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

Records after Repair: VortSentry®

Were Any Components Repaired? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Aperture?▼ : Yes, No

Flow Partition?▼ : Yes, No

Treatment Chamber Baffle?▼ : Yes, No

Head Equalizing Baffle?▼ : Yes, No

Outlet Flow Control Orifice?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Records after Replacement: VortSentry®

Were Any Components Replaced? ▼ : Yes, No

Manhole Cover(s)?▼ : Yes, No

Side Walls?▼ : Yes, No

Ceiling? ?▼ : Yes, No

Bottom? ▼ : Yes, No

Inlet Aperture?▼ : Yes, No

Flow Partition?▼ : Yes, No

Treatment Chamber Baffle?▼ : Yes, No

Head Equalizing Baffle?▼ : Yes, No

Outlet Flow Control Orifice?▼ : Yes, No

Inlet Pipe? ▼ : Yes, No

Outlet Pipe? ▼ : Yes, No

Was Entire Device Replaced? ▼ : Yes, No

**Auto Functions**

Last Maintenance Date: Import [Maintenance Date] data from previous record.

Projected Maintenance Date: [Maintenance Date] + [Maintenance Interval]

'Water Volume', 'Sediment Volume', 'Trash/Debris Volume', and 'Oil Volume' are estimated/calculated automatically based on the measured quantities from the "Inspection Form."

***(Select functions below to calculate based on type of the device)***

Aqua-Swirl®, CDS®, Downstream Defender®, Stormceptor® STC and VortSentry®

[Estimated Water Volume] = [Water Depth] (from Inspection Form) X [(Swirl) Chamber Area (from Asset Data Form)]

[Estimated Sediment Volume] = [Sediment Depth (from Inspection Form)] X [(Swirl) Chamber Area (from Asset Data Form)]

[Estimated Trash/Debris Volume] = [Trash/Debris Thickness (from Inspection Form)] X [(Swirl) Chamber Area (from Asset Data Form)]

[Estimated Oil Volume] = [Oil Thickness] X [(Swirl) Chamber Area (from Asset Data Form)]

Terre Kleen®

[Estimated Water Volume] = [Water Depth] (from Inspection Form) X [Device Footprint Area (from Asset Data Form)]

[Estimated Sediment Volume] = [Sediment Depth in Primary Chamber (from Inspection Form)] X [Primary Chamber Area (from Asset Data Form)] + [Sediment Depth in Grit Chamber (from Inspection Form)] X [Grit Chamber Area (from Asset Data Form)]

[Estimated Trash/Debris Volume] = [Trash/Debris Thickness in Primary Chamber (from Inspection Form)] X [Primary Chamber Area (from Asset Data Form)] +

[Trash/Debris Thickness in Grit Chamber (from Inspection Form)] X [Grit Chamber Area (from Asset Data Form)]

[Estimated Oil Volume] = [Oil Thickness in Primary Chamber (from Inspection Form)] X [Primary Chamber Area (from Asset Data Form)] + [Oil Thickness in Grit Chamber (from Inspection Form)] X [Grit Chamber Area (from Asset Data Form)]

Vortechs®

[Estimated Water Volume] = [Water Depth] (from Inspection Form) X [Device Footprint Area (from Asset Data Form)]

The water volume above maybe over-estimated since water in the baffle chamber, the flow control chamber, and the outlet chamber, if judged to be clean, does not need to be pumped out.

[Estimated Sediment Volume] = [Sediment Depth (in Swirl Chamber) (from Inspection Form)] X [Swirl Chamber Area (from Asset Data Form)]

If there is sediment in Baffle Chamber, add [Sediment Volume in Baffle Chamber], where

[Sediment Volume in Baffle Chamber] = [Sediment Depth in Baffle Chamber (from Inspection Form)] X [Device Width (from Asset Data

Form)] X [2.58 (use 3.00 if ‘Model’ is 16000 or larger (from Asset Data Form)]

If there is sediment in Outlet Chamber, add [Sediment Volume of Outlet Chamber], where

[Sediment Volume in Outlet Chamber] = [Sediment Depth in Outlet Chamber] X [Device Width (from Asset Data Form)] X [2.00]

[Estimated Trash/Debris Volume] = [Average Trash/Debris Thickness in Swirl Chamber and Baffle Chamber (from Inspection Form)] X [Device Width (from Asset Data Form)] X [Device Length (from Asset Data Form) – 3.50]

If there are Trash/Debris in Outlet Chamber, add [Trash/Debris Volume in Outlet Chamber], where

[Trash/Debris Volume in Outlet Chamber] = [Trash/Debris Thickness in Outlet Chamber] X [Device Width (from Asset Data Form)] X [2.00]

[Estimated Oil Volume] = [Average Oil Thickness in Swirl Chamber and Baffle Chamber (from Inspection Form)] X [Device Width (ft) (from Asset Data Form)] X [Device Length (from Asset Data Form) – 3.50]

If there is Oil in Outlet chamber, add [Oil Volume in Outlet Chamber], where

| |
|---|
| [Oil Volume in Outlet Chamber] = [Oil Thickness in Outlet Chamber (from Inspection Form)] X [Device Width (from Asset Data Form)] X [2.00] |

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# Acknowledgment for Previous Publications

The studies presented in Chapters 3 have appeared in the following:

Guo, Q. and Kim, J. (2011). Information for Inspection and Maintenance of Stormwater Manufactured Treatment Devices. World Environmental and Water Resources Congress 2011: Bearing Knowledge for Sustainability. R. Edward Beighley, Mark W. Killgore. ASCE Publications, 2011

The studies presented in Chapters 4 – 6 have appeared in the following:

Guo, Q. and Kim, J. (2010). Stormwater System Monitoring and Evaluation. Research Report, FHWA-NJ-2009-012, Prepared for New Jersey Department of Transportation, Bureau of Research, Trenton, New Jersey.

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