Appendix I. Sand Filter Study End-of-Year Report, 2008

DELDOT AGREEMENT 1351

ENVIRONMENTAL WATER QUALITY MONITORING

DELAWARE SAND FILTER STUDY
2008 REPORT

As part of the Delaware Department of Transportation's National Pollutant Discharge Elimination System permit, KCI Technologies, Inc. was contracted to evaluate the functionality of the stormwater management (SWM) device known as the Delaware Sand Filter (DSF). This is the third year of the study: Year 1 (2006) focused on selecting four DSFs to be studied, Year 2 (2007) focused on developing a study approach, cleaning/maintaining the DSFs, and beginning dry and wet weather observations. Year 3 (2008) focused on continuing the dry and wet weather observations, collecting sand samples for laboratory analysis, and critiquing the current study methodologies. KCI prepared Annual Reports for each of these years of study.

The *2006 DSF Study Annual Report* summarized the process of identifying DSFs (listed below) to be included in the study. These DSFs were determined to be representative of a variety of typical land use settings (commercial, roadway, and parking lot) and different sand chamber designs. A fourth DSF, located at the Chapman Maintenance Yard, was added to the study in the Summer 2008, when it was constructed as part of a BMP treatment train for a truck wash area.

- Lancaster Pike DSF (DelDOT BMP 72)
  - Treats Roadway Runoff
  - Uses Stone/Sand/Geotextile Sand Chamber Design
- Route 273 / Route 7 DSF (DelDOT BMP 46)
  - Treats Park and Ride Parking Lot Runoff
  - Uses Stone/Sand/Geotextile Sand Chamber Design
- Wilmington Delaware Transit Corporation (DTC) Bus Facility DSF
  - Treats Commercial Vehicle Parking Lot Runoff
  - Uses Sand/Geotextile/Stone Sand Chamber Design
- Chapman Maintenance Yard DSF – Stormceptor/DSF Treatment Train
  - Treats Truck Wash Wastewater at DelDOT Maintenance Yard
  - Uses Unique Sand Chamber Design (see description on page 3)

The *2007 DSF Study Annual Report* summarized the following:

- Initial Full Maintenance/Cleaning of the DSFs by DelDOT and DTC
- Methodology for Dry and Wet Weather Field Observations to Assess DSF Performance
- Results of the Year 2007 Dry and Wet Weather Field Observations
- Results of the 02/23/07 Lancaster Pike DSF Sand Analysis
- Initial DSF Maintenance Recommendations.

In 2008, DSF study activities centered on continuing dry and wet weather field observations, conducting two Sand Analyses at the Wilmington DTC DSF, critiquing the current study methodologies, and identifying initial maintenance recommendations. **Table 1** summarizes the DSF Study Field Activities for Year 2008.

TABLE 1
YEAR 2008 DSF FIELD ACTIVITIES

Field Activity	Delaware Sand Filter			
	Chapman MY	Lancaster Pike	Route 273/7 Park-Ride	Wilmington DTC DSF
Dry Weather Observation				
02-06-08		✓	✓	✓
04-16-08			✓	✓
05-21-08		✓	✓	✓
06-10-08		✓	✓	✓
07-22-08	✓	✓	✓	✓
08-25-08	✓	✓	✓	✓
10-09-08	✓	✓	✓	✓
11-11-08	✓	✓	✓	✓
12-30-08	✓	✓	✓	✓
Wet Weather Observation				
02-13-08		✓	✓	✓
04-29-08		✓	✓	✓
07-24-08	✓	✓	✓	✓
09-10-08	✓	✓	✓	✓
11-05-08		✓	✓	✓
12-11-08		✓	✓	✓
Sand Analysis				
05-05-08				✓
09-17-08				✓

A. 2008 DSF OBSERVATIONS AND RECOMMENDATIONS

The methodology for conducting the dry and wet weather field observations is described in detail in the *2007 DSF Study Annual Report*. In 2008, KCI performed more frequent observations than the four seasonal observations in 2007. The goal of this evaluation was to develop an observation protocol to assess DSF performance, which will aid in defining the maintenance requirements to restore DSF performance, and to identify long-term maintenance costs.

KCI performed dry weather field observations in February, April, May, June, July, August, September, November and December 2008. Wet weather field observations were conducted in February, April, July, September, November and December 2008. The results of the dry and wet weather field observations and associated recommended actions for each DSF are discussed below and summarized in Tables included in **Appendix 1**.

1. Chapman Maintenance Yard DSF

The DSF at the Chapman Maintenance Yard is connected downstream of the Stormceptor unit, providing treatment of wastewater (in contrast to stormwater for other DSFs) for DelDOT's truck wash pad after it is treated by the Stormceptor. The sand chamber design is unique. It consists of sand at the top and #57 stone at the bottom, with geotextile separating the sand and stone. In addition, the outflow is through two pipes rather than one single perforated pipe. The Stormceptor/DSF unit was monitored during truck wash operations in August and October 2008, the results of which are summarized in the *2008 Maintenance Yard Monitoring Annual Report*.

Observations

After several months of field observations, it became obvious that the use of this DSF as a secondary treatment of sediment-laden truck wash water was not appropriate. KCI staff observing this site and other DSFs in the State have determined that DSFs treating land uses with fine suspended solids have failed in less than one year, as these fine particles clog the sand by completely coating the DSF surface. .

Currently, the DelDOT NPDES group and the DelDOT North District maintenance staff are working to resolve the issue at the Chapman Maintenance Yard DSF. KCI and DelDOT concur that the use of a DSF to treat truck wash water will not be considered in the future.

Recommendations

Action 1 – To Be Performed by DelDOT:

Resolve the current DSF design issue with regard to long-term use of the truck wash treatment system at the Chapman Yard.

Action 2 – To Be Performed by KCI:

Suspend dry and wet weather observation of this DSF as part of the ongoing DSF study. KCI will monitor the Stormceptor/DSF treatment train solely as part of the Truck Wash Study (see *2008 Maintenance Yard Monitoring Annual Report*).

Action 3 – To Be Performed by KCI:

Select an additional DSF for ongoing study, preferably in a residential setting. Adding a residential DSF to the other three DSFs, which are located in highway, commercial, and park and ride land uses, would encompass the majority of land uses available.

2. Lancaster Pike DSF (No. 72)

This DSF consists of a series of separate DSFs treating roadway runoff along Lancaster Pike, only one of which, BMP 72, is being studied in detail. Lancaster Pike has multiple vertical curves, and is predominantly surrounded by residential land use. The sand chamber design consists of two inches of #57 stone placed on top of 18 inches of sand, with a single perforated effluent pipe wrapped with geotextile fabric.

The overall DSF is comprised of multiple pre-cast cells that are not linked with over-flow openings. The outflow point of the Lancaster Pike DSF is not specifically known, but is believed to be located in the catch basin on the west side of the sand filter. This assumption is based on observations made during the dry weather inspections.

Currently, KCI is observing only one chamber at BMP 72. This methodology may not represent the DSF as a whole, considering the multitude of chambers contained in this DSF. For example, the north end of BMP 72 is loaded with leaf litter and organic debris. However, at the far end of BMP 72 there is very little accumulation of organic debris and leaf litter.

Observations

Based on dry and wet weather field observations **(Appendix 1)**, this DSF is functioning properly. Over the past two years, KCI has observed a build-up of leaf litter and organic debris in the sand chamber during the Fall and Winter seasons. This is due to the large amount of deciduous vegetation in the surrounding residential area, which deposits leaf litter and organic debris into the roadway and ultimately ends up in the sand chamber of the DSF. Wet weather observations indicate that infiltration rates have not been severely affected by this accumulation, however, it is suspected that the organic matter will eventually clog the sand chamber.

Recommendations

Action 1 – To Be Performed by DelDOT:

Clean out accumulated leaf litter and organic material after the Fall season from the stone in the sand chamber.

Action 2 – To Be Performed by KCI:

Inspect every other chamber at BMP 72 to perform a thorough inspection.

Action 3 – To Be Performed by KCI:

Determine the outflow point of the DSF.

3. Route 273/7 Park and Ride DSF (No. 46)

This DSF consists of a long, single set of sedimentation and sand chambers. The sand chamber design consists of two inches of #57 stone placed on top of 18 inches of sand, with a single perforated effluent pipe wrapped with geotextile fabric. The drainage area consists of a large relatively flat paved parking area used as a park and ride bus stop. Cars and trucks are routinely parked in the area. There is also a public recycling center within the park and ride lot.

Observations

KCI field crews have observed a black hydrocarbon residue accumulating on the gravel in the sand chamber. However, it does not appear to diminish the sand filter performance. There were no other potential maintenance issues identified by field crews during the dry and wet weather field observations **(Appendix 1)**.

Recommendations

Action 1 – To Be Performed by KCI:

Record a turbidity reading of the outflow during wet weather observation to help determine the functionality of this DSF, which will aid in developing a maintenance schedule.

Action 2 – To Be Performed by KCI:

Determine retention time by observing an entire rain event to track the time for the start of rainfall to that when treated water flows out at the outfall. This will provide a baseline for treatment performance, which will aid in developing a maintenance schedule based on increased initial flow times.

4. Wilmington DTC Bus Facility DSF

This site consists of a series of chambers tied together with overflow openings. The surrounding area is commercial land use, which is entirely paved and sloped. The DTC parking facility is used for parking mass transit buses, and appears to have daily bus traffic. The sand chamber design consists of 12 inches of sand over six inches of #57 stone, with geotextile between the sand and stone. The perforated outflow pipe lies in the stone layer.

Observations

During dry and wet weather observations **(Appendix 1)**, KCI observed black residue that contains oily waste accumulating on the top layer of the sand. This black residue clogs the top of the sand, which impedes the flow of water through the sand media. In April 2008, KCI observed standing water in the sand chamber. Prior to a full maintenance of the DSF, KCI recommended performing a Sand Analysis to determine if replacing just the top layer of sand would be a cost-effective option, as opposed to a full maintenance.

The intent of the Sand Analysis was to determine the magnitude of pollutant loadings at four (4) vertical locations within the sand of this DSF, approximately one year after full maintenance was performed. Two stratified samples were collected from each of the following four layers of sand:

- (1) First sample = 1 inch depth
- (2) Second sample = 4 inch depth
- (3) Third sample = 8 inch depth
- (4) Fourth sample = 12 inch depth

One of the stratified samples was collected for chemical analysis and the second stratified sample was collected for particle size analysis. Upon completion of field observations and sample collection, the samples were delivered to Atlantic Coast Laboratory for chemical analysis and forwarded to American Geotech for particle size/moisture content analysis. The chemical analysis and particle size/moisture content analysis results are located in **Appendix 2**.

As evident by the analysis results **(Appendix 2)**, removing and replacing the top layer of sand was not recommended. It was recommended that the chemical analysis of the sand be repeated in September 2008 (3 months after the July 2008 full maintenance), to determine if removing and replacing the top layer of sand would be an appropriate maintenance measure at 3 month intervals. Because the May 5, 2008 samples were primarily comprised of sand, particle size was not analyzed for the September 2008 analysis

The Wilmington DTC DSF was fully maintained in early July 2008. A chemical analysis of the sand was repeated on September 17, 2008 (3 months after the July 2008 full maintenance), to determine if removing and replacing the top layer of sand would be an appropriate maintenance measure at 3-month intervals. One stratified sample was collected from four layers of sand and delivered to Atlantic Coast Laboratory for Chemical analysis: The chemical analysis results are located in **Appendix 2**.

Overall, there was variability in the parameter concentrations for the May 2008 versus the September 2008 analyses **(Appendix 2)**. Some "trends" were observed, as follows.

- Oil and Grease concentrations recorded in September were higher in all four layers than those in May.
- TPH, Soil concentrations were lower in September versus the May sample.
- TPH, DRO concentrations were lower in September (1" and 4" layers) versus the May sample.
- All Metals (ICP) concentration levels were higher in September than in May 2008.

After reviewing the results of the chemical analysis on the September 17, 2008 sand sample from the Wilmington DTC DSF, it was found that removing the top layer of sand as a cost effective maintenance strategy would not be appropriate. All four sample layers showed significant levels of oil and grease, with the top and bottom layers showing the highest concentration of 2300 mg/kg. There is also concern that if only the top layer of sand is removed, the pollutant concentration levels may be significant enough for them to be considered for hazardous waste disposal. If this is the case, the contaminated sand may need testing prior to disposal, which may be costly.

Recommendations

Action 1 – To Be Performed by KCI:

To obtain more valuable data related to potential maintenance at the Wilmington DSF, KCI will begin performing automated sampling during rain events in 2009. The automated sampler will be programmed to collect a first flush sample and nine composite samples every 20 minutes after first flush. First flush will be collected by pre-determined programmed parameters. The samples will then be collected and delivered to Atlantic Coast Laboratory for further analysis of the pollution parameters.

Action 2 – To Be Performed by KCI:

Conduct another Sand Analysis in February 2009 to provide a third sample that potentially provides a more conclusive statistical analysis.

Action 3 – To Be Performed by DelDOT:

Add a two-inch top layer of #57 stone to the existing sand chamber design (sand/geotextile/stone) during the next scheduled maintenance by DTC. This would enable KCI to evaluate a "third" design (stone/sand/geotextile/stone) for the sand chamber. Observations at the Lancaster Pike and Route 273/7 DSFs indicate that the stone on top design (stone/sand/geotextile wrapped outflow pipe) works well to prevent clogging of the sand, and observations of the Wilmington DTC DSF sand chamber design (sand/geotextile/stone) indicate that the geotextile layer beneath the sand may be acting as a pollutant barrier. To provide a proper statistical analysis, KCI recommends altering the sand chamber design on an every other year basis, so that the two designs can be evaluated over a long period of time.

B. NEXT STEPS

Chapman Maintenance Yard DSF

The Chapman Maintenance Yard DSF is repeatedly failing and is not an appropriate BMP for treating sediment-laden truck wash water. DelDOT is currently developing a solution to the current design which allows the truck wash to be functional. KCI will continue to offer input and observation of this DSF as part of the Truck Wash Study. KCI recommends suspending observations at the Chapman Maintenance Yard DSF as part of this DSF study. In 2009, KCI will consider adding another DSF to this study, preferably a DSF in a residential setting that is different than the Lancaster Pike setting.

Lancaster Pike DSF

KCI recommends that DelDOT begin an annual maintenance of this DSF after the Fall season. The maintenance should only involve removing the accumulated organic material on top of the stone in the sand chamber. Removing this debris and litter will more than likely prolong the life of the DSF and delay a full rehabilitation of the system. Also, KCI will observe several chambers of the Lancaster Pike DSF to provide a more representative analysis of the functionality of the filter at this location. Lastly, KCI will attempt to determine the exact outflow point of this DSF, which will enable observation of the BMP outflow.

Route 273/7 Park & Ride

KCI has not observed any major performance issues concerning this DSF. For future observations, KCI will record turbidity readings at inflow and outflow points, and attempt to determine retention times at this DSF, which will aid in determining an appropriate maintenance schedule.

Wilmington DTC DSF:

KCI will collect another sand sample for analysis in early 2009. In addition, KCI recommends altering the sand chamber design every other year at this DSF, allowing a comparison of a new design (stone/sand/geotextile/stone) with the current design (sand/geotextile/stone). Based on observations in 2007 and 2008 at the Lancaster Pike and Route 273/7 DSFs, KCI has observed the benefits of having a stone layer on top of the sand to reduce clogging of the sand. Results of the Sand Analysis at the Wilmington DTC DSF have shown that pollutants are concentrating at the bottom of the sand (above the geotextile), indicating that the geotextile beneath the sand may be providing a barrier. KCI believes a long-term study of both designs at the same DSF will allow quantitive conclusions to be reached.

DELAWARE SAND FILTER STUDY

2008 REPORT

APPENDIX 1

DRY AND WET WEATHER FIELD OBSERVATIONS

Chapman Maintenance Yard

Lancaster Pike

Route 273/7 Park & Ride

Wilmington DTC

CHAPMAN MAINTENANCE YARD DELAWARE SAND FILTER

DRY WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	DRY WEATHER OBSERVATION								
	02/06/08	04/16/08	05/21/08	06/10/08	07/22/08	08/25/08	10/09/08	11/11/08	12/30/08
Previous Precipitation	02/01/08	04/06/08	05/20/08	06/04/08	07/20/08	08/14/08	10/01/08	11/05/08	12/19/08
SEDIMENTATION CHAMBER									
Oil or Grease Present	--	--	--	--	N	N	N	--	N
Water Present	--	--	--	--	Y	Y	Y	--	Y
Water Depth (ft)	--	--	--	--	1.5	1.5	1.5	--	1.5
Sediment Depth (ft)	--	--	--	--	<0.1	<0.1	<0.1	--	<0.1
SAND CHAMBER									
Oil or Grease Present	--	--	--	--	N	N	N	--	N
Water Present	--	--	--	--	N	N	N	--	N
Clogging Evidence	--	--	--	--	Y	Y	Y	--	N
Gravel Depth (ft)	--	--	--	--	0.55	0.60	0.55	--	Unknown
Sand Depth (ft)	--	--	--	--	Varies	Varies	Varies	--	N/A
Discoloration Depth (ft)	--	--	--	--	<0.1	<0.1	<0.1	--	N/A
Debris Depth (ft)	--	--	--	--	0.0	0.0	0.0	--	0.0

September 2008 DSF Rehabbed

FIELD NOTES:

02/06/08 through 06/10/08: DSF not constructed

10/09/08: Sand is eroding away; in some areas sand is completely gone and rock is showing

11/11/08: DSF clogged - no inspection; see 11/07/08 Stormceptor-DSF Corrective Action Memorandum

12/30/08: Sand and gravel replaced with fist-sized stone

CHAPMAN MAINTENANCE YARD DELAWARE SAND FILTER

WET WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	WET WEATHER OBSERVATION					
	02/13/08	04/29/08	07/24/08	09/10/08	11/05/08	12/11/08
Precipitation Past 24 Hours (in)	2.72	0.72	0.27	0.14	0.10	0.52
SEDIMENTATION CHAMBER						
Oil or Grease Present	--	--	N	N	--	--
Water Present	--	--	Y	Y	--	--
Water Depth (ft)	--	--	1.5	1.5	--	--
SAND CHAMBER						
Oil or Grease Present	--	--	N	N	--	--
Water Present	--	--	N	N	--	--
Clogging Evidence	--	--	Y	Y	--	--
Infiltration Rate (hrs)	--	--	<12	<12	--	--

September 2008 DSF Rehabbed

FIELD NOTES:

02/13/08 and 04/29/08: DSF not constructed

09/10/08: Water channeling through sand

11/05/08 and 12/11/08: DSF clogged - no inspection; see 11/07/08 Stormceptor-DSF Corrective Action Memorandum

LANCASTER PIKE DELAWARE SAND FILTER

DRY WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	DRY WEATHER OBSERVATION								
	02/06/08	04/16/08	05/21/08	06/10/08	07/22/08	08/25/08	10/09/08	11/11/08	12/30/08
Previous Precipitation	02/01/08	04/06/08	05/20/08	06/04/08	07/20/08	08/14/08	10/01/08	11/05/08	12/19/08
SEDIMENTATION CHAMBER									
Oil or Grease Present	Y	--	Y	Y	Y	Y	Y	Y	Y
Water Present	Y	--	Y	Y	Y	Y	Y	Y	Y
Water Depth (ft)	1.7	--	1.7	1.7	1.7	1.75	2.1	2.1	1.5
Sediment Depth (ft)	0.2	--	0.2	0.2	<0.1	0.11	0.15	<0.1	0.15
SAND CHAMBER									
Oil or Grease Present	Y	--	Y	N	Y	N	Y	Y	Y
Water Present	N	--	N	N	N	N	N	N	N
Clogging Evidence	N	--	N	N	N	N	N	N	N
Gravel Depth (ft)	NA	--	0.2	0.5	0.5	0.5	0.4	0.4	0.4
Sand Depth (ft)	NA	--	0.9	1.2	1.0	1.0	1.4	1.4	1.4
Discoloration Depth (ft)	NA	--	<0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1
Debris Depth (ft)	0.2	--	0.15	0.1	0.1	0.1	0.15	0.1	0.15

May 2007 DSF Rehabbed

FIELD NOTES:

02/06/08: No sand or gravel in chamber

08/25/08: Oil sheen on top of water in sedimentation chamber

LANCASTER PIKE DELAWARE SAND FILTER

WET WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	WET WEATHER OBSERVATION					
	02/13/08	04/29/08	07/24/08	09/10/08	11/05/08	12/11/08
Precipitation Past 24 Hours (in)	**2.01**	**0.87**	**0.46**	**1.07**	**0.09**	**0.65**
SEDIMENTATION CHAMBER						
Oil or Grease Present	Y	Y	Y	Y	Y	Y
Water Present	Y	Y	Y	Y	Y	Y
Water Depth (ft)	2.0	1.5	2.0	2.0	2.0	2.4
SAND CHAMBER						
Oil or Grease Present	Y	Y	Y	Y	N	Y
Water Present	N	N	N	N	N	N
Clogging Evidence	N	N	N	N	N	N
Infiltration Rate (hrs)	<24	<24	<12	<12	<12	<12

May 2007 DSF Rehabbed

FIELD NOTES:

02/13/08: Needs sand and gravel in sediment chamber

04/29/08: Appears to be draining correctly with new type of stone in sand chamber

09/10/08: Sand chamber filled with organic debris

11/05/08: Sand chamber filled with organic debris

12/11/08: Organic debris in other sediment chamber; Sand chamber appears dry as if no water flowing in. Only first 4 sets sand chambers are wet or have water

ROUTE 273/7 PARK & RIDE DELAWARE SAND FILTER

DRY WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	DRY WEATHER OBSERVATION								
	02/06/08	04/16/08	05/21/08	06/10/08	07/22/08	08/25/08	10/09/08	11/11/08	12/30/08
Previous Precipitation	02/01/08	04/06/08	05/20/08	06/04/08	07/20/08	08/14/08	10/01/08	11/05/08	12/19/08
SEDIMENTATION CHAMBER									
Oil or Grease Present	Y	N	Y	N	Y	Y	Y	Y	Y
Water Present	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water Depth (ft)	1.9	1.8	1.8	1.8	1.8	1.75	1.8	1.8	1.8
Sediment Depth (ft)	0.2	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1
SAND CHAMBER									
Oil or Grease Present *	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water Present	N	N	N	N	N	N	N	N	N
Clogging Evidence	N	N	N	N	N	N	N	N	N
Gravel Depth (ft)	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Sand Depth (ft)	1.3	1.3	1.3	1.2	1.1	1.0	1.2	1.2	1.2
Discoloration Depth (ft)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Debris Depth (ft)	0.0	0.0	0.0	0.0	<0.1	0.0	0.10	0.1	0.0

May 2007 DSF Rehabbed

FIELD NOTES:

* Oil & Grease covering stones in sand chamber observed for each field visit

ROUTE 273/7 PARK & RIDE DELAWARE SAND FILTER

WET WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	WET WEATHER OBSERVATION					
	02/13/08	04/29/08	07/24/08	09/10/08	11/05/08	12/11/08
Precipitation Past 24 Hours (in)	**2.72**	**0.72**	**0.27**	**0.14**	**0.10**	**0.52**
SEDIMENTATION CHAMBER						
Oil or Grease Present	Y	N	Y	Y	N	Y
Water Present	Y	Y	Y	Y	Y	Y
Water Depth (ft)	3.4	1.75	1.8	1.8	1.8	2.0
SAND CHAMBER						
Oil or Grease Present	Y	Y	Y	Y	Y	Y
Water Present	Y	N	N	N	N	N
Clogging Evidence	Y	N	N	N	N	N
Infiltration Rate (hrs)	<24	<24	<12	<12	<12	<12

May 2007 DSF Rehabbed

FIELD NOTES:

02/13/08: Oil sheen visible on top water in sedimentation and sand chamber

04/29/08: Stones in sand chamber coated with oil and grease

11/05/08: Stones in sand chamber coated with oil and grease

WILMINGTON DELAWARE TRANSIT CORPORATION DELAWARE SAND FILTER

DRY WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	DRY WEATHER OBSERVATION								
	02/06/08	04/16/08	05/21/08	06/10/08	07/22/08	08/25/08	10/09/08	11/11/08	12/30/08
Previous Precipitation	02/01/08	04/06/08	05/20/08	06/04/08	07/20/08	08/14/08	10/01/08	11/05/08	12/19/08
SEDIMENTATION CHAMBER									
Oil or Grease Present	Y	Y	Y	N	Y	Y	Y	Y	Y
Water Present	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water Depth (ft)	2.0	2.0	1.9	1.9	1.9	2.0	2.0	1.9	2.0
Sediment Depth (ft)	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	<0.1
SAND CHAMBER									
Oil or Grease Present	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water Present	N	Y	N	N	N	N	N	N	N
Clogging Evidence	N	Y	N	N	N	N	N	N	N
Gravel Depth (ft)	1.0	1.0	1.0	1.0	1.0	0.5	1.0	0.8	1.0
Sand Depth (ft)	1.0	0.75	1.0	0.7	1.0	1.0	1.0	1.0	1.0
Discoloration Depth (ft)	0.1	0.05	0.1	0.1	<0.1	<0.1	0.05	0.1	0.05
Debris Depth (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0

July 2008 DSF Rehabbed

FIELD NOTES:

08/25/08: Black layer on top of sand in sand chamber

10/09/08: Black layer on top of sand in sand chamber

WILMINGTON DELAWARE TRANSIT CORPORATION DELAWARE SAND FILTER

WET WEATHER FIELD OBSERVATIONS

2008 SUMMARY

Category	WET WEATHER OBSERVATION					
	02/13/08	04/29/08	07/24/08	09/10/08	11/05/08	12/11/08
Precipitation Past 24 Hours (in)	**1.48**	**0.63**	**2.22**	**0.66**	**0.08**	**0.68**
SEDIMENTATION CHAMBER						
Oil or Grease Present	Y	Y	Y	Y	Y	Y
Water Present	Y	Y	Y	Y	Y	Y
Water Depth (ft)	4.7	2.65	2.4	2.1	2.0	2.4
SAND CHAMBER						
Oil or Grease Present	Y	Y	Y	Y	Y	Y
Water Present	Y	N	Y	N	N	N
Clogging Evidence	Y	N	Y	N	N	N
Infiltration Rate (hrs)	<24	<24		<15	<12	<12

July 2008 DSF Rehabbed

FIELD NOTES:

02/13/08: Oil sheen visible on top water in sedimentation and sand chamber

04/29/08: Sand covered with oil and grease

07/24/08: Sand chamber has 0.6' water

11/05/08: Black layer on top of sand; minor organic debris in sand chamber

DELAWARE SAND FILTER STUDY

2008 REPORT

APPENDIX 2

SAND ANALYSES – WILMINGTON DTC DSF

May 5, 2008

September 17, 2008

WILMINGTON DTC - DELAWARE SAND FILTER STUDY

CHEMICAL LABORATORY ANALYSIS

PARAMETER	UNITS	May 5, 2008 One Year of Use				September 17, 2008 Three Months of Use			
		TOP 1"	4" DEPTH	8" DEPTH	12" DEPTH	TOP 1"	4" DEPTH	8" DEPTH	12" DEPTH
OIL & GREASE	(mg/Kg)	<500	<500	<497	1810	2300	1600	1400	2300
TPH, SOIL (SGT-HEM)	(mg/Kg)	4660	3875	6845	4240	920	<204	<207	<205
TPH, DIESEL RANGE ORGANICS	(mg/Kg)	1405.0	443.0	36.1	23.2	212.0	44.8	24.8	22.3
TPH, GASOLINE RANGE ORGANICS	(mg/Kg)	<0.05	<0.05	<0.05	<0.05	<5.5	<5	<5	<5
AMMONIA	(mg/Kg as N)	<11	<11	<11	<11	<11.4	<10.6	<10.6	<10.6
TOTAL KJELDAHL NITROGEN	(mg/Kg)	374	3	3	<2.22	558	<84.6	<84.4	<86.4
NITRATE / NITRITE-ION	(mg/Kg)	23.20	1.13	0.94	1.53	5.93	0.85	0.58	<0.15
TOTAL PHOSPHORUS	(mg/Kg as P)	85.1	45.1	34.3	143.0	111.0	30.9	97.9	29.6
CADMIUM, ICP	(mg/Kg)	<0.42	<0.41	<0.40	<0.44	0.51	<0.414	2.38	<0.408
CHROMIUM, ICP	(mg/Kg)	8.92	3.60	2.00	1.64	21.80	3.22	2.38	2.83
COPPER, ICP	(mg/Kg)	14.20	1.52	1.06	1.20	25.50	1.85	1.57	2.51
LEAD, ICP	(mg/Kg)	9.51	1.46	1.04	<1.09	19.80	<2.07	<1.95	<2.04
NICKEL, ICP	(mg/Kg)	4.54	2.31	1.28	1.47	10.20	2.19	1.35	1.57
ZINC, ICP	(mg/Kg)	94.9	13.0	10.8	11.8	211.0	17.9	10.7	10.7
ARSENIC, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.228	<0.21	<0.21	<0.216
BARIUM, TCLP	(mg/L)	<0.21	0.35	0.30	0.28	1.14	0.67	0.45	0.48
CHROMIUM, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.228	<0.212	<0.21	<0.216
CADMIUM, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.114	<0.106	<0.105	<0.108
LEAD, TCLP	(mg/L)	<0.10	<0.10	<0.10	<0.10	<0.228	<0.212	<0.21	<0.216
MERCURY, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.0002	<0.0002	<0.0002	<0.0002
SELENIUM, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.228	<0.212	<0.21	<0.216
SILVER, TCLP	(mg/L)	<0.21	<0.21	<0.21	<0.21	<0.228	<0.212	<0.21	<0.216
TOTAL PHENOLICS	(mg/Kg)	<2.65	<2.67	<2.68	<2.78	<2.845	<2.645	<2.635	<2.7

Yellow = 05/05/08 concentrations ABOVE laboratory equipment detection limit

Blue = 09/17/08 concentrations ABOVE laboratory equipment detection limit

July 2008 DSF Rehabbed

WILMINGTON DTC - DELAWARE SAND FILTER STUDY

CHEMICAL LABORATORY ANALYSIS

BTEX & PAH

PARAMETER	UNITS	May 5, 2008 One Year of Use				September 17, 2008 Three Months of Use			
		TOP 1"	4" DEPTH	8" DEPTH	12" DEPTH	TOP 1"	4" DEPTH	8" DEPTH	12" DEPTH
BENZENE	(mg/Kg)	<0.10	<0.10	<0.10	<0.10	<0.11	<0.1	<0.1	<0.1
TOLUENE	(mg/Kg)	<0.10	<0.10	<0.10	<0.10	<0.11	<0.1	<0.1	<0.1
ETHYLBENZENE	(mg/Kg)	<0.10	<0.10	<0.10	<0.10	<0.11	<0.1	<0.1	<0.1
TOTAL XYLENES	(mg/Kg)	<0.10	<0.10	<0.10	<0.10	<0.22	<0.2	<0.2	<0.2
CARBOZOLE	(mg/Kg)	<2.5	<2.5	<1.2	<1.2	<2.5	<2.5	<1.2	<1.2
DIBENZOFURAN	(mg/Kg)	<1.0	<0.50	<0.50	<0.50	<1.0	<0.50	<0.50	<0.50
NAPHTHALENE	(mg/Kg)	<1.4	<0.70	<0.70	<0.70	<2.5	<0.5	<0.5	<0.5
ACENAPHTHYLENE	(mg/Kg)	<0.80	<0.40	<0.40	<0.40	<2.5	<0.5	<0.5	<0.5
ACENAPTHENE	(mg/Kg)	<0.80	<0.40	<0.40	<0.40	<2.5	<0.5	<0.5	<0.5
FLUORENE	(mg/Kg)	<0.80	<0.40	<0.40	<0.40	<2.5	<0.5	<0.5	<0.5
PHENANTHRENE	(mg/Kg)	<0.70	<0.35	<0.35	<0.35	<2.5	<0.5	<0.5	<0.5
ANTHRACENE	(mg/Kg)	<0.70	<0.35	<0.35	<0.35	<2.5	<0.5	<0.5	<0.5
FLUORANTHENE	(mg/Kg)	0.75	<0.30	<0.30	<0.30	<2.5	<0.5	<0.5	<0.5
PYRENE	(mg/Kg)	<0.80	<0.40	<0.40	<0.40	<2.5	<0.5	<0.5	<0.5
CHYRSENE	(mg/Kg)	0.68	<0.30	<0.30	<0.30	<2.5	<0.5	<0.5	<0.5
BENZO (A) ANTHRACENE	(mg/Kg)	<0.70	<0.35	<0.35	<0.35	<2.5	<0.5	<0.5	<0.5
BENZO (B) FLUORANTHENE	(mg/Kg)	<0.80	<0.40	<0.40	<0.40	<2.5	<0.5	<0.5	<0.5
BENZO (K) FLUORANTHENE	(mg/Kg)	<1.3	<0.65	<0.65	<0.65	<2.5	<0.5	<0.5	<0.5
BENZO (A) PYRENE	(mg/Kg)	<0.60	<0.30	<0.30	<0.30	<2.5	<0.5	<0.5	<0.5
DIBENZO (A,H) ANTHRACENE	(mg/Kg)	<0.60	<0.30	<0.30	<0.30	<2.5	<0.5	<0.5	<0.5
INDENO (1,2,3-CD) PYRENE	(mg/Kg)	<0.60	<0.30	<0.30	<0.30	<2.5	<0.5	<0.5	<0.5
BENZO (G,H,I) PERYLENE	(mg/Kg)	<0.70	<0.35	<0.35	<0.35	<2.5	<0.5	<0.5	<0.5

Yellow = Concentrations ABOVE laboratory equipment detection limit

May 2008 = Majority of parameter concentrations were BELOW detection

September 2008 = ALL parameter concentrations were BELOW detection

July 2008 DSF Rehabbed

WILMINGTON DTC - DELAWARE SAND FILTER STUDY

PERCENT PARTICLE SIZE AND MOISTURE CONTENT

May 5, 2008

SAMPLE SITE	BOULDERS	COBBLES	GRAVEL		SAND			SILT & CLAY	MOISTURE CONTENT
			Coarse	Fine	Coarse	Medium	Fine		
	Sieve Range								
	>12"	12" - 3"	3" - 3/4"	3/4" - #4	#4 - #10	#10 - #40	#40 - #200	< #200	105C
	PERCENT RETAINED								
TOP 1"	0	0	0	1	13	44	36	6	5.65
4" DEPTH	0	0	0	1	0	27	71	1	6.45
8" DEPTH	0	0	0	0	0	28	67	5	6.76
12" DEPTH	0	0	0	1	5	50	42	2	10.00

September 17, 2008: No analysis of Particle Size and Moisture Content

SAMPLE SITE	BOULDERS	COBBLES	GRAVEL		SAND			SILT & CLAY	MOISTURE CONTENT
			Coarse	Fine	Coarse	Medium	Fine		
	Sieve Range								
	>12"	12" - 3"	3" - 3/4"	3/4" - #4	#4 - #10	#10 - #40	#40 - #200	< #200	105C