Bio Clean Downspout Filter TSS & Hydrocarbons Removal Testing

Prepared by

Bio Clean Environmental Services, Inc.

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Testing Laboratory - PAHs

D-Tek Analytical Laboratories, Inc.

9020 Kenamar Drive, Suite 205
San Diego, CA 92121
Phone: 858-566-4542

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Background

A number of specialty post-construction BMPs have been developed in recent years to deal with unique situations and constraints. Situations in which traditional proprietary and non-proprietary BMPs are not feasible nor even possible. Many new and retrofit projects characterized by curb to curb structures, such is the case with taller buildings and parking structures in highly urbanized or down town areas. Due to these constraints, the need for BMPs that can be incorporated into these types of projects has arisen. The majority of the impervious surfaces on these sites are roof tops and parking area. Therefore, a BMP that will address the “pollutants of concern” and related concentrations and forms unique to these impervious areas has been in great demand in recent years. As stormwater regulations become more stringent the demand for BMPs the effectively and feasibly deal with these situations will increase. More importantly, these BMPs will have to be designed to work with the current drainage infrastructure of rooftops and parking structures. The most commonly used method for conveying runoff from these areas are downspouts. Downspouts are a series of vertical pipes the collect runoff from rooftops and parking areas, channels the water either internally or externally of the building and discharges at ground level either to the street or the existing drainage infrastructure usually sub-surface of the street.

Bio Clean Environmental Services has been offering a downspout filter over the past three years to address the need for a stormwater BMP that will effectively treat runoff from rooftops and parking areas. Downspout filters are source controls, being inexpensive, easy to retrofit to most new and existing downspout drainage infrastructures, and keeping pollutants out of the water bodies. Bio Clean Environmental Services, Inc, of Oceanside, California performed testing on a Bio Clean Downspout Filter (BCDF) to determine its pollutant removal effectiveness for TSS and hydrocarbons that are associated with storm water runoff. The hydrocarbon testing (PAHs) was performed on April 25th of 2007. Attached are photographs from the test and the accompanying laboratory test analysis and results performed by D-Tek Analytical Laboratories, Inc. The TSS and turbidity testing was performed on June 3rd, 2007. A full scale laboratory test was performed on a standard BCDF. The particle size gradations where used to represent both coarse and fine total suspended solids. Considering the pollutants usually found in roof runoff are comprised of both coarser roofing material and finer solids associated with atmospheric decomposition and wind blown material, these particle ranges are most closely correlated to actual field conditions.

The Bio Clean Downspout Filter is designed to use numerous media types. The filter is designed to trap sediment, TSS, leaves, organic debris, metals, and hydrocarbons, thereby preventing these pollutants from entering the storm drain system where they would cause detrimental impacts on downstream water bodies. The Bio Clean Downspout Filter is a two piece metal fabricated filtering device. The filters outer shell is made of 1/8th inch powered coated rolled steel. The inner removable filter housing/bypass cone is constructed of 316 stainless steel. The inner cylinder is perforated allowing for media to be wrapped around it. The storage of trapped pollutants occurs in the area between the inner cylinder and outer shell. The capacity of the pollutant capture chamber is approximately 2.94 cubic feet. The overflow capacity of the BCDF is designed to be greater than the peak design flow, thereby insuring that there will be no loss of hydraulic capacity due to the device being inline of the downspout pipe.

Water flowing through the downspout filter first encounters the pollutant capture chamber where runoff passes through the filter media. As mentioned above the media is wrapped around the internal cylinder. If the flow rate through the filter media reaches capacity the higher flows will enter the bypass located in the middle of the top end of the internal cylinder.

Downspout filters such as the BCDF are generally designed to capture hydrocarbons, sediment, and debris. Depending on the specified media the filter can be effective at capturing fine TSS, heavy metals, and nutrients. The Bio Clean Flume Filters standard filter media is a combination of BioSorb booms and X-Tex Filter Fabric. This combination of media allows for very effective removal of pollutants commonly present in stormwater runoff, particularly runoff from rooftops and parking structures.

Methodology – Hydrocarbon Testing

Two tests where performed at separate times. The first test focused on the BioSorb booms removal of TPH (total petroleum hydrocarbons). A test was designed to simulate a rainfall event and measure the ability of a BCDF to remove hydrocarbons. A mock downspout was constructed of 6” SD40 PVC piping. The constructed downspout was approximately seven feet in height, with the filter placed inline approximately half way between the bottom of the collection chamber and the top of the downspout. A new downspout filter installed inline of the downspout (see pictures). A forklift with a 500 gallon tank was allowed to discharge through a 2” valve used to regulate the flow of the discharged batch water into the flume at a rate of 25 gpm. It was observed that the visible hydrocarbons (a rainbow sheen floating on the surface) were present in the influent, prior to the downspout filter and were not visible in the discharge collection chamber (effluent), which indicated that the hydrocarbons were being absorbed by the media booms. The effluent was collected down stream in a container after passing through the filter.

The batch was created by making a concentrated solution of hydrocarbon enriched water. The batch was intended to be mixed in 250 gallons to create a solution of highly contaminated water. This solution was added to the 250 gallon water tank and agitated with a mixer for a period of 15 minutes before the test and also throughout the test period. Once mixed thoroughly a grab sample was taken form the tank. This sample provided the background levels in the tank to be compared to the five tests that were run through the flume filter and its media.

By the use of a flow meter and control valve the flow was maintained at 25 gpm. Each test was conducted for approximately 2 minutes. Each water sample was done by taking three grab samples of effluent water that had passed through the filter. This was done to get an average sample concentration. Water was allowed to flow through the filter for 30 seconds then one third of the sample water was collected in a clean vessel and poured into the sampling bottle. The second and third sample was taken at one minute of flow and the final portion of the sample was taken at approximately 2 minutes as the final amount of water from the test was flowing through the filter.

As part of the initial sample of the influent readings where taken for pH, NTU and temperature. This initial information is as follows: time of testing started at 2:06, wind was 0.9 mph, temperature 79.4, Barometric pressure 1014.3 hPa, starting pH = 9.3 and NTU= 20.5, altitude = 60 feet MSL.

Results

Following is a summary of the results of removal of Total Petroleum Hydrocarbons.

Downspout Filter - Bio Sorb

Run	Pollutant	Influent (mg/L)	Effluent (mg/L)	Percent Reduction
1	TPH	223.5	40.3	**81.97%**
	pH	7.07	7.22	
2	TPH	223.5	18.4	**91.77%**
	pH	7.07	7.22	
3	TPH	223.5	31.3	**86.00%**
	pH	7.07	7.19	
4	TPH	223.5	40.6	**81.83%**
	pH	7.07	7.19	
5	TPH	223.5	17.26	**92.28%**
	pH	7.07	7.18	

Pollutant	Average Concentration	Average Removal %
TPH	29.57	86.77%
pH	7.20	

Methodology – TSS Testing – Sil-Co-Sil 106

The second test was performed to measure the Bio Clean Downspouts filters ability to remove TSS from stormwater runoff. As with the last test, a full scale laboratory test was designed to simulate actual field conditions. As described above, a mock downspout was constructed of 6” SD40 PVC piping. The constructed downspout was approximately seven feet in height, with the filter placed inline approximately half way between the bottom of the collection chamber and the top of the downspout. The bottom part of the downspout was constructed with a cut away to allow to the gathering of grab samples. A new downspout filter installed inline of the downspout (see pictures). A forklift with a 500 gallon tank was allowed to discharge through a 2” valve used to regulate the flow of the discharged batch water into the flume at a rate of 25 gpm.

The TSS was measured in two fashions. For this test two separate soil gradations where used to simulate both the fine and coarse TSS associated with stormwater runoff. Exact weights where calculated for the two gradations. For the Sil-Co-Sil 106, exactly 4.67 pounds where weighed out and mixed into the 400 gallons of water present in the water tank. This calculates to precisely 1400 mg/L. The water tank was agitated with a mixer for a period of 15 minutes before the test and also throughout the test period. Once mixed thoroughly a grab sample was taken form the tank and measured for turbidity. Due to the fine nature of the Sil-Co-Sil 106 (mean particle size of 20 microns) turbidity provides an accurate indication of the level of fine TSS present in the water. A grab sample of the mix was taken and measured for turbidity. The resulting reading for the influent concentration was 429 NTUs. A grab sample was taken of the influent prior to each test run to ensure the turbidity level remained constant, the readings ranged from 408 to 437 NTUs throughout the influent samples, indicating consistency in influent concentration. These samples provided the background levels in the tank to be compared to the effluent grab samples of the eight runs. The influent concentration (known by weight) and the relating turbidity reading was plotted against several and readily available correlation studies between TSS and turbidity on particle gradations similar to that of the Sil-Co-Sil 106. Through statistical analysis it was proven with a high level of certainty that the influent concentration and related turbidity reading strongly correlated to the existing data. The r value was greater than .999, which proves the strength of this correlation. Following are the results of this statistical analysis.

Statistical Analysis - Correlation

Pearson Product Moment Correlation - Monitoring Report - Lab Data with Bio Clean Data Point (weight)		
Statistic	Variable Y	Variable X
Mean	128.886667	39.866667
Variance	117954.5665	11085.18222
Standard Error	343.445143	105.286192
Covariance		36147.15156
Correlation		0.999644
Determination		0.999288
T-Test		135.052132

Critical 2-sided T-value (5%)	2.16
2-sided p-value	0
Critical 1-sided T-value (5%)	1.771
1-sided p-value	0
Degrees of Freedom	13
Observations	15

By the use of a flow meter and control valve the flow was maintained at 25 gpm. Each test was conducted for approximately 2 minutes. Each water sample was done in three grab samples of effluent water that had passed through the filter. This was done to get average sample turbidity. Water was allowed to flow through the filter for 30 seconds then one third of the sample water was collected in a clean vessel and poured into the sampling bottle. The second and third sample was taken at one minute of flow and the final portion of the sample was taken at approximately 2 minutes as the final amount of water from the test was flowing through the filter. Following are the results of the turbidity readings gathered from the grab samples.

Results – Sil-Co-Sil 106

TSS - Sil-Co-Sil Testing Log

	TSS (mg/L)**	Turbidity (ntu)*
Influent mg/L	**1400**	**429**
Test Run 1		
Grab 1	**1128.998**	**346**
Grab 2	**1292.148**	**396**
Grab 3	**929.955**	**285**
Average Reduction %	**41.8%**	
Test Run 2		
Grab 1	**956.059**	**293**
Grab 2	**978.9**	**300**
Grab 3	**704.808**	**216**
Average Reduction %	**53.0%**	
Test Run 3		
Grab 1	**952.796**	**292**
Grab 2	**796.172**	**244**
Grab 3	**750.49**	**230**

Average Reduction %	56.0%	
Test Run 4		
Grab 1	952.796	292
Grab 2	838.591	257
Grab 3	721.123	221
Average Reduction %	55.7%	
Test Run 5	0	
Grab 1	832.065	255
Grab 2	877.747	269
Grab 3	724.386	222
Average Reduction %	57.5%	
Test Run 6		
Grab 1	907.114	278
Grab 2	695.019	213
Grab 3	867.958	266
Average Reduction %	56.7%	
Test Run 7		
Grab 1	655.863	201
Grab 2	567.762	174
Grab 3	613.444	188
Average Reduction %	76.2%	
Test Run 8		
	688.493	211
	642.811	197
	652.6	200
Average Reduction %	70.6%	
Total Average Reduction %	58.4%	

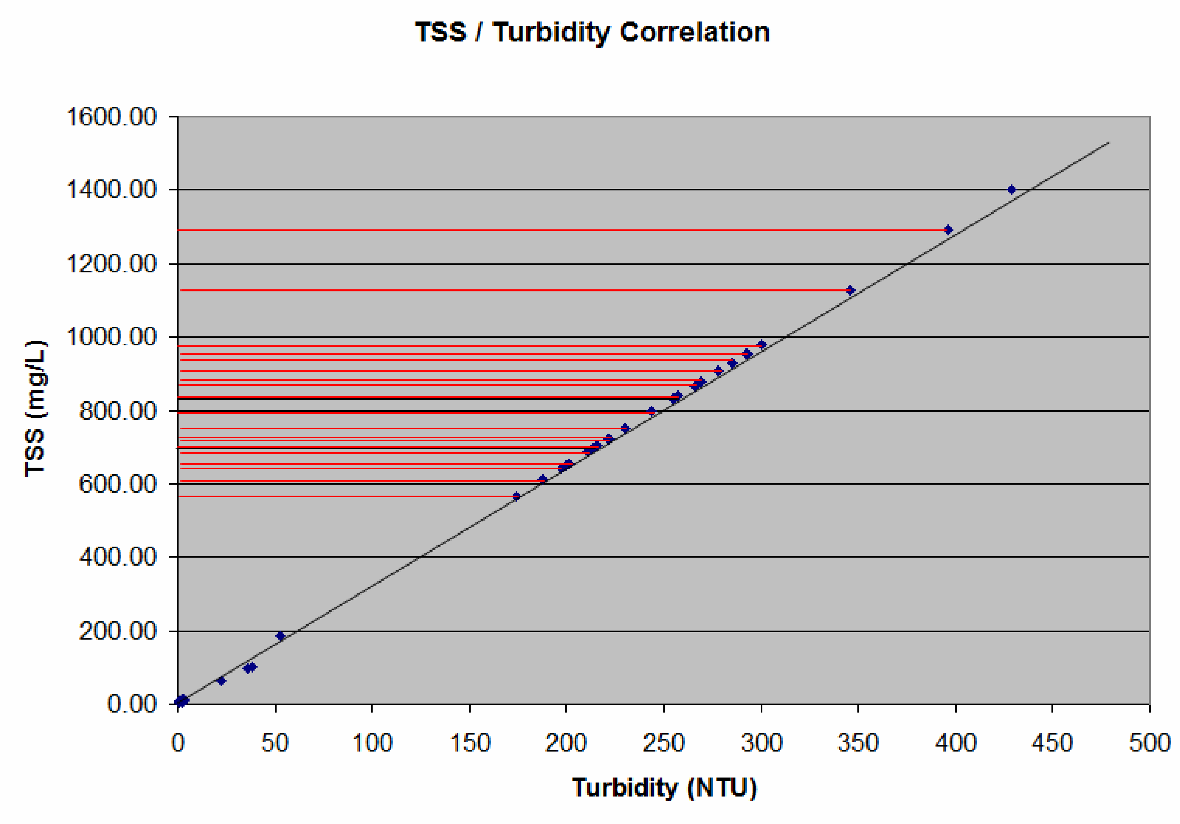
***Turbidity (NTU) data was taken during the full scale laboratory testing of the Bio Clean Downspout Filter. During the testing 8 two minute test runs where performed at a flow rate of 25 gpm. 3 grab samples where taken at the 30 second, 1 minute and 1.5 minute intervals.**

**** Approximations based upon Turbidity readings and its proven strong correlation to TSS, particularly particles less than 50 microns. Influent fine TSS concentration (mg/L) batch mix was 1400 mg/L (400 gallons and 4.67 pounds of Sil-Co-Sil 106, mean particle size of 20 microns).**

The TSS concentrations above where calculated by the following statistical analysis.

The Following Scatter Plot compiled from existing laboratory data was used to plot results of the grab samples (turbidity readings) in order to find the related TSS concentration in mg/L.

Scatter Plot



Data Table

TURBIDITY (NTU)	TSS (mg/l)
38	102.60
36	96.60
2	14.60
3	11.40
2	9.60
2	11.20
53	184.30
22	61.60
2	10.00
1	9.00
1	3.40
2	5.20
2	7.20
3	6.60

429	1400.00
346.00	1128
396.00	1292
285.00	929
293.00	956
300.00	978
216.00	704
292.00	952
244.00	796
230.00	750
292.00	952
257.00	838
221.00	721
255.00	832
269.00	877
222.00	724
278.00	907
213.00	695
266.00	867
201.00	655
174.00	567
188.00	613
211.00	688
197.00	642
200.00	652

Methodology – TSS Testing – Sand

Taking into account the quick settling velocities of coarse TSS it was determined that a different method should be employed to accurately measure the Bio Clean Downspout Filters removal of coarser TSS. For this test it was concluded to most accurate method for calculating the removal efficiency of coarse TSS is by weight comparison between the amounts added to the influent and compare it by the amount collected in the filter. As a precautionary measure, any TSS that passed through the filter was collected in a discharge collection chamber. The amount collected by the filter plus the amount collected in the discharge collection chamber would be added to see if the total was equal to the amount added to the influent. Exactly 6.67 pounds of sand where metered into the influent over the 2 minute period of each test run. Approximately .834 pounds of sand were metered into each test run. This method ensured that the concentration of 2000 mg/L would be maintained throughout the entire period of each test run. Following are the results of this test.

Results – Sand

TSS - Sand Testing Log

[redacted]	TSS (mg/L)***
Influent mg/L	**2000**
Test Run 1	
(in pounds)	**0.834**
Test Run 2	
(in pounds)	**0.834**
Test Run 3	
(in pounds)	**0.834**
Test Run 4	
(in pounds)	**0.834**
Test Run 5	
(in pounds)	**0.834**
Test Run 6	
(in pounds)	**0.834**
Test Run 7	
(in pounds)	**0.834**
Test Run 8	
(in pounds)	**0.834**
Total Sand Added (Influent) (lbs)	**6.7**
Total Sand Collected in Downspout Filter - at Conclusion of Test Run 8 - Dried and Weighed (lbs)	**6.2**
******Total Reduction %**	**92.9%**

*****To obtain a concentration of 2000 mg/L of TSS (sand) approximately 6.67 pounds of sand needed to be added evenly to 400 gallons of water. Due to sands fast settling time, sand was metered into the influent at a rate of .417 pounds per minute. This was done during the duration of the tests runs, totaling a time of 16 minutes.**
******Calculated by weight difference between sand added and sand removed from Bio Clean Downspout Filter.**

Conclusion

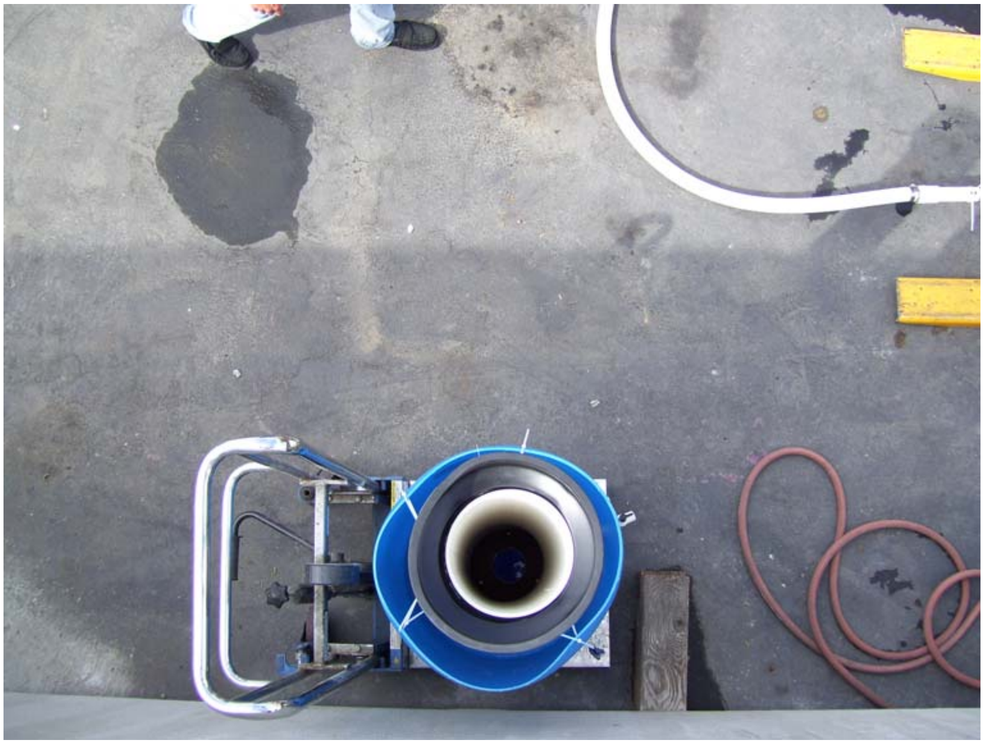
A total of five runs where performed to provide statistical verification of the removal efficiencies of TPH. There was an average effluent concentration of 29.57 mg/l for TPH (total petroleum hydrocarbons), resulting in an average removal efficiency of 86.7% respectively. The Average TSS removal efficiency of Sil-Co-Sil 106 (mean particle size of 20 microns) was approximately 58.4%. The Average TSS removal efficiency of Sand (mean particle size of 250 microns) was approximately 92.9%.The conclusion of the test indicates that the BCFF filter is a very good device for the removal of oil and grease and TPH with removal rates of 86% and an overall removal of TSS through a range of particle sizes of 75.65% (average of Sil-Co-Sil 106 and sand combined). Particle gradations for both the Sil-Co-Sil 106 (fly ash) and sand (sand clay) are provided in appendix B. Also, considering the Bio Clean Downspout Filter utilizes X-Tex fabric as it primary filter media it can be noted that this fabric has a wet sieve size of 86 microns. Thus, the Bio Clean Downspout Filter utilizing the X-Tex fabric has the potential to capture 100% of TSS particles greater than 86 microns up to a peak flow rate of .3 CFS or 135 gpm. This flow rate has been calculated by finding the total surface area of the internal cylinder (which the fabric is wrapped around), equal to 1.2775 square feet times the X-Tex fabric stated flow rate of 106 gpm per square foot.

At the flow rate of 25 gpm, the Bio Clean Downspout Filter had a TSS removal efficiency of 75.65%. The BCDF has sediment removal capabilities rivaling those found in many structural BMPs, at a fraction of the cost, and without disruptive construction. In conclusion the Bio Clean Downspout Filter is invaluable tool that can be used to prevent pollutants from entering our waterways. The Bio Clean Flume Filter has the potential to utilize different media, which may allow this filter to be effective at removing metals and nutrients.

Appendix A

Field Installation

Testing Photos




F-300
GPM
LPM
140
550
120
450
100
350
80
250
40
150
Read Float at Top
Liquid Sp. Gr. 1.0
Calibrated with Water
www.Blue-White.com
FLOW

Appendix B

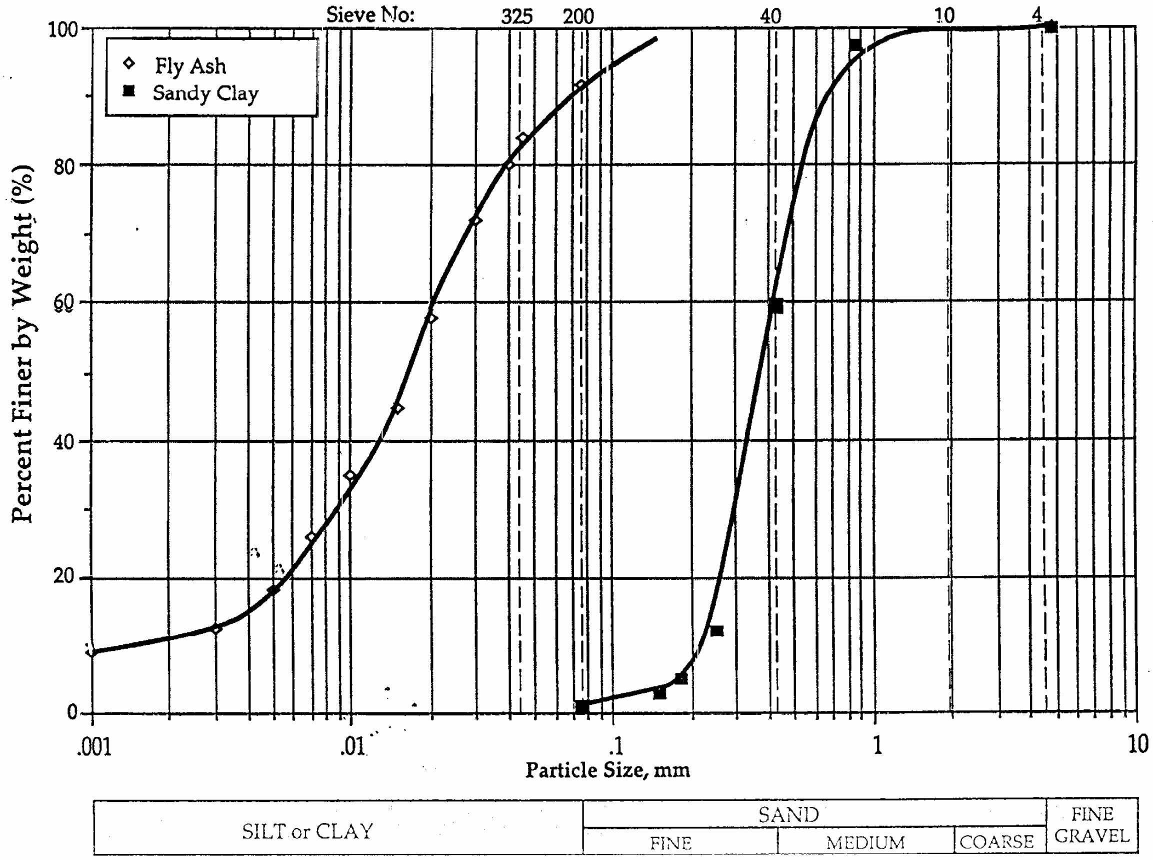


Figure 4.2: Grain Size Distribution Curves of Chosen Sediments for Model Study.

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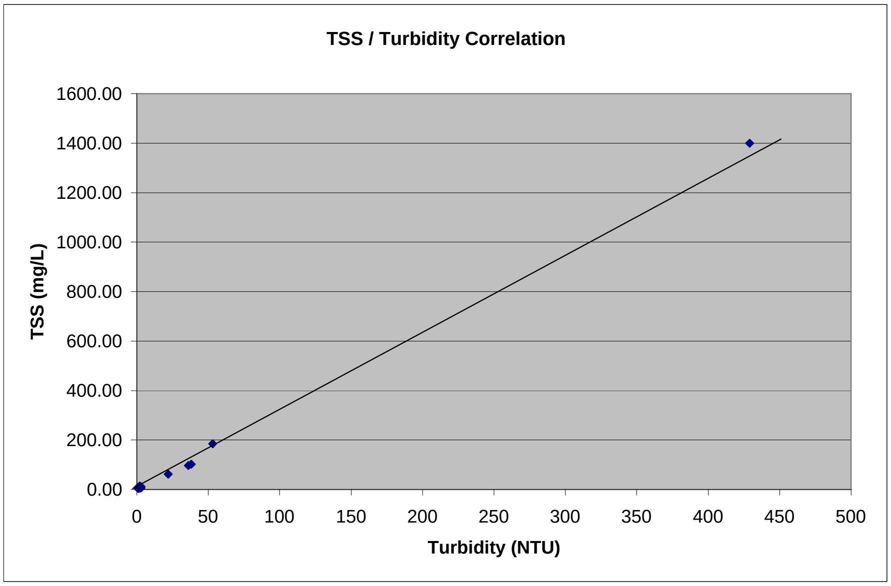

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Column 1	1	
Column 2	0.999644	1

Date	Mon, 04 Jun 2007 10:55:21 -0700
Cite	Wessa, P. (2007), Free Statistics Software, Office for Research Development and Education, version 1.1.21, URL http://www.wessa.net/

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Pearson Product Moment Correlation - Monitoring Report - Lab Data with Bio Clean Data Point (weight)		
Statistic	Variable Y	Variable X
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1-sided p-value		0
Degrees of Freedom		13
Observations		15

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396.00	1292
285.00	929
293.00	956
300.00	978
216.00	704
292.00	952
244.00	796
230.00	750
292.00	952
257.00	838
221.00	721
255.00	832
269.00	877
222.00	724
278.00	907
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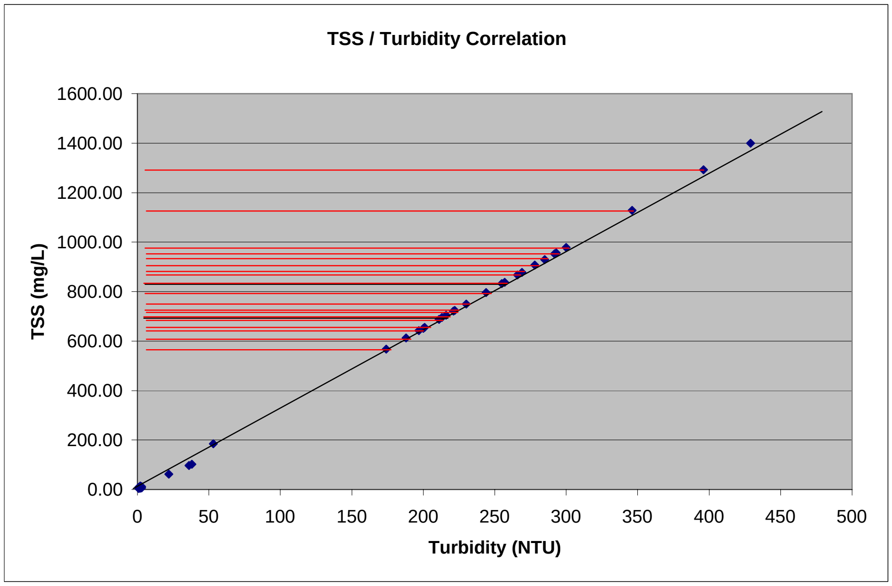
201.00	655
174.00	567
188.00	613
211.00	688
197.00	642
200.00	652



X-TEX® ENVIRONMENTAL INNOVATIONS

Jerry M. Brownstein
President & CEO
Phone:
(425) 392.3848
Fax:
(425) 392.0222
Email:
jbxextex@comcast.net

Physical Test Data- To understand all the physical properties of the X-TEX blanket and to help in developing other applications additional physical testing was conducted.

The table below is a summary of those tests.

Physical Test Results of the X-TEX Blanket

Test	Method	Units	Result
Thickness	ASTM D5199	Mills	115.5
Mass Per Unit Area	ASTM 5261	oz/yd	8.0
Grab Tensile MD	ASTM D4632	lbs	56
Grab Tensile TD	ASTM D4632	lbs	66
Elongation at Peak MD	ASTM D4632	percent	102
Elongation at Peak TD	ASTM D4632	percent	96
Wide Width Tensile MD	ASTM D4595	lbs/in	19
Wide Width Tensile TD	ASTM D4595	lbs/in	24
Elongation at break MD	ASTM D4595	percent	75
Elongation at break TD	ASTM D4595	percent	73
Pucture Resistance	ASTM D4833	lbs	54
Trapezoid Tear Strength MD	ASTM D4533	lbs	26
Trapezoid Tear Strength TD	ASTM D4533	lbs	29
Mullen Burst Strength	ASTM D3786	psi	135
Permittivity(Constant Head)	ASTM D4491	sec-1	1.42
Permeability	ASTM D4491	cm/sec	0.36
Flow Rate	ASTM D4491	gal/ft2	106
Apparent Opening Size	ASTM D4751	mm	100-140
Static Puncture Resistance	ASTM D6241	lbs	175
Wet Sieving	ISO 12956	um	83
Asphalt Retention MD	ASTM D6140	grams/m2	2433
Asphalt Retention TD	ASTM D6140	grams/m2	2305
Note MD = Machine Direction TD = Transverse Direction*			

Total Suspended Solids-Turbidity Correlation in Northeastern Wisconsin Streams

Timothy J. Randerson[1], Jessie C. Fink[1], Kevin J. Fermanich[1], Paul Baumgart[1], Timothy Ehlinger[2]

[1]University of Wisconsin-Green Bay, [2]University of Wisconsin-Milwaukee

http://www.uwgb.edu/watershed

AWRA – Wisconsin Section Meeting
Delavan, WI, 3-4 March 2005

Abstract

Knowledge of sediment loading is fundamental to assessing non-point source pollution in streams. The cost of collection and analysis of sediment samples could be reduced if total suspended solids (TSS) can be accurately estimated from continuously monitored turbidity. This poster presents TSS-turbidity correlations for three high sediment-yielding tributaries to the Lower Fox River in northeastern Wisconsin. Continuous turbidity measurements were matched with 195 TSS samples from automated event samplers and manual low-flow samples collected during WY2004. R^2 values for linear regressions exceeded 0.95 for the four sites analyzed. Regressions were site specific and significantly different from each other. Flow did not have a significant effect on the regressions. We hypothesize that differences between sites are due to variances in watershed hydrologic response, soils, bank sediment characteristics and land use/cover. Loads from turbidity-derived TSS concentrations were within 10% of loads calculated using TSS observations.

Introduction and Project Objectives

Estimation of sediment loading in a stream typically requires utilizing automated flow and event samplers to collect a limited number of TSS samples for laboratory analysis. Others have found that continuously monitored turbidity measurements may closely correlate with TSS concentrations in streams (Christensen 2000). Turbidity is a measure of the decrease in transparency of stream water as light is scattered by suspended matter (Ziegler 2002). Because optical sensors can be used to continuously monitor turbidity throughout a storm event, turbidity-derived predictions of TSS may yield an accurate estimate of sediment fluctuations with reduced sample costs. Particle properties, such as color, shape, and size distribution, may impact turbidity readings (Ankcorn 2003). Although general TSS-turbidity relationships have been reported, relationships must be established on a site-by-site basis, and reliability may vary due to water color and suspended particle composition (Packman et al 1999).

This poster presents research conducted on Apple, Ashwaubenon, and Baird Creeks in Northeastern Wisconsin as part of a larger watershed monitoring project (Figure 1). Objectives of this study were to:

1) Establish relationships between real-time turbidity and TSS in Lower Fox River watershed tributaries.
2) Determine if the relationships differed between sites or by flow.
3) Compare turbidity-derived loads to those based on TSS samples.

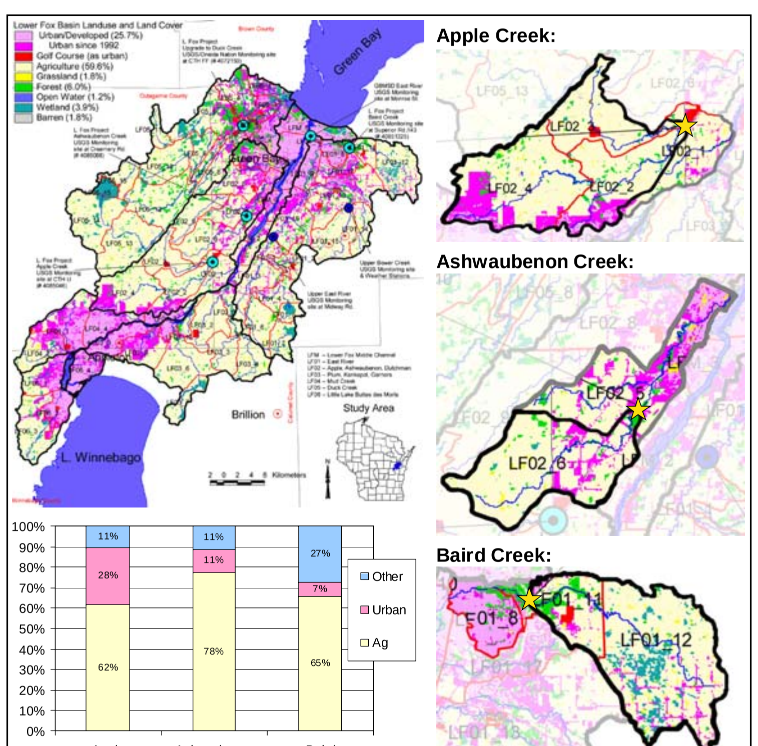


Figure 1. Land use and sampling locations in the Lower Fox River watershed.

Methods

Fully automated flow and water sampling stations were established in cooperation with the Wisconsin USGS Office in 2003. Standard methods were used for gaging streamflow and for collecting, processing, and analyzing water samples (Shelton 1994, Figure 2). Stage-triggered event samples were collected at the USGS gaging stations. In addition, a manually-activated sampler was located at a site upstream of the USGS station on the North Branch of Baird Creek. Biweekly low-flow samples were collected at each site using the equal width increment (EWI) method. YSI-6200 multi-parameter sondes were also deployed at each site and logged T, pH, DO, specific conductance, depth, and turbidity at 10 minute intervals (Figure 3). The optical turbidity sensors had automated wipers to reduce fouling.

Figure 2. Refrigerated ISCO sampler.

Figure 3. YSI-6200 sonde.

Sonde data was processed to exclude anomalous observations due to sediment deposition and equipment-associated false spikes in turbidity. Linear regression analysis was performed using Microsoft Excel 2003 and SAS 9.1 (SAS Institute 2003) to generate predictive relationships between TSS and turbidity. Comparisons were made between sites and between event versus low-flow samples and samples taken on the rising versus falling limbs of flow event hydrographs. There were not sufficient data to test for the significance of seasonality.

Results

Annual precipitation was about 10% below the 30 year average. However, November, May and June were a combined 218 mm (+202%) above average. This rainfall led to several major runoff events during the study period.

Figure 4 shows an example of the automated data and TSS event samples collected at each site. This figure illustrates:

- The dynamic real-time response and variability of turbidity in events.
- The close correlation between turbidity and TSS.
- The need for data processing to remove false-spikes and erratic responses of the optical sensor during high flows.

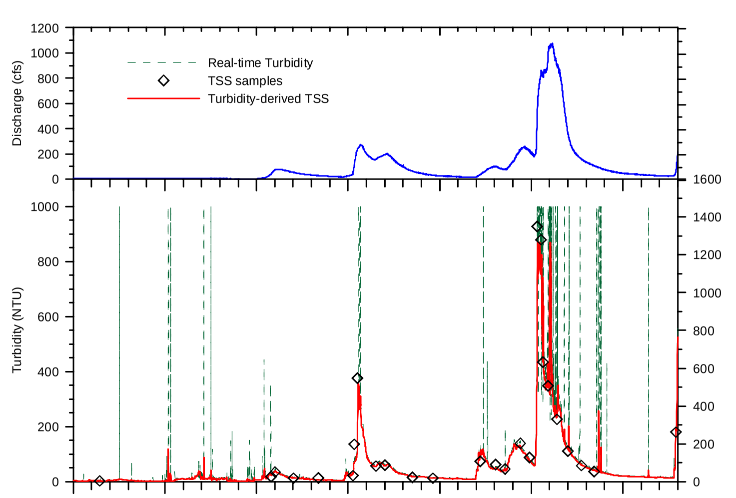


Figure 4. Discharge, TSS concentration, and turbidity data from 28 to 31 April 2004 at the Apple Creek USGS Station.

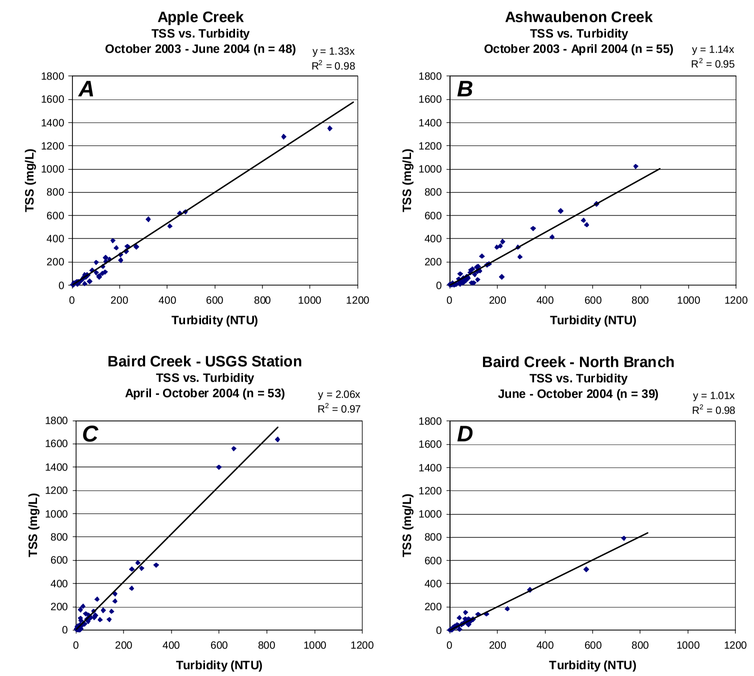


Figure 5. TSS-turbidity relationships for Apple Creek (A), Ashwaubenon Creek (B), Baird Creek USGS Station (C) and the Baird Creek North Branch site (D).

Linear regressions for the four sites are presented in Figure 5. The results show the following:

- The relationship between TSS and turbidity was highly significant at the 0.05 confidence level for all four sites.
- The slope of the TSS vs. turbidity line ranged from 1.01 to 2.06.
- In no case was the intercept significantly different from zero.
- All TSS-turbidity between-site relationships are significantly different from each other at the 0.05 confidence level.
- The Ashwaubenon-Baird (North Branch) relationship was the closest ($p = 0.0178$ compared to $p < 0.0001$ for all others). Statistically, however, they are different from each other.
- Flow (event vs. low-flow) and hydrograph position (rising vs. falling) did not have a significant effect on the regressions.

Load Comparisons

Real-time turbidity measurements from Apple Creek were processed with an algorithm that replaced observations that were >0.3 standard deviations from the running median with a 70-minute median value. These turbidity values were converted to TSS using the Apple Creek regression (TSS = 1.33 x Turbidity) and matched to 15 minute discharge values to calculate instantaneous and daily loads (Figures 5A, 4). The turbidity-derived TSS loads were compared to loads calculated by USGS scientists using TSS observations and graphical interpolation software (metric tons).

Period	Turbidity Loads	USGS Loads	Difference
14 April – 22 May	312	348	-10.2%
14 April – 30 May	2458	2327	+5.7%
10 – 20 June	1170	1125	+4.0%

Figure 6. Baird Creek at Superior Road during a runoff event, Fall 2003.

Figure 7. Event samples showing sediment concentration change during a storm.

Figure 8. Ashwaubenon Creek during May 2004 storm events: (A) May 14, (B) May 23.

Conclusions

- Turbidity of the three creeks within the Lower Fox River Watershed is highly dynamic, and increased turbidity measurements coincided with runoff events and sharp rises in stream discharge.
- Turbidity and TSS concentrations were highly correlated for our data sets, but the TSS-turbidity relationship appears to be site specific. We hypothesize that these differences result from sediment particle properties and varying hydrological responses from urban and agricultural land uses.
- The two Baird Creek sites displayed the largest difference despite being located only 1 mile apart. A study by Fink et al. (2005) found that development and bank erosion on urbanizing tributaries contributed significant amounts, and likely different, sediment particles above the USGS station but below the North Branch site.
- No significant difference was found due to event vs. low-flow or hydrograph position. The effect of seasonality was not analyzed due to lack of data from equipment fouling.
- Turbidity-derived sediment loads were similar (+/- 10%) to TSS sample load methods.

Continuous turbidity monitoring appears to be a reasonable surrogate for TSS prediction in Apple, Ashwaubenon, and Baird Creeks, and may provide long-term, cost effective and rapidly available information on watershed sediment delivery due to changes in land use. Refining multi-probe sonde deployments for turbidity monitoring could contribute to fewer false spikes and/or equipment fouling and, thus, more complete data sets and higher relationship confidence. Research on suspended particle properties would also provide information needed to better explain site-to-site differences in the TSS–turbidity relationships.

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MONITORING REPORT No. 7
DREDGING AND RECLAMATION PROGRAMME IN KINGSTON HARBOUR

Prepared for:
The Port Authority of Jamaica

Prepared by:
T.E.M.N. Limited
April 4th, 2002

BACKGROUND:

Water quality sampling fieldwork was carried out on March 11, 2002, and data from fixed stations at Middle, Angel, and Bustamante beacons was reviewed.

The sampling exercise carried out on March 11, was intended to provide measurement of TSS (total suspended solids)/turbidity in the channel (H1 and H2) where dredging was in progress.

A monitoring flight took place on 18th March and a selection of the photographs taken are attached.

An inspection of the berm at R1 was carried out on March 13th. The R1 bund preparation continued during the period covered by this report. The first sector was completed and work continued in the extension of the berm by PIHL. Significant plume from this activity was noted in our monitoring flight of March 19. The screen around the berm preparation activity was down at the time of our flight and was being repaired.

METHODOLOGY:

Monitoring on March 11 was carried out in the channel near Port Royal, where the dredge Cristoforo Colombo was operating. Other sites monitored included wake of a small container vessel (Heinrich – Plate 1), a site east of Delbert Sicard beacon, and Angel beacon (Figure 1). In order to assess the impact of dredging, sampling was carried out in an identified plume (Plate 2) as soon as the dredge departed, and the same site was re-sampled approximately ½hr later. The sampling sites were designated KTP 1 – 6 (Table 1).

Table 1: Dredging And Reclamation In Kingston Harbour Water Quality Sampling Sites March 22, 2002

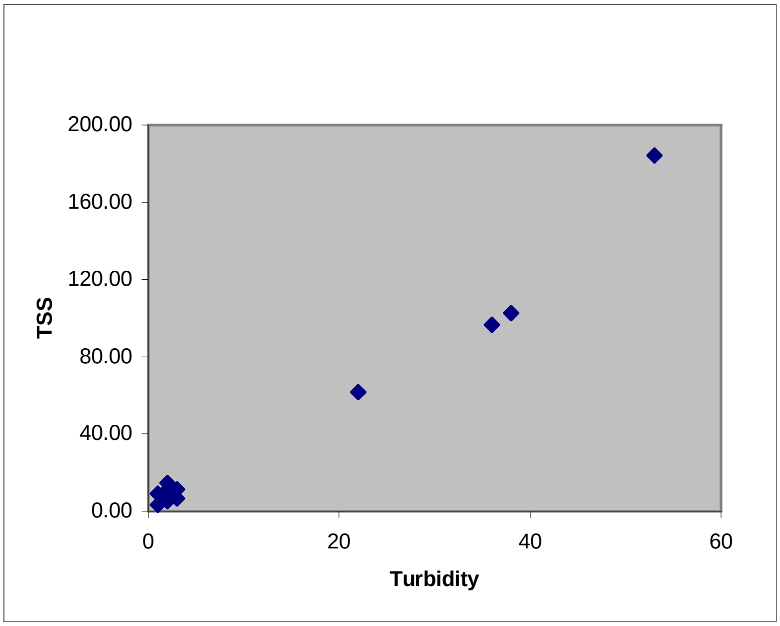
DESCRIPTION N COORD. W COORD	STATION NO.
Wake of Heinrich (Surface) 18^{o} 00.218' 76^{o} 46.736'	1
Dredge Plume North of Dredge 17^{o} 57.417' 76^{o} 50.999'	2
Area recently dredged 17^{o} 57.147' 76^{o} 51.197'	3
West of Delbert Sicard Beacon 17^{o} 56.894' 76^{o} 51.525'	4
Station 3 Resampled 17^{o} 57.150' 76^{o} 51.201'	5
Angel Beacon 17^{o} 57.180' 76^{o} 49.607'	6

Samples were generally collected at three depths (sub-stations) at each site sampled using the Van Dorn sampler. These sub-stations were denoted T (surface sample), M (middle depth), and B (bottom depth). The exception was station 6 - Angel beacon where sampling was confined to the surface.

Samples were analysed by Poly-Diagnostic Centre in accordance with Standard Methods for the Analysis of Water and Waste Water. TSS was determined by filtration of a known sample volume through a dried, pre weighed filter. After filtration, the filter was dried and re-weighed. TSS in mg/l is obtained through a determination of the weight difference of the filter before and after filtration. As a precaution against salt-water interference, filters were rinsed with warm distilled water after filtration of the sample. This precaution was employed in analysing samples collected subsequent to February 18.

Relying on the good correlation between turbidity and TSS determined from the February data (Figure 2) the WQ team was able to collect more samples. Most of these samples were analysed to determine turbidity. TSS was then determined from the plot of TSS vs. turbidity (Figure 2). Turbidity only was determined at Stations 1, 2, and 4, while as a control, turbidity and TSS were measured at stations 3, 5, and 6.

Figure 2: TSS vs Turbidity – February 22nd



OBSERVATION AND RESULTS

During the exercise, sea state was calm, with a light SW wind. There was no visible plume associated with a small container vessel traversing the channel. On approaching sector H1 a plume was observed just north of where the dredge was operating. There was a visible plume remaining after the departure of the dredge.

Laboratory and field data are summarised in Table 2.

Laboratory Results:
Laboratory analysis results indicate a range of TSS for all sites monitored of 3.6–76.1mg/l. The highest values were reported for the dredge site (Station 5) where TSS was determined to be 34.0mg/l at the surface, 43.1mg/l at middle depth, and 78.1mg/l at the bottom. At station 2 (fugitive plume) TSS was 12mg/l at the surface, 32.3mg/l at middle depth and 18.2mg/l at the bottom. In the wake of the small container vessel, TSS was 5.5mg/l at the surface, 3.6mg/l at middle depth, and 6.7mg/l at the bottom. At station 5 (dredge site after 30min) TSS was 7.6mg/l at the surface, 14.6mg/l at middle depth, and 69.2mg/l at the bottom. At station 6 TSS was 9.7mg/l at the surface. At station 4 (west of Sicard beacon) TSS was 13.5mg/l at the surface, and 7.8mg/l below the surface.

Table 2: Kingston Container Terminal Water Quality Data March 11, 2002

STATION NO	TIME	DEPTH (M)	LAB. RESULTS TURBIDITY (NTU)	LAB. RESULTS TSS (mg/l)	FIELD DATA* TSS (mg/l)
1T	1030	0.5		5.5	15
1M		6.5		3.6	5
1B		13.0		6.7	20
2T	1050	0.5		12.0	20
2M		6.0		32.3	10
2B		12.0		18.2	10
3T	1057	0.5	6.0	34.0	50
3M		6.0	7.0	43.1	100
3B		12.5	19.0	78.1	300
4T	1112	0.5		13.5	5
4M		5.0		7.8	5
4B		9.5		7.8	10
5T	1129	0.5	1.0	7.6	20
5M		6.0	3.0	14.6	10
5B		12.5	15.0	69.2	150
6T	1148	0.5	1.0	9.7	5
6M		2.0		-	10
6B		4.0		-	50

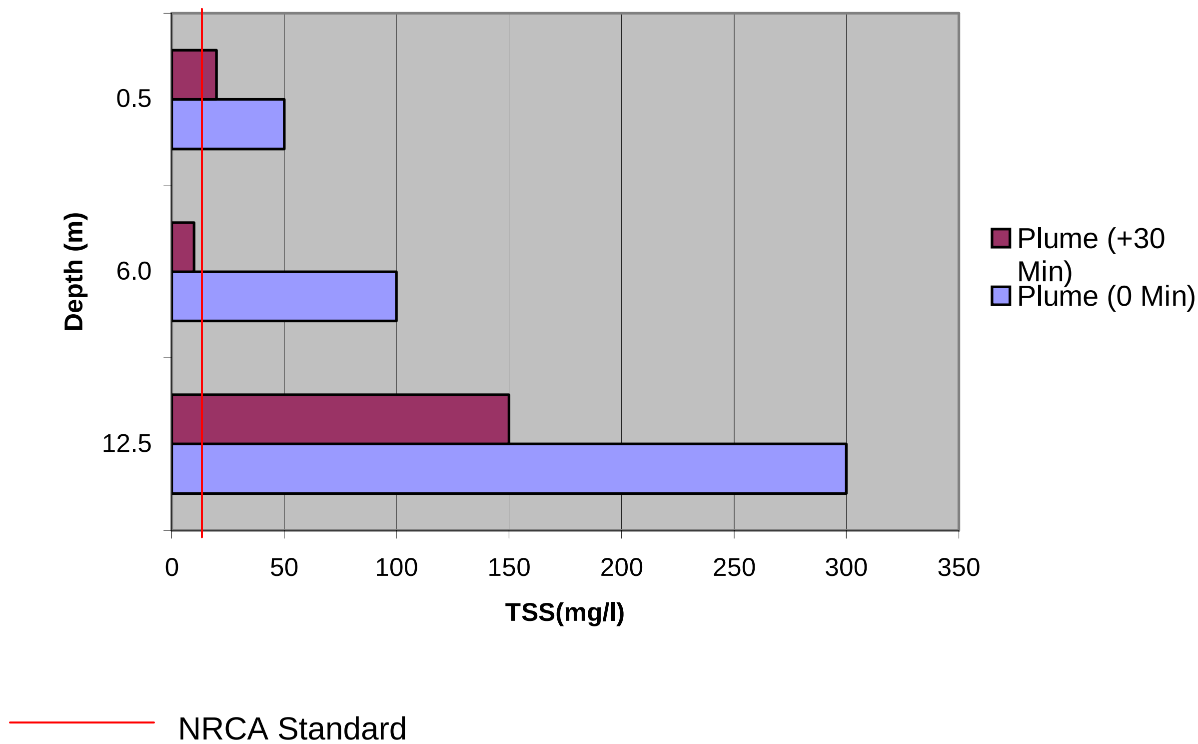
Field Data

Field data collected by Jan De Nul on March 11 indicated a range of 5 – 300mg/l for TSS at the sites monitored. The highest values were determined for Station 3, the dredge site.

At the dredge site TSS was 50mg/l at the surface, 100mg/l at middle depth (6.0M), and 300mg/l at the bottom (12.5M). At this same site approximately thirty minutes later, the values were significantly reduced to 20mg/l at the surface, 10mg/l at middle depth, and 150mg/l at the bottom (Figure 3).

In the wake of the Heinrich, Station 2 TSS was determined to be 15mg/l at the surface, 5mg/l at middle depth (6.5M), and 20mg/l at the bottom (13M).

Figure 3 : TSS Profile at Dredge Site March 11



At Station 3 - the plume north of the dredge site, TSS was determined to be 20mg/l at the surface, and 10mg/l below the surface.

At Station 4 (west of Delbert Sicard beacon), TSS was determined to be 5mg/l at surface and middle, and 10mg/l at the bottom.

At Angel beacon (Station 6) TSS was 5mg/l at the surface, 10mg/l at middle depth (2.0M) and 50mg/l at the bottom (4.0M).

Data from the **fixed stations** indicated a range of 20 – 200mg/l TSS at Middle ground. For March 4, TSS was around 50mg/l increasing to 200mg/l prior to cleaning on March 5. Subsequent to cleaning TSS reading dropped to around 20mg/l increasing to 160mg/l at around 1100 on March 7. TSS remains high even after cleaning on March 8. After cleaning on March 9 however, TSS drops to 20mg/l through March 10.

At Bustamante beacon the range for TSS -was 5 – 40mg/l throughout March 4 to March 10.

CONCLUSION/ENVIRONMENTAL IMPACT

Results indicate that effects of the dredging were confined to the channel. The effect was not noticeable at the sampling location to the west of the dredge site or at Angel beacon.

The significant fall off in TSS at the dredge site over a 30 minute period indicates that the impact from dredging on water quality is significant for a relatively short period. The fact that the bottom values are also significantly higher than at the surface suggests that much of the disturbed material settled rapidly.

Data from the fixed stations suggest that impact from TSS is greater at Middle Ground.