FULL-SCALE UP-FLO® STORMWATER FILTER FIELD PERFORMANCE VERIFICATION TESTS

by

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ABSTRACT

The Up-Flo® Filter is an innovative high-rate, small footprint, stormwater treatment device based on upward filtration technology. It was originally developed by environmental engineers at the University of Alabama with grant support from the U.S. EPA-funded Small Business Innovative Research (SBIR) Program and commercialized by Hydro International. Prior data was collected and the performance was evaluated under different conditions and scales during SBIR phase I and phase II testing, pilot-scale field testing, full-scale one module testing, and full-scale six module testing. These data verified the expected Up-Flo® Filter treatability for solids, inorganic nutrients, bacteria, and metals in stormwater runoff.

The primary objective of this research was to extend the field performance verification tests of a full-scale six-module Up-Flo® Filter using the Hydro International CPZ Mix ™ that were initially conducted by Dr. Noboru Togawa. Hydraulic performance observations through a one-year monitoring period indicated that about 74% of the total flow was completely treated with no bypass. The maximum bypass observed was about 50% under the most intense rains having about 5 in/hr peak rain intensities. The bypassed flows received partial treatment through sedimentation in the filter's sump and floatable control by the siphon bypass. The

effluent samples collected blended flows and therefore consider the combined effect of complete treatment and the partial treatment of the bypassed flows. The maximum treatment flow rate (before any bypassing) was about 150 GPM (25 GPM per module) for the first 9 months of the monitoring period (totaling about 34 inches of rainfall) and then dropped to about 50 GPM for the duration of the monitoring period. Therefore, the media bags should be replaced after about 30 inches of rainfall.

The flow-weighted TSS removals (for all 50 storms) were about 88%, with an average effluent concentration of about 21 mg/L. The influent median particle size was about 300 µm, with a median specific gravity of about 3.0 g/cc, while the effluent median particle size was about 40 um, with a median specific gravity of about 1.6 g/cc. Particles up to about 3 µm had removals of about 35%, increasing to about 70% for particles in the range of 3 to 120 µm, and more than 90% for larger particles. High reductions (58 to 100%) were observed for total Cr, Cu, Pb, and Zn. Moderate reductions (about 50%) were observed for *E. coli* and enterococci, while low reductions (22 to 34%) were observed for P and N compounds.

DEDICATION

For my dear parents, Linzhi Cai and Yun Liang, who offered me unconditional love and support through my life

For my beloved wife, Xiuping Chen, who always encouraged and stood with me in difficulties and each step of the way

For my advisor, Dr. Robert E. Pitt, who showed me the light in the darkness and enlightened me the direction of future

LIST OF ABBREVIATIONS AND SYMBOLS

AL	Alabama
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
Cd	Cadmium
CI	Confidential Interval
cm^2	Square Centimeter
COC	Chain of Custody
COD	Chemical Oxygen Demand
COV	Coefficient of Variation
Cr	Chromium
Cu	Copper
DQI	Data Quality Indicator
ETV	Environmental Technology Verification
GPM	Gallons per minute
g/L	Grams per Liter
HDPE	High-density polyethylene
IDF	Intensity, Duration and Frequency curve
L	Liter

MDL	Method Detection Limit
mg/L	Milligrams per liter
mL	Milliliters
mm	Millimeters
NJCAT	New Jersey Corporation for Advanced Technology
NPS	Nonpoint Source
NSQD	National Stormwater Quality Database
NTU	Nephelometric Turbidity Units
PAHs	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PSD	Particle Size Distribution
PSH	Penn State Harrisburg
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPD	Relative Percent Difference
SBIR	Small Business Innovative Research
SSC	Suspended Solids Concentration
TARP	Technology Acceptance Reciprocity Partnership
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

μm	Micrometer
U.S. EPA	United States Environmental Protection Agency
Vs.	Versus
WinSLAMM	Windows Version of the Source Loading and Management Model
Zn	Zinc

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In the final stage of this research, I would like to give my best regard again to all the faculty and staff of Department of Civil, Construction, and Environmental Engineering for your full support that has contributed to the success of this project.

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CHAPTER 1

INTRODUCTION

1.1 Challenges of Urban Stormwater Runoff and Associated Pollutions

As urbanization occurs in developing areas, the amounts of impervious surfaces increase. These impervious surfaces, such as rooftops, asphalt roads and concrete pavements, cause stormwater runoff to flow through the landscape and drainage systems rapidly instead of being naturally absorbed by soil and plants, which considerably increases the flow velocities and volumes of stormwater runoff. This can result in flooding and erosion. Along with the runoff, pollutants from urban source areas (i.e., gas stations and vehicular parking lots) are moved from the source areas and can enter the receiving waterbodies without proper treatment. The most common pollutions concern include sediments, nutrients, metals, bacteria and hazardous organic compounds, and they can affect water and sediment quality of the receiving water, destroy aquatic and wildlife habitat, and jeopardize sources of drinking water.

Urban runoff-derived pollution is one of the major water pollution sources, defined as “Nonpoint Source (NPS) Pollution”, which was originally from section 502(14) of federal Clean Water Act in 1987, and demonstrated by the United States Environmental Protection Agency (U.S. EPA) that nationally its extent is much larger than point sources pollution’s discharges (U.S. EPA, 2010). One challenge of urban runoff-derived pollution is that the source areas are diffuse with limited opportunities for centralized processing as for residential sewage treatment (separate storm drainage systems usually outfall to the nearest surface receiving water and are not collected by interceptors for centralized treatment).

Many types of stormwater treatment technologies have been developed to treat urban runoff at source areas and at outfalls from individual drainage areas at different scales. The Up-Flo® Filter is a treatment unit that can be located at critical source areas and is able to treat multiple pollutants with a relatively large treatment flowrate with a small footprint. This device uses sedimentation and filtration technology and is capable of capturing relatively small stormwater particulates and associated pollutants.

1.2 Overview of Up-Flo® Filter

The Up-Flo® Filter is a modular robust, but passive, subsurface filtration system that can be installed into commonly-sized 4-ft diameter catchbasins or precast vaults (for larger drainage areas). It incorporates a combination of treatment technologies including gravitational separation of settleable gross sediments, coarse screening of floatable materials, and upflow filtration through a treatment media mixture incorporating physical filtration along with ion exchange and sorption. Overall, much finer stormwater particulates can be removed compared to sedimentation processes alone at the design treatment flow rates. Each Up-Flo® Filter system can have up to seven filter modules, depending on the annual runoff volume of contributed source areas. Large areas can contain several systems located in treatment vaults for larger source areas. Each filter module has a design hydraulic loading rate of about 25 gallons per minute (GPM).

For typical stormwater conditions, the Up-Flo® Filter has been found to remove at least

80% of total suspended solids during field tests, with variable amounts of treatment for other stormwater pollutants including metals, nutrients, and bacteria. The main advantages of the Up-Flo® Filter is that it is small and can be retrofitted in small areas, significantly decreases clogging problems compared to conventional downflow treatment devices, and has high treatment flowrate capacity with reduced maintenance costs.

1.2.1 Composition

Figures 1 and Figure 2 are a schematic and cross section of the Up-Flo® Filter showing the major components of a typical six-module configuration.

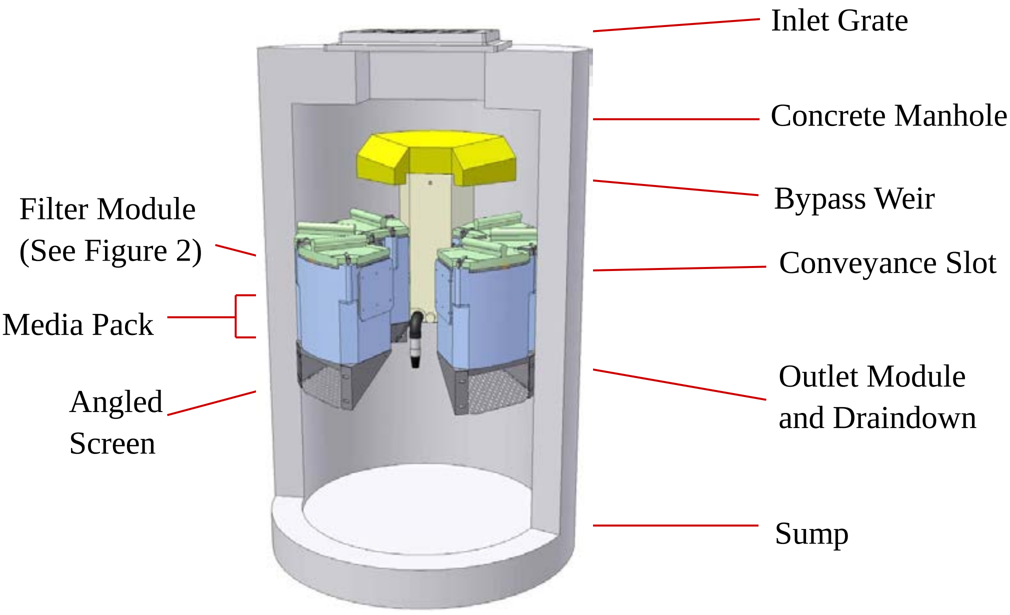


Figure 1: Up-Flo® Filter Components

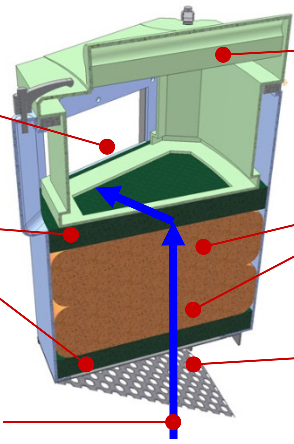


Figure 2: Filter Module Components

Inlet Grate, Sump and Angled Screening. Stormwater runoff is conveyed into the sump (manhole or catchbasin) from a surface inlet or directly from the drainage system's pipe network. The stormwater is retained in a water column above the filter media causing upward filtration through the bottom of the media. The angled screening is designed to capture the floatable materials in the sump, minimizing the chance of ragging and blinding the bottom of the filter by protecting the filter module from the direct path of the upward flow.

Filter Module. The filter module, as shown in Figure 2, consists of two filter media bags, distribution metalla materials, and a restraining lid with a conveyance slot designed as the main outlet weir for the treated flow. Several types of proprietary filter media mistures are available, including CPZ™ (a combination of activated carbon, spganum peat moss, and manganese coated zeolite), CPS™ (activated carbon, spganum peat moss, and filter sand) and HFS™ (Hydro filter sand). The treatment flow rate through each filter module generally ranges from 10 to 25 GPM, depending on the height of the water column above the filter media, but can also be regulated by adjusting the type of media. The distribution metalla material, which is a polyethylene fiber web material, is used to distribute the upward flow evenly across the filter media bags, as well as to perform as the support and baffle for the filter media, provides expansion volume upon compression during high flows, and prevents damage and breaking of filter media bags during the high flow conditions. During this research, the tested full-scale Up-Flo® Filter was fitted with six filter modules (for a total of 12 filter media bags), plus corresponding distribution materials above and below the filter media bags. The standard CPZ™ media was used, along with the addition of 5% iron fillings in order to test for accelerated phosphorus removals.

Outlet Module, Draindown and Bypass. The outlet module is where the draindown and bypass controls are installed and where the mixture flow (blended treated and partially treated) exits the filter system. During a storm event, the treated flow is discharged by the conveyance slot from the filter modules, while the partially treated flow is from the implementation of draindown and bypass. The draindown (with screening inside) is designed to ensure that the water stage in the sump between storm events is lower than the level of filter media, minimizing the development of anaerobic condition and the risk of degradation of filter media, as well as preventing leaching of captured pollutants from the media. The overflow bypass is siphon-activated and directly discharges the excess flow to the outlet module with partial treatment associated with the catchbasin sump. The hood on the top of the outlet module is also designed to prevent the floatable trash and deris from escaping along with the bypass flow. The bypass flows are mixed with the media treated flows as they exit the filter system.

1.2.2 Operating Processes

During a rain event, the stormwater enters the filter chamber and the sump water stage rises. Larger particles settle quickly to the bottom of the sump and the gross debris and floatables are separated by the angled screens placed below the upflow filter modules. The flow continues to rise and flows through the screens to the filter module. This rising water column in the sump provides a driving head and differential pressure between sump and filter module so that the upward flow can go through the restrained filter media. Runoff treatment with high flow rates is accomplished by controlled fluidization of the filter media in the media bags so that fine particulates are captured throughout the surface area and the depth of the media bags. During peak rainfall periods, the flow may exceed the treatment capacity, with the excess bypass flow discharges to the outlet directly from the siphon-activated bypass, while the filter module still keeps treating and the large sediment is captured in the sump due to gravitational settling. Following a storm event, the elevated water column drains down slowly through the depth of the filter media bags through the draindown outlet. During this period, a slight backwashing effect occurs with some of the captured particulates washed from the filter bags, helping to minimize clogging and prolonging media life. The sump water continues to drain to the standing water level below the level of the media by draindown port, thereby allowing the media to drain completely and remain aerated between rains. At the same time, the screened trashes and debris on the angled screens are also released by the downward flow of the water and then settle into the sump.

1.2.3 Maintenance

Routine and periodic maintaining is critical for continued proper functioning of the Up-Flo® Filter. The Up-Flo® Filter design allows for convenient inspection, monitoring and clean-out procedures. Both routine maintenance and periodic clean-out of old filter media bags and distribution metalla materials are necessary as the maintenance requirements. One aspect of this research was to determine the life of the media bags before they required replacement and how long the sump could operate before requiring cleaning.

Routine maintenance includes general inspections in addition to floatables and possibly sediment removal. Routine maintenance does not require access to the filter chamber, but a vacuum truck is needed for sump sediment removal. A wide central opening, as shown in Figure 3, is used for access during these maintenance activities. Less-frequent periodic maintenance includes replacement of filter media bags and distribution metalla materials, plus sediment and floatables removal. The periodic maintenance interval is about once per year in most areas of the US, but can be somewhat more frequent in areas having larger rainfall. More filter modules will increase the maintenance interval, depending on the nature and size of the contributing drainage area.

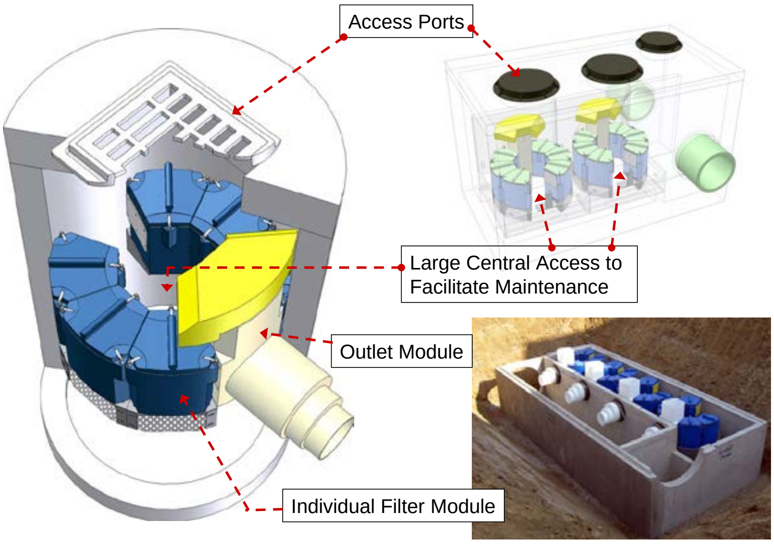


Figure 3: Configurations Showing Access for Maintenance

1.3 Research Objective

The primary objective of this research is to conduct field testing to verify the stormwater quality treatment performance of Hydro International's full-scale Up-Flo® Filter having six filter modules using the CPZ Mix™ filter media. These tests extended the monitoring period during actual storm events that was previously conducted by Dr. Noboru Togawa (Togawa, 2011). These tests resulted in obtaining an additional 30 sets of influent and effluent water quality samples and detailed flow data, added to the prior 20 storm event samples collected by Dr. Noboru Togawa. Additionally, sediment accumulation in both the filter chamber and the filter media was also measured at the end of the monitoring period as part of the overall performance demonstration and maintenance frequency evaluation of the whole filter system.

Before this extended monitoring period began, complete maintenance was conducted so that the sump and all the filter components were cleaned, and the old filter media bags and distribution metalla materials were replaced by new ones. A series of hydraulic flow tests were also conducted in the field before the storm event monitoring to determine the hydraulic capacity of the Up-Flo® Filters by recording and analyzing different sump stage and effluent flowrates under known conditions (using pumped water from the Black Warrior River, adjacent to the test site).

1.4 Contributions

The main contributions of this research are listed as follow:

- Verify that the full-scale Up-Flo® Filter is able to function under a wide-range of actual precipitation and runoff conditions, with minimal bypassing of large flows;
- Evaluate the frequency, intensity and duration of bypassing for different storm events, and verify the draindown functions during the complete monitoring period;
- Verify that the Up-Flo® Filter is able to sustain long-term treatability for specific pollutants, especially for particulate constituents;
- Evaluate the maintenance schedule required for proper functioning of the Up-Flo® Filter.

CHAPTER 2

LITERATURE REVIEW OF STORMWATER TREATMENT BY UP-FLOW FILTRATION

2.1 U.S. EPA Small Business Innovative Research (SBIR) – Phase I

From October, 2002 through July, 2003, an initial project funded by the US EPA's Small Business Innovative Research (SBIR) program was conducted to further test the upflow filtration for stormwater treatment (U.S. Infrastructure Inc., 2003). This phase 1 project was comprised of laboratory-scale and pilot-scale testing, mainly focusing on hydraulic and specific pollutants performance for different filter media.

During the laboratory-scale testing, columns examined different types of filtration media and mixtures under controlled flow rates and pollutant loadings. Four different media were used, including fine (sandblast) grade sand, compost-sand mixed media, peat moss-sand mixed media, and coarse sandbox play sand. The sand used for the mixtures was equal in volume to the media (compost and peat moss), serving to maintain a relatively consistent hydraulic conductivity between the different filters and provide structural support to minimize compaction and premature failure of the media.

The filter columns were constructed using one-liter glass tubes with 51 mm inner diameters and 20 cm^2 cross-sectional areas. The filter media had a depth of 12 inches (30 cm) and was restrained by 7.5 cm layers of gravel placed above and below the media in the columns to minimize the filter media from entering the upflow exit and to control bed fluidization. Fiberglass window screen material was placed surrounding the gravel on the bottom to prevent the gravel from blocking the inlet. A sump was also provided in the upflow entrance so that large solids in the inflow could settle into the sump before the column inlet, simulating the concept of the future upflow filtration system.

The first testing used pumped tap water with 500 mg/L clay having a nominal diameter of less than 200 μm (test material prepared by sieving local clayey soils). Both the influent and the effluent were analyzed for turbidity, total solids, and particle size distributions. The testing continued until breakthrough or clogging was observed. The results showed that the treatment flow rates for the different tested media mixtures were not significantly diminished until breakthrough occurred. The results also showed that both mixed media types had the best removal performance for turbidity, while the peat-sand mixed media had the greatest total solids removal (consistently >60% before breakthrough). The testing of dissolved pollutant removals using these filter media indicated that the peat-sand mixed media had the best performance for metal removals at low influent concentrations.

For the pilot-scale testing, Star Lake, a stormwater detention pond located in Hoover, Alabama, was used for extended filter runs. This pond received runoff from an adjacent medium-density residential area and some commercial areas. The drainage area is about 150 acres, and the pond is about 4.6 acres. The filtration columns for the testing were constructed using large 55 gallon Nalgene polyethylene tanks. The filtration media setups were similar in column height as the laboratory-scale testing, but the diameters of the tanks were about 18 inches (46 cm). A floating pump was used to convey the pre-settled stormwater from the pond through flow-measuring manifolds to each filter column. During the test period, eight filtering runs were conducted, with each lasting between 5 and 8 hours. Samples were collected at both influent and effluent for pollutant removal analyses (solids, nutrients, metals, bacteria and particle size distribution), along with measurements of media retention and head loss changes. The overall pollutant removal performance during this testing phase were compared to earlier downflow filtration tests conducted at the same location using similar test setups conducted previously (Clark and Pitt, 1999; Clark, 2000). The pollutant removal results were found to be generally similar for both upflow and the downflow filtration, but with the notable benefit that the head losses in the upflow filtration setup were significantly reduced, allowing longer operating lives and better structural stability of the upflow filtration media.

2.2 U.S. EPA Small Business Innovative Research (SBIR) – Phase II

Following the successful SBIR phase 1 testing, SBIR phase 2 funding was obtained by researchers of University of Alabama to further commercialize upflow filtration (Pitt and Khambhammettu, 2006; Khambhammettu, 2006). A prototype full-scale upflow filter with CPZ Mix™ filter media (a mixture of bone char activated carbon, sphagnum peat moss, and manganese coated zeolite) was tested during actual rain events. The test site was a retrofitted catchbasin located in the parking lot of Tuscaloosa City Hall in Tuscaloosa, Alabama. The runoff originated from a 0.9 acre drainage area that included roofs, parking lots and storage areas. The prototype upflow filter installed in this catchbasin had a design treatment filtration rate of about 25 GPM that was only about 0.25X of the optimal size needed. This subjected the prototype device to a wide range of flow conditions, including relatively large flows that would not have been possible in the short study period. The treatment filtration rate at the test site required for treatment 90% annual flow was estimated to be 100 GPM, while the average runoff flow for the observed rain events was about 44 GPM (NJCAT, 2008). The testing conducted in this phase consisted of two phases: controlled sediment and flow tests and performance testing under actual storm events over a 10-months period.

During the controlled sediment removal tests, particulate solids with different known concentrations and particle sizes were manually fed into the influent water during different flow rate conditions. The test water was obtained from a metered adjacent municipal fire hydrant. The water depths in the sump before the filter were also measured to determine the head loss of the prototype device. The test sediment used was a mixture of equal weight fractions of Sil-Co-Sil 250, Sil-Co-Sil 106, coarse sand, and fine sand, resulting in particle sizes ranging from about 0.45 µm to 2,000 µm. The fire hydrant was used as a stabilized influent flow source, and the tests were conducted at three different flow rates: about 27 GPM as a "high" flow rate (the maximum the hydrant could deliver), 15 GPM as a "medium" flow rate and 5 GPM as a "low" flow rate. The influent particulate concentration were also controlled during each of these three flow rates at about 500 mg/L, 250 mg/L, 100 mg/L and 50 mg/L.

Effluent subsamples were manually collected every one minute using a dipper grab sampler and placed in a churn sample splitter during each 30-minute test period. One liter samples for each of the three different influent flow rates at each influent sediment concentration were analyzed for sediment and particle size, for a total of 12 sets of samples analyzed. The test results showed that the prototype full-scale upflow filter had excellent sediment removal performance (all greater than 80% reductions) for the test sediment for all influent concentrations at all influent flow rates. The results also indicated that the test sediment percent removal increased as the influent flow rate decreased, as expected, with one exception due to sample variability.

For testing during actual storm events, influent and effluent flows of the prototype upflow filter were sampled simultaneously using two ISCO 6712 programmable automatic samplers, along with YSI 6600 water quality sondes. During the monitoring period (February 2 to November 21, 2005), 31 storm events occurred with 10 events sampled. Several portions of events were separately evaluated for a total of 24 paired samples analyzed. The average overall removal performance for total suspended solids (TSS) was 74%, and indicated that the removal of particulate pollutants was highly dependent on the influent TSS concentration, as well as the flow rate (Pitt and Khambhammettu, 2006). At the end of the monitoring period, the sediments in the sump were collected and analyzed to calculate the mass balance, considering the larger particles that are not well captured by automatic sampler. The overall particulate removal performance of the filter system, considering the captured sump sediments, was calculated to be about 80%.

2.3 Hydro International Laboratory Testing

Following the U.S. EPA-funded SBIR 1 and 2 testing, Hydro International commercialized and improved the prototype under the SBIR commercialization option. They developed a modular filter system that retained the main design components, such as the sump, bypass weir, filter media options, and debris screening. Laboratory studies were conducted at the Hydro International test facility in Portland, ME, using a full-scale single filter module setup fitted into a 4-ft by 4-ft square chamber having a 2-ft depth sump. This setup was used to evaluate effluent water quality and hydraulics under controlled influent conditions. Four different media mixes (Filter Sand, Hydro International's CPZ Mix™, CPS Mix™ and Perlite) were tested, with the research mainly focusing on the CPZ Mix™ media.

The test facility set up used a submersible 3-inch Flygt pump that delivered test water from a 23,000-gallon clean water reservoir through an 8-inch PVC pipe network to the open top of the filter chamber. The 8-inch PVC delivery line was equipped with clear standpipes and a Hershey VP-820 butterfly valve that redirected flows in excess of the desired influent flow rate of 25 GPM back into the clean water reservoir. A flanged 12-inch outlet pipe delivered effluent from the test chamber to a large underflow sedimentation basin. Water from the underflow sedimentation basin was redirected back to the clean water reservoir by two submersible 2-inch Flygt pumps. Hydraulic performance evaluations were conducted by determining the filtration rate (the amount of time required for the filter effluent to fill two cubic foot increments of the underflow sedimentation basin) vs. water depths of the driving head on the filter.

TSS removal efficiency tests were implemented using the test water that had specific particulate concentrations and particle sizes added. Test TSS concentration of 200 to 300 mg/L were used by mixing Sil-Co-Sil® 250 into the test water using feeder screw hoppers directly into the 8 inch PVC water lines (Hydro International, 2005). Additional TSS removal tests were conducted using Sil-Co-Sil® 106 as the test sediment having concentration ranging from 110 to 300 mg/L (Hydro International, 2007). Sil-Co-Sil® 250 has over 90% of the particles less than 150 µm in diameter and 50% less than 45 µm, while Sil-Co-Sil® 106 has particles with 100% of the particles smaller than 212 µm and 75% of particles smaller than 45 µm.

The influent delivery line discharged the test water with the particulates directly into the open top of the filter chamber at a set flow rate of 25 GPM. All of the TSS removal tests were conducted at the driving head of 20 inches. After the test water had been fed to the test chamber for 15 minutes (filter status was assumed to be steady at this time), simultaneous grab samples from both the influent and effluent flows were collected at one-minute intervals and analyzed. Suspended sediment concentration (SSC) analyses followed the SSC Test Method 2 Filtration in ASTM, 1999, D 3977-97. Throughout testing, the water levels in the filter chamber were also continuously monitored to note if the water level was changing, confirming that the filtration rate was operating as desired at 25 GPM.

The test results (Glennon et al., 2006 and Andoh et al., 2007) indicated the flow rate through the CPZ Mix™ was determined to be 21 GPM/ft^2 of filtration surface area at an operating head of 20 inches, consistent with the flows found during the SBIR prototype tests. Tests at different driving heads showed that the flow rates through the filtration media is linearly dependent on the height of driving head in the filter chamber.

The results of the particulate removal testing showed that the Up-Flo® Filter with a CPZ Mix™ media removed over 94% of Sil-Co-Sil® 250 and 87% of Sil-Co-Sil® 106 during average flow rates of 1.6 L/s (25 GPM) per filter module. Dixon's Q tests showed that there was a 99.9% confidence of no outliers in the influent and effluent sample sets. ANOVA analyses showed that the effluent sample concentrations were significantly different from the influent sample concentrations with >99.9% confidence.

Field testing done by Khambhammettu (2006) in Alabama showed that the prototype Up-Flo™ Filter was capable of removing over 95% of particles greater than 30 µm, 80% of particles from 20 to 30 µm, and at least 50% of particles from 1 to 10 µm. The percentage of material removed for the given particle size bands from the field work suggests that the Up-Flo® Filter can be expected to remove greater than 80% of Sil-Co-Sil 250, which was consistent with the laboratory tests results.

2.4 U.S. EPA Environmental Technology Verification (ETV) Testing

Controlled laboratory testing of the commercially available full-scale one filter module configuration was conducted at the Penn State Harrisburg (PSH) Environmental Engineering Laboratory in Middletown, Pennsylvania under the U.S. EPA's Environmental Technology Verification (ETV) Program. The objective of this testing was to verify the Up-Flo™ Filter's treatment performance for a challenge water containing a variety of contaminants, including sediments, hydrocarbons, water-soluble organics and fertilizer, as well as to evaluate the hydraulic capacity under a variety of contamination and flow conditions (Penn State Harrisburg, 2007). The PSH Wastewater Research laboratory is a physical testing laboratory which is capable to perform medium scale (up to 50 GPM flow) testing for this research. The tested Up-Flo™ Filter was installed in a cuboid tank having a 24 inch sump depth, outlet with 12 inch diameter, and an 18 inch acrylic viewing port. The height of the bypass was 21 inches of driving head. Throughout the testing, the test chamber was fed by city water through the open top of the tank, simulating grated-inlet field conditions. All of the sampling was done by manual grab sampling, reducing the problems associated with the inability of automatic sampler for capturing large particles. The testing was accomplished in four phases: performance under intermittent flow conditions (Phase I), performance under continuous flow conditions (determination of capacity of the unit) (Phase II), performance under varied hydraulic and concentration conditions (Phase III), and contaminant capacities at high hydraulic throughput (Phase IV).

In Phase I testing, an intermittent flow rate of approximately 11 GPM was used for a many-hour testing period. This intermittent flow was turned on and off every 15 minutes, with 16 flow periods for analyses (15 minutes “ON” and 15 minutes “OFF” as one flow period). The effluent flow rate was also recorded during the “OFF” period to determine the draindown time. Influent and effluent samples were collected after every 500 gallons of flow treated by manual grab sampling. Samples were analyzed for solids and phosphorus.

During the Phase II testing, a series of continuous flow conditions were conducted until the capacity of the filter media for suspended solids and/or phosphorus was likely exceeded. Each flow condition maintained 12 hours/day with 16 GPM flow rate. Increasing water elevations in the test tank while the flow rate is constant was an indicator of clogging of the filter media. Samples were also collected manually for every 10,000 gallons during this phase and analyzed for TSS, SSC, and phosphorus.

During Phase III, new filter media was used and the hydraulic capacity of the unit was tested using both clean water and polluted water. The drain down port was plugged before the test and the flow was increased beyond the bypass level to determine the maximum treatment flow rates before and after bypassing occurred. During testing using polluted challenge water, chemical feed pumps and hopper were used to add the stock solutions to the fresh water during two conditions: certain concentrations for all constituents and spike concentration loading (four times higher than used previously) for solids and phosphorus. These conditions were designed to evaluate the removal performance at different pollutant concentrations.

After the Phase III tests, the filter unit was cleaned and the media pack replaced for the last tests. The Phase IV testing was similar to the Phase II testing, with the exception that the treatment performance and capacity was evaluated under a very high continuous hydraulic loading (about 32 GPM), which definitely overflowed the bypass level. The test period was for 12 hours and grab samples were collected every 30 min for the first 2 hours and then once per hour.

These test results demonstrated that the Up-Flo™ Filter had solids removal rates ranging from 50% to 90% for the widely varying test conditions. Chemical Oxygen Demand (COD) analyses, representing hydrocarbons, indicated large ranges of removals, from negative to >85%, which was similar to the observed TP removals. The Up-Flo™ Filter system was shown to be capable of treating up to 35 to 40 GPM flow with no bypassing per filter cartridge, but treatment efficiency is notably decreased when during high hydraulic flows. Premature failures occurred during the Phase II and IV testing, resulting in the very low removals, likely due to the constant high pressures on the media without typical intermittent decreasing flows that occur during actual storms.

2.5 Full-Scale Up-Flo® Filter Monitoring during Storms

The field verification testing of Hydro International's Up-Flo® Filter had been conducted by researchers at the University of Alabama for several years (Togawa, 2011). The purpose of this field testing is to examine the stability and treatability of a full-scale six-module configuration under a wide range of hydraulic and pollutant challenges during controlled tests and actual storm runoff conditions. The test site was at the Riverwalk parking lot near the Bama Belle on the Black Warrior River in Tuscaloosa, Alabama. The drainage area of the test site is approximately 0.9 acres, including a parking lot, driveways, sidewalks, and a small landscaped area. The site also had no other existing stormwater runoff control with only one inlet and outlet.

Initial field analyses were conducted to evaluate local meteorological and hydrological conditions, and determine the background information of water quality and pollutants on the site. Manual grab sampling was used to collect random runoff samples during events for the analyses of sediments, total dissolved solids (TDS), pH, conductivity, turbidity, nutrients, chemical oxygen demand (COD), metals, bacteria and particle size distribution (PSD). A total of 7 storm events were monitored and analyzed during the period from October, 2007 to April, 2008 before the installation of the treatment device. The results of this initial field analysis indicated that the Up-Flo® Filter was likely to treat more than 90 percent of the annual flows during a typical rain year at the 0.9 acres test site, with less than 10 percent flows being bypassed. The results also showed that the coefficient of variation (COV) values for most of the targeted constituents were less than 0.5, but significant first-flush effects were observed for some of constituents, such as turbidity, conductivity and sediment (but surprisingly not for bacteria).

On January, 2009 after the initial field investigation was completed, the full-scale six modules Up-Flo® Filter was installed in a city-owned catchbasin at the test site. Both controlled flow and sediment removal tests were conducted at the test site in late summer of 2009 (Togawa et.al, 2009; Togawa et.al, 2010; Togawa et.al, 2011; Togawa, 2011). During these controlled tests, both the CPZ™ Mix along and filter sand media were evaluated.

The hydraulic flow tests used Black Warrior River water pumped from the adjacent river. The influent water was pumped into a large plastic drum that has two outlets with valves so that the influent flow rate could be controlled and manually measured using a graduated chamber.

Different influent flow rates were used to examine the hydraulic performance and maximum capacity of the Up-Flo® Filter. Once the influent flow rate was changed, manual measurements of sump water stage and automatic readings of effluent flow rate were collected after about 15 minutes ensuring steady hydraulic conditions in the sump stage and effluent flows. Analyses were then conducted to evaluate the filtration behavior based on the relationships between manually and automatically measured water stage, automatically measured effluent flow rate and manually measured influent flow rate.

The methodology used for the controlled particulate removal tests was similar to that used for the hydraulic flow tests, with the test particulates being manually added to the inflowing water at specific rates corresponding to the desired concentrations. The test particulate mixture was comprised of Sil-Co-Sil 250, Sil-Co-Sil 106, coarse and fine concrete sands. The mixture was made based on specific ratios by mass (fine sand: coarse sand: Sil-Co-Sil 106: Sil-Co-Sil 250 = 5: 17: 70: 8) so that a relatively even particle size distribution was created, ranging from about 20 to 2,000 μm. Since Black Warrior River water was used as the base water during these tests, the river also supplied large amounts of finer suspended material that was also evaluated. This mixture was designed to provide sufficient amounts of large particles for the test so the quantification of the particles removal could be accurately determined; it was not intended to represent actual stormwater runoff PSD conditions that generally have smaller median particle sizes. The effluent samples were analyzed using particle size analyses so performance could be determined for many particle size categories independently (as during the full-scale research during actual storm events). During the controlled sediment tests, the influent flow rates (river water) were set at approximately 25, 75, and 150 GPM respectively, for each particulate concentration. The pre-mixed aliquots of dry test sediments were manually fed into the influent pumped river water according to the different desired sediment concentrations (50, 100, 250, and 500 mg/L). Each test was conducted over a 30 minute period, with relatively constant particulate concentrations and flow rates. Manual effluent sampling began after about a 10 minute delay to flush any effects from the prior tests and to ensure steady conditions in the filter. Grab sampling was used to collect effluent sample aliquots every 1 minute and composite in a churn sample splitter during the 30-minute test period. Two samples of 1 L each were placed in sample bottles from the churn splitter for duplicate laboratory analyses for each test. Total solids, suspended sediment concentration (SSC), total dissolved solids (by difference), and particle size distribution (PSD) analyses (all duplicated) were analyzed for each test condition. The results of controlled tests were found to be consistent with the results of previous pilot-scale testing (Pitt & Khambhammettu, 2006), with the filter capturing about 90 to 100% of the particles larger than 30 µm, and about 40 to 90% of the smaller particles, irrespective of the influent solids concentrations. The influent flow rate was found to have a slight influence affecting the rate of sediment capture, but was not statistically significant. The full-scale Up-Flo® Filter had good hydraulic stability during these controlled tests, with highly repeatable regression relationships between treatment flow rate and water depths in the sump.

Monitoring of actual storm events for full-scale Up-Flo® Filter performance began in July 16, 2010. The methodology used during this initial full-scale monitoring was basically the same as conducted during this most recent thesis research, with details presented in Chapter 3. Flow-weighted composite samples were collected by two programmed ISCO 6712 automatic samplers simultaneously from the influent and effluent flows. The samplers were triggered to initiate sampling by the tipping rain gage when 0.02 inches of precipitation was recorded within 30 minutes. Shallow plastic trays were placed at the influent and effluent sampling locations to collect cascading flows falling directly onto the sample intakes to ensure completely mixed samples. The YSI 6600 water quality sondes were also placed in the trays for continuously monitoring the changes in water quality during the runoff events. A pressure transducer for water stage measurements was located in the sump and an ISCO area-velocity sensor was installed in the effluent pipe for flow rate measurements.

The influent and effluent samples were analyzed for a number of pollutants, including: solids, nutrients, metals, bacteria and water quality indexes. A total of 20 storm events were monitored and sampled. These results showed that the full-scale Up-Flo® Filter had statistically significant removals for solids, bacteria, most of the nutrients and metals (many of the metals, especially the dissolved fractions, were below the detection limits for most events, resulting in few quantified values being available for statistical analyses). The average SSC concentrations were about 76 mg/L for the influent and about 22 mg/L for the effluent, which average TSS concentrations were about 62 mg/L for the influent and about 21 mg/L for the effluent. Therefore, the percentage removal rates were on the low side due to the influent concentrations; however, the average particulate effluent concentrations were below 25 mg/L. Because of the low influent concentrations and large numbers of values below the detection limits, the full-scale monitoring during actual rains was extended to obtain additional observations to increase the confidence and power of the performance measurements. The additional test results, combined with these earlier results, are presented in this thesis.

CHAPTER 3

EXPERIMENTAL DESIGN AND TESTING METHODOLOGY OF THE FULL-SCALE UP-FLO® FILTER

3.1 Testing Goal and Objective

The goal of the field testing during this research was to continue to verify the performance of Hydro International's Up-Flo® Filter using a full-scale six filter modules configuration having CPZ Mix™ filter media during storm events. The testing was divided into both hydraulic and water quality phases. Hydraulic performance was determined by monitoring the influent water loading during both controlled and actual storm conditions, and measuring the repeatability of the stage-discharge relationship in the filter system. Water quality performance was evaluated by taking influent and effluent samples during each targeted storm event, following by laboratory analyses for many constituents. Sump sediment sampling and analyses were only conducted at the end of the monitoring period, providing supplemental information and confirmation of water quality performance of Up-Flo® Filter, as well as verifying the maintenance frequency. However, continuous sump accumulations were manually obtained and were also measured using a scour sensor in the sump.

3.2 Complied Demonstration Protocols

The field performance verification testing of Up-Flo® Filter was conducted following the procedures as outlined in the Quality Assurance Project Plan (QAPP) that was prepared by Hydro International with the assistance of UA project personnel. The purpose of the QAPP is to document the procedures used for data collection, processing, and analysis of the Up-Flo® Filter field performance verification. The QAPP was created in accordance with the Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations endorsed by California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia (TARP, 2001, Updated 2003), and TARP Field Protocol for Manufactured Treatment Devices, Protocol for Total Suspended Solids Removal Based on Field Testing (TARP Amendments, 2009). According to the complied demonstration protocols described above, an eligible storm event for this research should meet the criteria as listed below:

1) Have a minimum rain depth of 0.1 inch;
2) Minimum duration of dry period between individual storm events is six hours;
3) Use automatic samplers to collect samples, except for constituents that require manual grab samples;
4) Flow-weighted composite samples covering at least 70% of the total storm flow, including as much of the first 20% of the storm as possible;
5) Rainfall monitoring interval should be 15 minutes or shorter;
6) Quality Control (QC) should be performed on at least 10% of the analyzed samples;
7) At least 10 aliquots (6 aliquots) are needed for each flow-weighted composite sample for the events which the duration is greater (or shorter) than one hour.

3.3 Hydraulic Flow Tests

3.3.1 Objective of Hydraulic Flow Tests

The primary objective of the hydraulic flow tests (after cleaning out the old filter units and the whole filter modules, install new filter bags and new filter modules) was to calibrate the flow rate vs. water stage relationship of the new media bags in preparation of continued performance monitoring under actual stormwater runoff conditions. The hydraulic flow tests were not able to simulate the highly variable influent runoff flow rates during actual storm events. Therefore, stage vs. effluent flows were also continuously monitored and evaluated during the whole monitoring period.

3.3.2 Flow Tests Preparation

Before the flow tests, complete maintenance activities were carried out, including the cleanup of retaining sump material, replacement of old filter media and modules and installation of new filter media, modules and monitoring equipment. The tested Up-Flo® filter was fitted with 6 filter modules and a total of 12 filter media bags, plus corresponding distribution materials above and below the filter media bags. The filter bags used in this research contained the standard CPZ Mix™, with the addition of 5% iron fillings. This is a proprietary mixture of manganese coated zeolite, bone char activated carbon and sphagnum peat moss, plus the iron fillings to test for accelerated phosphorus removals. Both the placement and corresponding weights of each new numbered media bags were recorded before they were installed for purpose of mass balance calculation at the end of the monitoring period. Figure 4 shows some of these preparation activities.

Vacuum truck used to clean out Up-Flo® Filter vault

Used flow distribution material and media bags

Newly installed roto-molded Up-Flo® filter modules

Figure 4: Cleaning Up-Flo® Filter and Replacement of Media Bags

3.3.3 Methodology and Process of Hydraulic Flow Tests

The full-scale Up-Flo® Filter field hydraulic flow tests were conducted with the cooperation of Hydro International engineers on March 27, 2012 at the Riverwalk parking lot near Bama Belle in Tuscaloosa, Alabama. River water from the Black Warrior River was pumped into a large Nalgene drum that has two outlet pipes with control valves, to control the influent runoff flow. This allowed a constant head on the valves and adjustable flows. The fire hose from the pump was directed into the drum, and excess water was allowed to overflow and run down a plastic tarp (that protected the grass slope) and then flowed back into the river.

The flow rate from the drum was determined by timing how long it took to fill up 10-gallon graduated plastic pan. The flow rate for each drum outlet pipe was measured at least three times to determine the average and variation of the flows for each setting. When the water stage in the filter main chamber was stable for the set flow rate, the flow was maintained for about 30 minutes with multiple stage and outflow rate measurements to verify the steady conditions. The water stage was measured manually along with continuous recording of sump water stage by an ISCO 4250 area-velocity flow meter set in the sump to measure water depth and another flow meter at the filter outlet to measure the treated flow rate. These data were used to verify the calibration of the pressure transducer in the influent sump vault. Several flow rates were tested covering the range of conditions that were expected to typically occur during actual storm events.

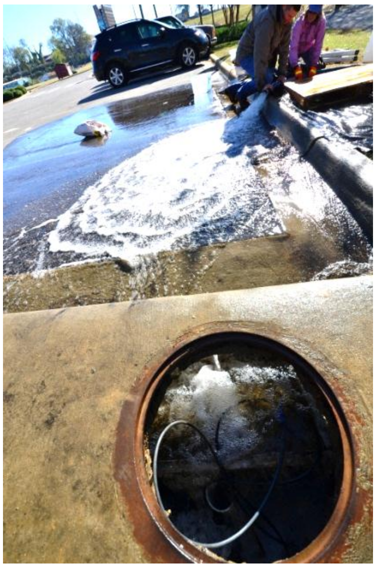
Tests were also conducted at the maximum pump flow rate. The manual flow measurements were not possible, but the outfall area-velocity monitor was used to measure the influent flow rate. The water stage in the filter was also measured manually. After the sump water stage was approximately stable at its maximum depth with the maximum flow rates, the pump was shut off and the lowering of the water level in the sump vault was recorded continuously with time. This provided a composite stage-discharge curve for the multiple outlets. These tests also included measuring the stage through the next day to determine how long the sump water stage requires to reach the minimum water elevation (the draindown port). Figure 5 illustrates the scene during the hydraulic flow tests.

Calibration setup and monitoring equipment shelter

Flow tests of new media bags showing controlled flow

Checking outfall flow monitor (area-velocity sensor) and chamber stage monitor during calibration

Checking stage in stilling well placed in filter chamber for comparison with continuously recording stage monitor



Maximum flow rate and draindown test

Maximum flow at Upflow Filter outfall sampling box

Recording water level drop after completely filling Upflow Filter

Figure 5: Hydraulic Flow Tests Measurements

3.4 Actual Storm Events Field Monitoring

The second-phase field monitoring of the full-scale Up-Flo® Filter during actual storm events began at the Bama Belle test site on March 30, 2012, as the extended evaluation of hydraulic and water quality performance combined with the test results from first-phase actual storms monitoring, providing more confidence for the field performance verification.

3.4.1 Testing Site Characteristics

3.4.1.1 Test Location and Land Use

The test site used for this field research is located at the Bama Belle parking area beside the Black Warrior River in Tuscaloosa, Alabama. The full-scale (6 modules) Up-Flo® Filter tested was installed in a city-owned catchbasin at the test site that was originally retrofitted in early 2009. The total contributing drainage area is about 0.9 acres, and includes asphalt paved parking, concrete sidewalks, asphalt roadways, a small building, and landscaped park areas. The impervious area, mainly consisting of asphalt pavement, was about 68%. The Up-Flo® Filter receives and treats the runoff from these land uses, and discharge the flow directly to the Black Warrior River through a 30 feet long pipe from the filter after treatment. Figure 6 and Table 1 show an aerial photograph and the land uses details of the test site. Figure 7 includes some photographs taken at the test site.

Figure 6: Aerial View of Bama Belle Test Site

Table 1: Land Uses of Bama Belle Test Site

Land Use	Area (ft^2)	Area (acres)	Percentage of Drainage Area (%)
Landscaped park area	12,400	0.29	32
Asphalt parking	11,800	0.27	31
Asphalt entrance road	10,990	0.25	28
Concrete sidewalks	2,100	0.05	5.4
Small roof area	1,300	0.03	3.4
Total drainage area	38,610	0.89	100
Impervious area	26,190	0.60	68
pervious area	12,400	0.29	32


Runoff enters filter inlet through roadside gutter and sheet flow


Asphalt pavement with apparent vehicle oil and grease on the surface


Only one building at the site with small roof area


Slight slope in the parking entrance road directs the runoff into the parking area

Landscape with concrete walkway surrounds the parking area

Large fraction of impervious asphalt pavement and crosswalk

Exposure of some soils beside the roadway due to the activities of ants

Ant hills beside the filter inlet may affect the influent quality during storms

Figure 7: Bama Belle Test Site Photographs

3.4.1.2 Local Meteorological Conditions

Tuscaloosa has a typical southeastern US humid subtropical climate. During the spring, fall and winter seasons, warm, moist air from the Gulf of Mexico interacts with cooler, drier air from the North, creating precipitation. Hurricane season starts at the beginning of spring, which has different rainfall conditions than other seasons of the year. Hurricanes may move from the south to the north from the Gulf or even from the east to the west when it is landing.

Figures 8, Figure 9 and Table 2 show the average monthly temperature and precipitation, and seasonal climatic information. The average monthly temperatures in Tuscaloosa, shown in Figure 8, range from about 45 ˚F to about 90 ˚F over the year. Figure 9 indicates that most precipitation occurs in March, with about three inches of rainfall on average occurring during the relatively driest period (October). Tuscaloosa has rare measurable snowfall, with most years receiving none. Table 2 shows that there is an average of about 53.6 inches of total rainfall over a year. Winter (December, January, and February) and spring (March, April, and May) contributed about 58 percent of total annual rainfall, while summer (June, July, and August) and fall (September, October, and November) periods have less rainfall.

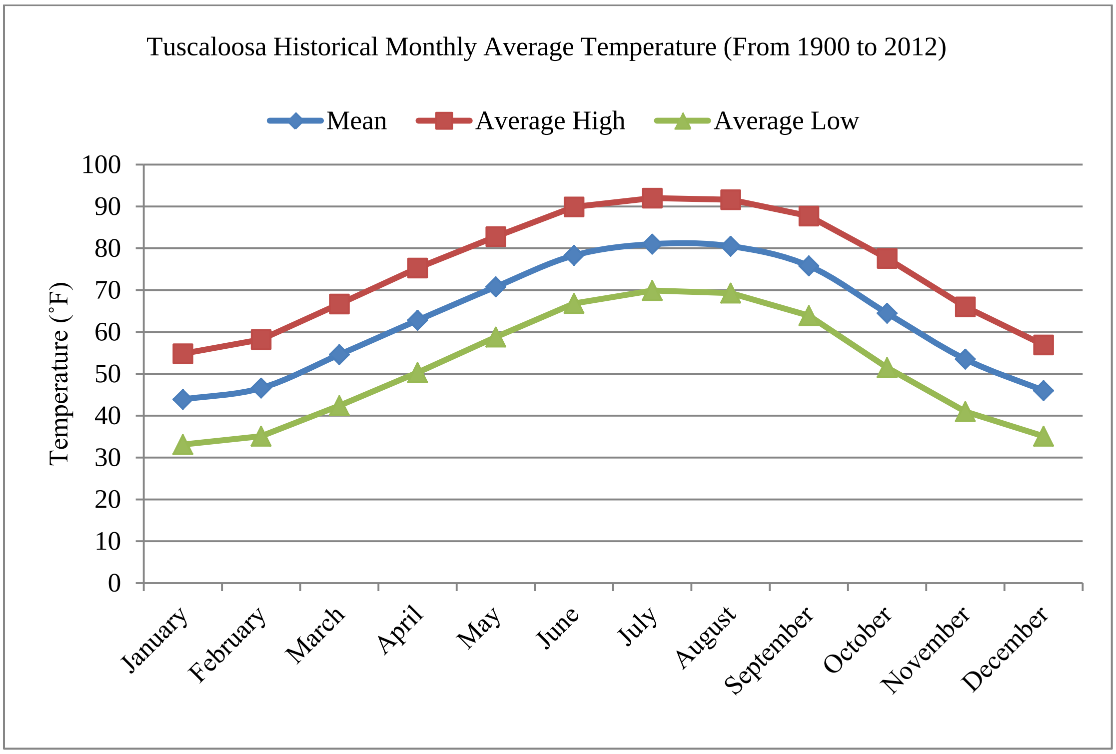


Figure 8: Tuscaloosa AL Historical Monthly Average Temperature (1900 to 2012)

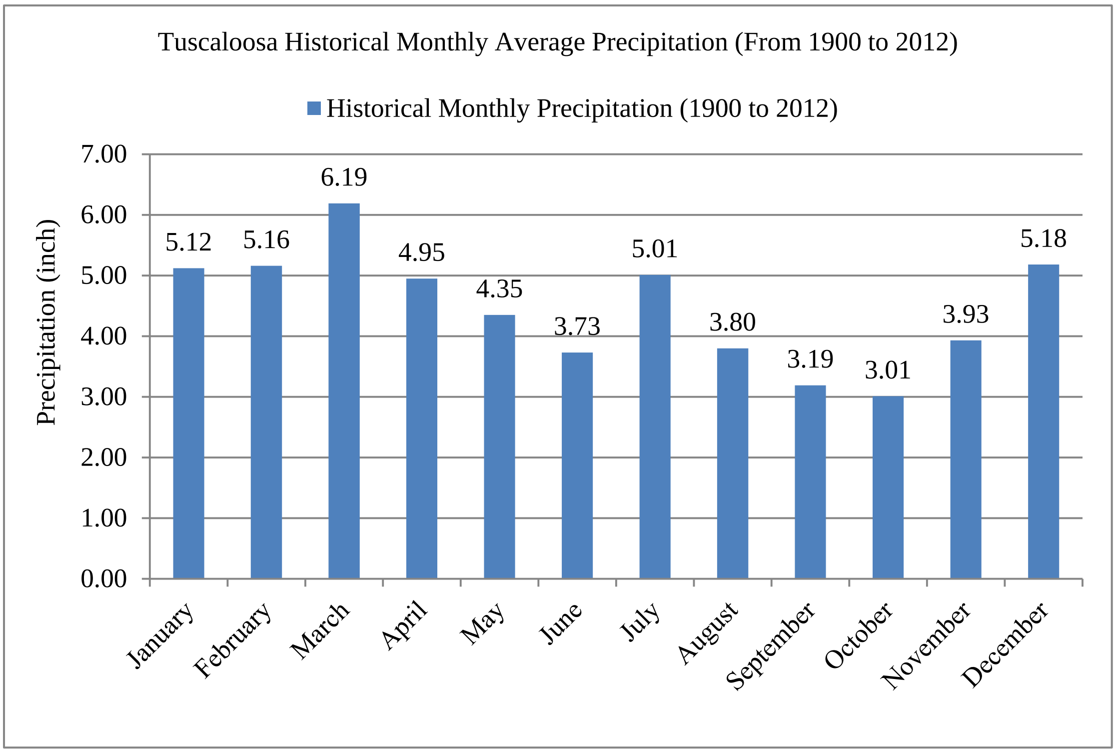


Figure 9: Tuscaloosa AL Historical Monthly Average Precipitation (1900 to 2012)

Table 2: Tuscaloosa AL Seasonal Temperature and Precipitation

TUSCALOOSA OLIVER DAM, ALABAMA (1900 to 2012)						
	Temperature (˚F)			Precipitation (Inch)		
	Mean	Average High	Average Low	Mean	Average High	Average Low
Winter	45.5	56.6	34.5	15.47	26.17	6.57
Spring	62.7	74.9	50.5	15.49	33.97	5.43
Summer	79.9	91.2	68.7	12.54	25.17	4.59
Fall	64.6	77.1	52.2	10.13	28.67	2.3
Annual				53.63	113.98	18.89

Figure 10 is the intensity-duration-frequency (IDF) curve for the design storms for Tuscaloosa, AL area, prepared using the Alabama Rainfall Atlas by Dr. S. Rocky Durrans of the University of Alabama. It shows the rain intensity for 2 to 500-year inter-event periods and for 5 minutes to 48 hours of rainfall durations (corresponding to the appropriate times of concentration for an area). As shown, the Tuscaloosa area has typical subtropical rainfall characteristics with high rain intensities. A storm event having a fifty percent probability of occurring in any one year (the "two-year" return period) would have about an 8 inch/hour rain intensity lasting for about 5 minutes (the likely time of concentration for small paved areas where the Up-Flo® Filter may be located..

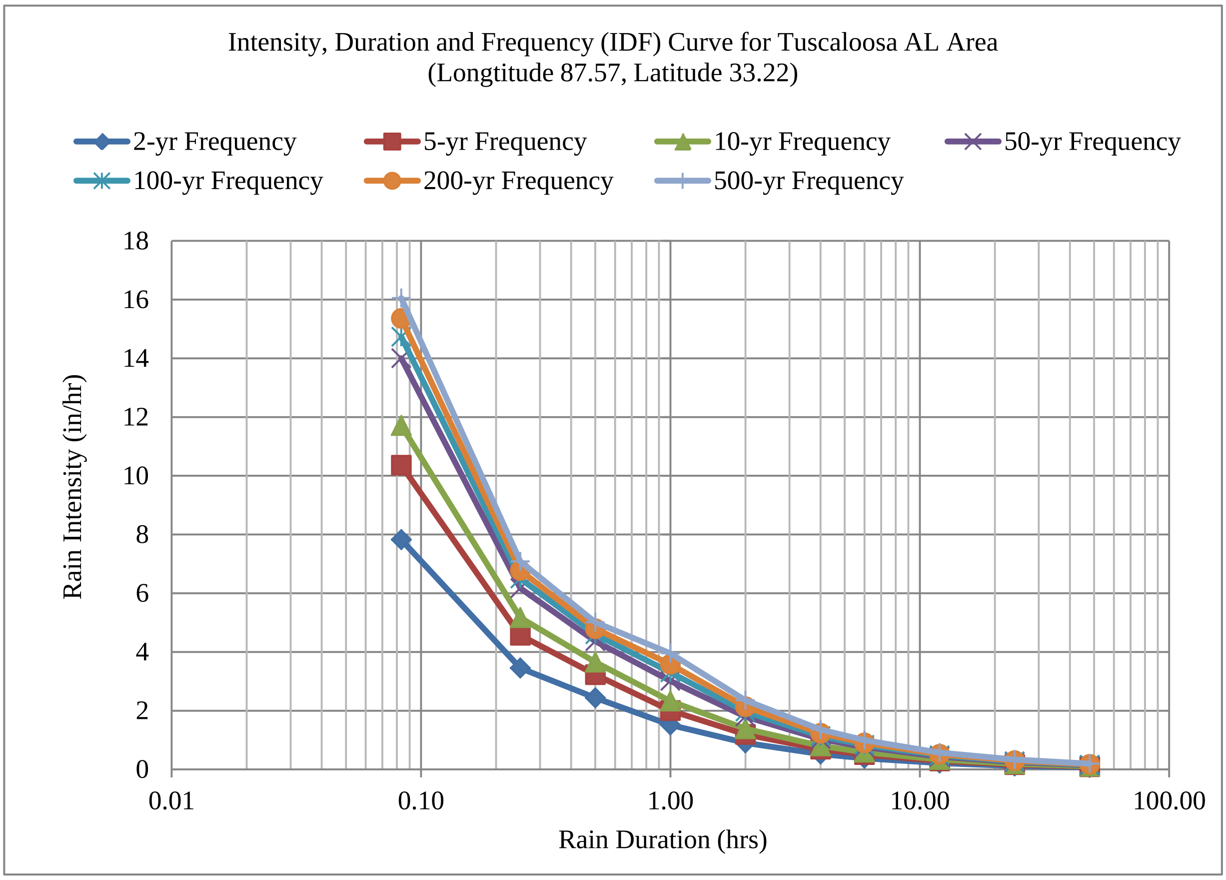


Figure 10: IDF Curve produced by Alabama Rainfall Atlas (S. Rocky Durrans, The University of Alabama)

3.4.1.3 Water Quality and Pollutant Sources

Initial site evaluations and background water quality monitoring was conducted in 2007 through 2008 before the Up-Flo® Filter was installed (Togawa, 2011). Stormwater runoff samples were obtained by manual grab sampling using a dipper sampler. Each sample was analyzed for several constituents, included: pH, conductivity, turbidity, ammonia, nitrate, chemical oxygen demand (COD), *E. Coli*, Enterococci, sediment, total dissolved solids (TDS), metals, and particle size distribution (PSD). Samples were obtained during seven events.

The results of separate runoff analyses indicated that turbidity and most of targeted constituents had significant first-flush effects, but their concentrations generally had low levels of variation (COV < 0.5) when compared to the National Stormwater Quality Database (NSQD) 3rd version (Pitt et al., 2008). The site had relatively large median particle sizes. The conductivity, turbidity, and nutrients concentrations were generally similar to the NSQD values reported nationally, while copper and zinc concentrations were much smaller than the reported average NSQD values.

3.4.1.4 Runoff and Drainage Hydrology

The hydrology of the test site is critical for designing the capacity of the Up-Flo® Filter. The objective is to treat a large portion of the annual stormwater flow, with an acceptable amount of bypass flow. For this site, treating 90% of the annual flow (with 10% bypassing with partial treatment) was the goal.

Initial hydrological data of the Bama Belle test site had been collected during the monitoring of the first 20 storm events by Togawa (2011). Figure 11 is a plot of the observed 5-minute peak rain intensities and the corresponding instantaneous peak runoff rates. The equation had a coefficient of determination (R^2) of about 0.69, with a highly significant slope term and no intercept. This corresponded to an average rational coefficient of about 0.6, which corresponds well to the site that had a 68% directly connected impervious value.

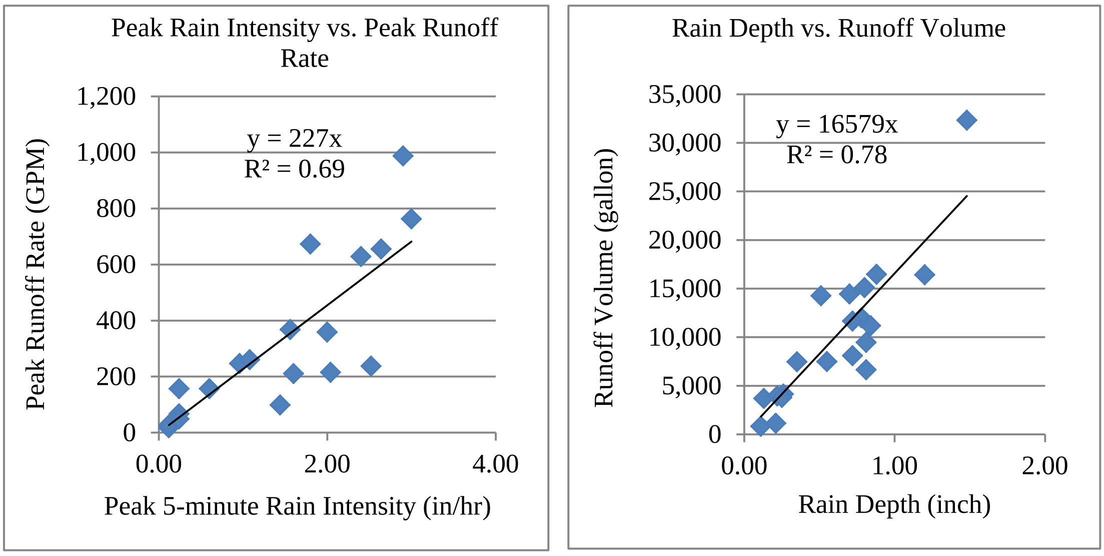


Figure 11: Relationship of rainfall and runoff characteristics for First 20 Monitored Storm Events (Togawa 2011**)**

Hydrological evaluations had also been conducted during prior testing of the pilot-scale filter at the Tuscaloosa City Hall test site (Pitt & Khambhammettu, 2006). Figures 12 and 13 are plots showing the fraction of the annual total flow that would be treated for different treatment flow rates for the City Hall test site. This plot was created using a calibrated version of WinSLAMM for the 0.9 acre test site using the first nine months of the 1999 rain year, which was determined as representative of typical rain year. Figure 13 shows that about 90% of the annual total flow would be treated with a treatment flow rate of about 100 GPM (approximately the design treatment flow rate for the Up-Flo® Filter installed at the Bama Belle test site). Therefore, more than 90% of the total annual flow during a typical rain year is expected to be treated by the full-scale Up-Flo® Filter, with less than 10% as bypass flow.

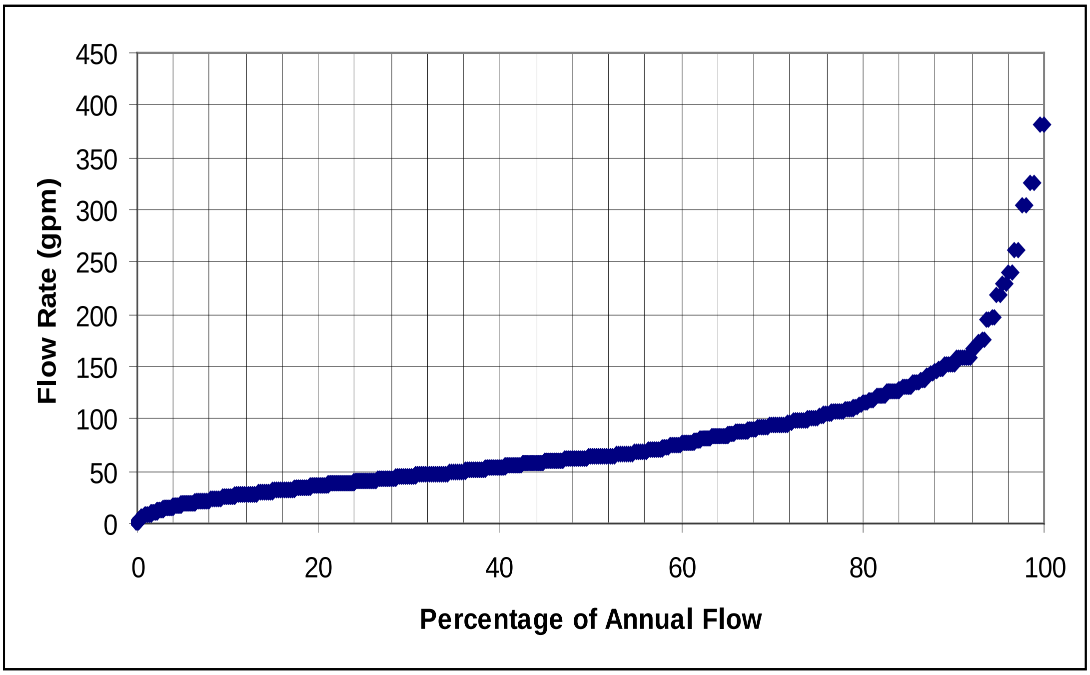


Figure 12: Percentage of annual flows at Tuscaloosa test site with 0.9 acre impervious area (Pitt & Khambhammettu, 2006)

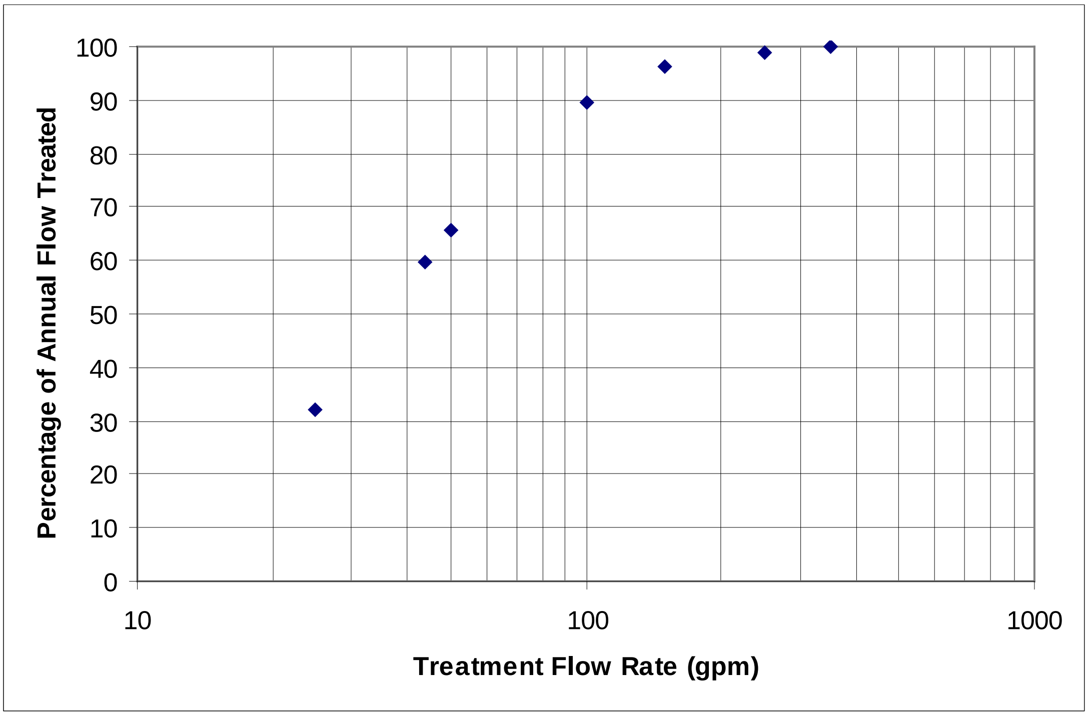


Figure 13: Treatment Flow Rate and Percentage of Annual Flow Treated For Tuscaloosa, AL, Test Site with 0.9 Acre Impervious Area ((Pitt & Khambhammettu, 2006)

3.4.2 Pollutant Constituents Analyzed

Several categories of constituents were monitored during the Up-Flo® Filter evaluation, including solids, nutrients, bacteria and metals. Additional water quality data from continuous YSI 6600 water quality sondes for influent and effluent were obtained. The constituents analyzed were:

- Primary Pollutants/Basic Treatment:
  - Total Suspended Solids (TSS) (Sub-sampled by churn sample splitter and pipetted by magnetic stirrer)
  - Suspended Solids Concentration (SSC) (Sub-sampled by cone splitter)
  - Total Dissolved Solids (TDS) (Particle size <0.45µm)
  - Total Solids (TS) (By summation)
  - Particle Size Distribution (PSD) (By sieving, filtering and Coulter Counter)
- Secondary Pollutants/Enhanced Treatment:
  - Volatile Suspended Solids (VSS)
  - Total/Dissolved Phosphorus as P
  - Total/Dissolved Orthophosphate as P
  - Total/Dissolved Nitrogen as N
  - Ammonia as N
  - Nitrate plus nitrite as N
  - Total/Dissolved Metals (Cadmium, Chromium, Copper, Lead and Zinc)
  - Bacteria (Total Coliforms, *E. Coli*, and Enterococci)
  - Particulate Specific Gravity (Only for the 3 to 250 µm particle size range)

- pH (Sample analyses)
- Turbidity (Continuous monitoring by sonde and sample analyses)
- Conductivity (Continuous monitoring by sonde and sample analyses)
- Temperature (Continuous monitoring by sonde)

Table 3 summarizes the laboratory analytical methods, the method detection limits (MDL), needed preservatives, samples holding time, and analytical laboratory for each constituent.

Table 3: Water Quality Analyses Information Summary (Per sample)

Constituents	Units	Analytical Methods	MDL	Preservative	Holding Time	Laboratory
TSS	mg/L	SM 2540D	1mg/L	Cool 4°C	7 days	UA
SSC	mg/L	ASTM D3977-97B	1mg/L	Cool 4°C	7 days	UA
TDS	mg/L	EPA 160.1/ SM 2540C	1mg/L	Cool 4°C	7 days	UA
VSS	mg/L	SM 2540E/ EPA 160.4	1 mg/L	Cool 4°C	7 days	UA
PSD	NA	Coulter Counter/ sieving and filtering	0.45 µm	Cool 4°C	7 days	UA
Total/Dissolved N as N	mg/L	SM 4500-NH_3 C/ SM 4110B	0.1mg/L	Cool 4°C, H_2SO_4 to pH<2.	28 days	Stillbrook lab
Total/Dissolved P as P	mg/L	SM 4500-P-E	0.02mg/L	Cool 4°C, H_2SO_4 to pH<2.	28 days	Stillbrook lab
Ammonia as N	mg/L	SM 4500-NH_3 C	0.1mg/L	Cool 4°C, H_2SO_4 to pH<2.	28 days	Stillbrook lab
Nitrate as N	mg/L	SM 4110B	0.02mg/L	Cool 4°C	2 days	Stillbrook lab
Total/Dissolved Orthophosphate as P*	mg/L	SM 4110B	0.02mg/L	Cool 4°C	2 days	Stillbrook lab
Total/Dissolved Metals**	mg/L	EPA 200.8	0.005mg/ L	Cool 4°C,HNO_3 to pH<2.	180days	Stillbrook lab
Total Coliform	MPN	IDEXX Method (EPA Approved)	<1	Cool 4°C	6-24hrs.	UA
E. Coli	MPN	IDEXX Method (EPA Approved)	<1	Cool 4°C	6-24 hrs.	UA
Enterococci	MPN	IDEXX Method (EPA Approved)	<1	Cool 4°C	6-24 hrs.	UA
pH	NA	SM 4500-H^+ B/ EPA 150	-2.00	Cool 4°C	ASAP	UA
Turbidity	NTU	SM 2130B/ EPA 180.1	0 NTU	Cool 4°C	2 days	UA
Conductivity	µS	SM 2510B/ EPA 120.6	0 µS	Cool 4°C	28 days	UA
Specific Gravity (3-250µm)	g/cm^2	Coulter Counter/Filtering	NA	NA	NA	UA

Note:

* Total Orthophosphate was only analyzed after November 27, 2012.

**The analyzed metals include Cd, Cr, Cu, Pb and Zn (Total and Dissolved Respectively).

3.4.3 Monitoring Design and Process

The performance monitoring of the Up-Flo® Filter consisted of hydrologic, water quality, and sediment monitoring, in accordance with the demonstration protocols and regulations discussed in section 3.2. ISCO 4250 area-velocity flow meters with flow sensors were used to continuously monitor the hydrological conditions at both the inlet and outlet locations of the Up-Flo® Filter, and ISCO 6712 automatic water samplers were used to collect flow-weighted composite samples at both influent and effluent locations for analyses of constituents listed in Section 3.4.2. In addition, sediment monitoring was conducted using a liquid-filled, load-cell USGS scour sensor placed on the bottom of the sump for continuously monitoring deposition and scour conditions during storm events (manual measurements were also made). Sediment in the sump was also collected at the end of the monitoring period for the analyses of particle size distribution (PSD), nutrients, metals, and percent volatile solids.

3.4.3.1 Hydrological Monitoring

Hydrological monitoring of the Up-Flo® Filter included:

1) Effluent discharge rate,
2) Rain depth and intensity,
3) Water stage of the filter sump,
4) Bypass frequency, duration and volume,
5) Draindown performance after events.

Both ISCO 4250 area-velocity sensors were calibrated during the hydraulic flow tests and were used to continuously monitor the water stage in the influent sump and the flow rate in the effluent pipe. The internal data logger of the flow meters were set up before each targeted storm event. The rain depth and intensity were monitored continuously by the ISCO 674 tipping bucket rain gage installed on the top of the monitoring station. A totalizing rain gage was located beside the ISCO rain gage for rain depth verification. However, the rainfall data from these rain gages is not expected to represent accurate rainfall information since there are some tall trees closer to the monitoring station than desired (about half of the tree height). The tipping bucket rain gage's main function was as a trigger for the automatic samplers, not accurate depth measurements. The rain depth information obtained is secondary while the actual flow conditions are of the most importance. The selection of events to monitor is based on some reliable weather prediction information, such as contained at: http://www.weather.com/weather/hourbyhour/graph/Tuscaloosa+AL+USAL0542:1:US

3.4.3.2 Water Quality Monitoring

During water quality monitoring, the ISCO 674 tipping bucket rain gage was used as a sampler trigger while the area-velocity sensor in the effluent pipe was used for the sampling pacing and for hydraulic performance analyses of the Up-Flo® Filter. At the beginning of each event, both automatic samplers were initiated when the rain gage registered 0.02 inch (2 tippings) of rainfall within 30 minutes. The samplers then obtained subsamples simultaneously from the influent and effluent of the Up-Flo® Filter based on the programmed sampling pacing, which was proportional to the monitored effluent flow rates. The water samples were obtained in small secured plastic trays where the runoff cascaded directly onto the sampler intakes, reducing the problems associated with stratified flows. However, the automatic samplers are not able to effectively capture large particles (sampler performance decreases for particles larger than about 250 µm) (Clark and Siu 2008; Clark and Pitt 2008; Clark, et al. 2009), so full unit mass balances were used to indicate possible sampler losses of the larger influent particles when the monitoring period ended. Figure 14 shows the pre-storm field setup and cleaned plastic trays at the influent and effluent locations respectively.

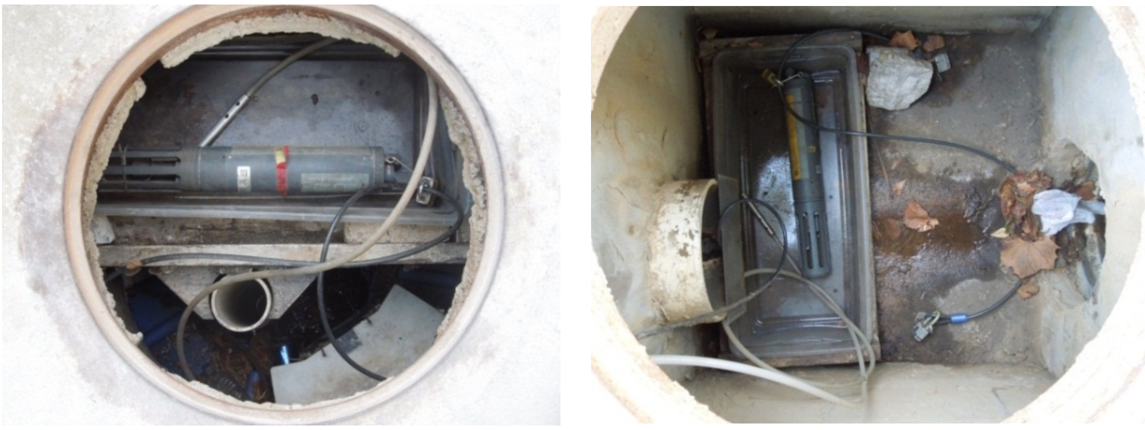


Figure 14: Pre-Storm Field Setup and Cleaned Plastic Trays of Influent and Effluent

Continuous water quality monitoring was also conducted for turbidity, conductivity, and temperature (the storage and use conditions were too harsh for reliable use of the DO, pH, and ORP sonde probes without excessive maintenance) using continuous water quality sondes. As shown in Figure 14, both YSI 6600 water quality sondes were secured in the plastic sampling trays at the inlet and outlet of the Up-Flo® Filter. Each measurement was taken every 5 minutes, setting the data resolution as high as possible to detect frequent changes and trends in stormwater quality during the events. After the samples were retrieved and brought to the UA laboratory for initial processing and shipping, the plastic tray at the inlet was emptied into the filter sump for the overall mass balance through the monitoring period.

3.4.3.3 Sump Sediment Monitoring

Sediment monitoring was also part of the mass balance calculations during the monitoring period. Two kinds of sediment monitoring are conducted as described below.

Before the monitoring period, the filter sump was cleaned and a liquid-filled (degassed water), USGS load-cell scour sensor from Rickly Hydrological Company was placed on the bottom of the filter sump. The scour sensor continuously monitored the sump sediment accumulation rate (sediment depth and mass) over the monitoring period, and continuously detected any sump sediment scouring during storm events, especially during peak storm flows. Manual sediment depth measurements were also taken after each storm event to evaluate the use of this unique monitoring tool. The scour sensor was not able to detect accumulations until the sediment depth was at least several inches.

At the end of the current monitoring activities, sediment grab samples were collected and analyzed as they were after the first series of tests. The sediments were air dried, weighed, sieved, and analyzed within multiple size ranges for heavy metals (Cd, Cr, Cu, Pb and Zn), specific gravity, nutrients and sulfur compounds (COD, TP, TN, Total Sulfide, Total Sulfate and Total Sulfite), percent volatile solids, and particle size distributions (PSD). The filter media bags and flow distribution material were also dried and weighed to estimate the accumulation of solids within the media to complete the mass balance calculations.

3.4.4 Automatic Samplers Programming Design

The ISCO 6712 automatic samplers used in this research are programmable for meeting different demands of sampling. Initially, nine rainfall-runoff events were monitored from

January 20 to March 21, 2010 at the Bama Belle test site to develop the sampler protocols. Flow-weighted composite sampling was required at the site and the samplers needed to collect subsamples covering at least 70% of each storm's total runoff volume with a minimum of 10 subsamples to be collected to represent each event (TARP, 2001, Updated 2003). A minimum sample volume was also needed for the laboratory analyses, and the maximum sample volumes were limited by the volume of the composite sample bottle (15 Liter). The sampler programming was therefore a compromise that needed to consider all of these criteria. The most appropriate solution was found to have more than one sampler programming scheme based on the expected rain depth, with small rains less than 0.5 inches, moderate rains from 0.4 to 2 inches, and large rains from 1.5 to 8 inches.

Table 4 shows the sampler programming for these three rain categories. As shown, the programmed subsample volume for all three setups was always 250 mL, with the only sampler change being the amount of passed effluent flow associated with each subsample taken. Also, the minimum number of subsamples expected is 11 and the subsample collection rate enables subsamples to be collected every several minutes at the shortest interval. The ISCO samplers require an interval of about 1.5 minutes to collect each subsample, considering the required time for the initial back flush of the sample line, sample collection, and the final back flushing of the sample line (Burton and Pitt, 2001). The moderate-sized rain program was routinely used, unless an unusually large, or small, rain was expected.

Table 4: Automatic Sampler Programming for Different Sized Rain Events

	Small Size Rain Event	Moderate Size Rain Event	Large Size Rain Event
Precipitation (in)	0.1 - 0.5	0.4 - 2	1.5 - 8
Duration (hr)	2 - 6	4 - 20	> 15
Runoff Volume (gal)	1,440 - 7,190	4,310 - 28,800	21,600 - 115,000
Average Rain Intensity (in/hr)	0.05 - 0.08	0.08 - 0.1	0.19 - 0.33
Average Runoff Rate (GPM)	46 - 76	68 - 91	171 - 304
Programmed Subsample Volume (mL)	250	250	250
Runoff Volume per Subsample (gal / L)	120 / 454	480 / 1817	2,000 / 7571
Estimated Number of Subsamples	12 - 60	12 - 60	11 - 58
Sample Volume per Event (L)	3.0 - 15	3.0 - 15	2.7 - 14
Filling Percentage of 15 L Capacity (%)	20 - 100	20 - 100	18 - 96
Subsample Collection Rate (min. for each sub-sample)	6 - 10	20	25 - 45

3.4.5 Processing and Handling of Samples

High-density polyethylene (HDPE) sample bottles (15 L) were used to collect the composite samples taken by the ISCO 6712 automatic samplers at both the influent and effluent of the Up-Flo® Filter. After each targeted storm event, the two large sample bottles were retrieved from the monitoring sites and brought to the UA laboratory as soon as possible and preserved in a refrigerator if immediate analysis was not possible/needed.

A total sample volume of about 3.2 L was needed to meet the laboratory analytical volume requirements for both the primary and secondary constituents. In some cases, additional sample volume was needed for QA/QC analyses. After the samples were transported to the UA laboratory, the following sample processing steps were used:

1. The entire composite sample was poured into the churn splitter. Back washed the 15 L

sample bottle to ensure that all the particles were visually flushed into the churn splitter, especially those that stick on the corners or bottleneck. About 1 liter subsample was placed into a 1 liter HDPE sample bottles from the churn (while churning) for TSS, VSS and TDS analyses in UA lab.

2. The USGS/Dekaport Teflon™ cone splitter, obtained from Rickly Hydrological Company (Columbus, Ohio), was used to split each entire sample evenly into each of ten 1 liter HDPE sample bottles that were placed under each tube of the cone splitter. As shown in Figure 15, nylon screening material having about 1,180 µm mesh openings was placed on the top of the cone splitter to capture large particles and debris such as coarse sand, leaves, twigs, and insects to prevent clogging of the cone splitter. This screening material was washed / soaked in hot soapy water for one hour, and then thoroughly rinsed in DI water before use (Pitt 2009). The entire volume of each sample from the churn splitter (entire churn volume was cone split, after the TSS samples were removed) was split by the cone splitter and recorded using graduate cylinders (250 mL or 1000 mL, depending on the sample volume in churn splitter). The total volume of each subsample was used for the PSD and SSC calculations, including the amount caught on the 1180 µm screen. The material captured on the screening was dried and weighed by analytical balance as part of the PSD analyses.

Figure 15: Cone Splitter Setup in Laboratory Sample Processing

3. Four clean 250 mL graduated cylinders and one clean HDPE sample bottle (250 mL or 500 mL) were placed under the tubes of the cone splitter (Two tubes for one graduate cylinder or sample bottle) and then the collected subsamples in the 1 liter sample bottles from previous steps were poured into the cone splitter. The actual volumes in each graduated cylinder were recorded immediately as precisely as possible for SSC and associated duplicate analyses. Repeated this splitting step if there were multiple 1-liter subsamples for SSC analyses, making sure that the volume of split subsamples was always proportional to that of the initial sample. These SSC samples represented the SSC method prepared by cone splitter for comparison to the pipetted TSS results.
4. Ten clean 250 mL graduated cylinders were placed under the tubes of the cone splitter and then the collected subsamples in 1 liter sample bottles from the initial sample were poured into the cone splitter. The actual volumes in each graduated cylinder were

recorded. The split subsamples were then mixed according to different needed analytical volumes for different analyses. The subsamples for analyses of dissolved constituents needed to be filtered by 0.45 µm filters before they were transferred to clean sample bottles.

5. Immediate analyses were conducted in the UA laboratory for bacteria, pH, and turbidity, followed by TSS, SSC, VSS, TDS, and PSD, while filtering, preservatives and cooling were used for those samples (nutrients and metals) that were sent to Stillbrook lab for further analyses, in accordance with the water quality analysis summary table shown before.

Figure 16 is the flow chart showing the detail steps of the sample processing and water quality analysis. The needed analytical volume for each constituent includes the extra water needed for sample processing and a margin of safety for the laboratory analyses.

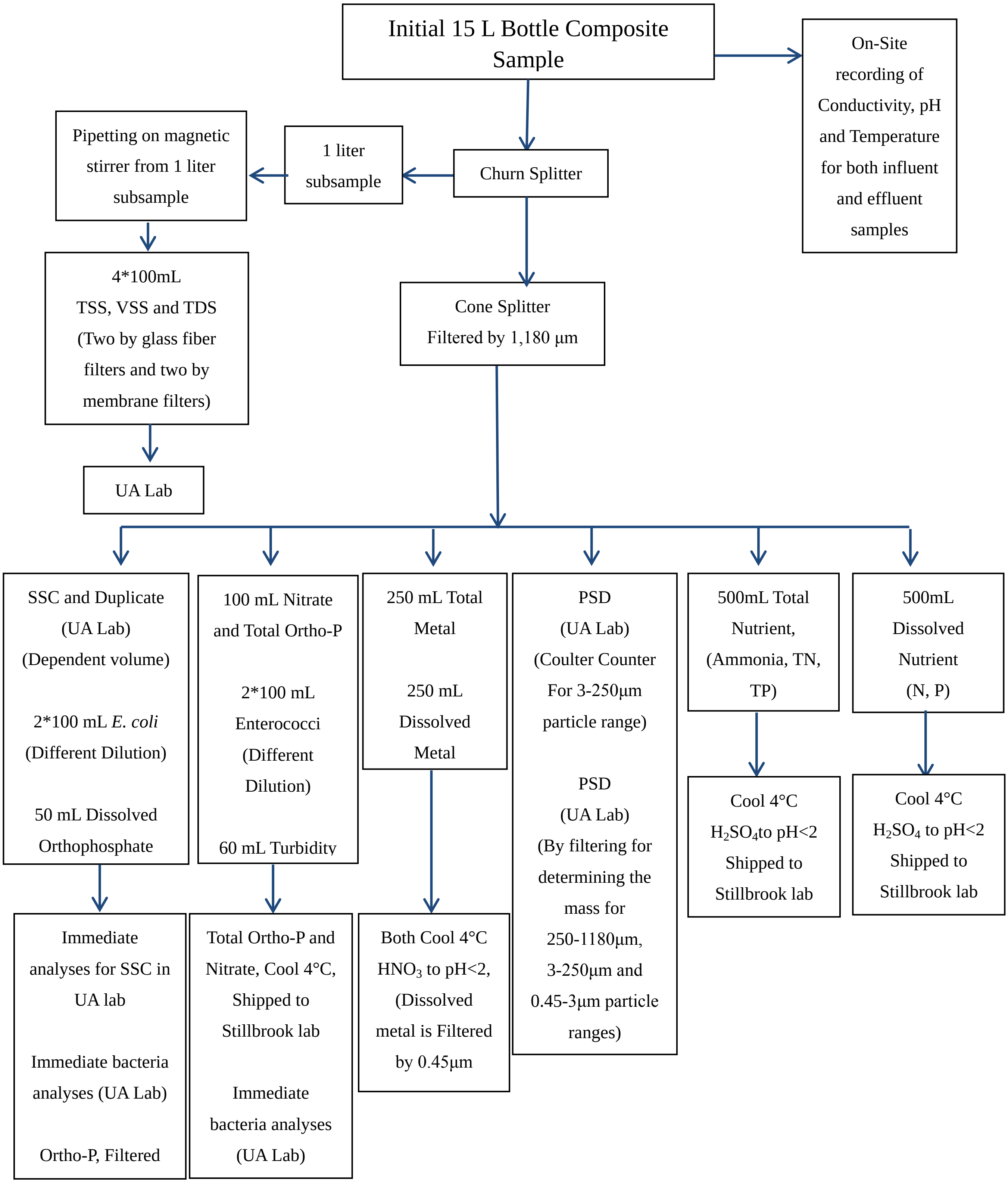


Figure 16: Water Quality Analyses Flow Chart

3.4.5.1 Analyses Procedures for Total Suspended Solids (TSS)

Total Suspended Solids (TSS) was analyzed at the UA Laboratory using test methods in accordance with Standard Methods 2540D, 20th Edition (Standard Methods, 1999). The following section lists the procedures of TSS analyses:

1. The preserved clean filter (Whatman® 934-AH™ Glass Fiber Filter or nominal 0.45 µm MF-Millipore™ membrane filter) with aluminum weighing dish is removed from the desiccator by tweezers and placed carefully onto the analytical balance. Repeat weighing at least twice until no variance is shown on the mass indicator. The initial mass of filter with dish is recorded.
2. The filter with wrinkled side up is assembled with the cleaned filtration apparatus and vacuum is applied. The filter is seated by a small volume of DI water.
3. The 1 liter subsample from the churn splitter is placed on a stir plate with a magnetic stir bar. When it is being stirred, pipette a 10 mL subsample using a wide-bore pipet at an approximate both mid-depth and midway point between bottle wall and vortex. Take ten times to get a 100 mL subsample in a graduated cylinder for verifying (Other volumes are also available, but 100 mL is preferable). Pour the subsample into the filtration apparatus.
4. Use successive DI water to wash down all the retaining particles, which are in the graduated container and on the inner wall of filtration funnel, onto the filter. Remove the funnel holder (clamp) and hold the funnel on the top of the filter by hand. Use successive DI water again to wash the filter contact edge of funnel carefully to make sure that all the visible particulates that stick on the contact edge are flushed down to the filter.
5. The filter is washed by a small volume of continuous DI water. Keep vacuuming until no

visible trace of drainage occurs.

6. The filter is carefully removed from the filtration support by tweezers and placed into previous weighed aluminum weighing dish. The filter with dish is then placed into the drying oven at 103 to 105 ˚C for at least 24 hours.
7. The filter with dish is cooled to room temperature in the desiccator and then weighed on the analytical balance. Repeat weighing at least twice until no variation is shown on the mass indicator. The mass of filter with dish after filtering is recorded.

Total Suspended Solids (TSS) is calculated based upon the following equation:

Total Suspended Solids (TSS) (mg/L)

= [Weight of clean filter with dish (mg) – Weight of filter with dish after filtering (mg)]/ Subsample Volume (L)

3.4.5.2 Analyses Procedures for Suspended Solids Concentration (SSC)

Suspended solids concentration (SSC) is analyzed at the UA Laboratory using test method in accordance with ASTM D 3977-97B (ASTM, 1997, Reapproved in 2002). The following section lists the procedures of SSC analyses conducted at the UA lab:

1. The preserved clean filter (Whatman® 934-AH™ Glass Fiber Filter) with aluminum weighing dish is taken out from the desiccator using tweezers and carefully placed onto the analytical balance. Repeat weighing at least twice until no variance is shown on the mass indicator. The initial mass of the filter with dish is recorded.

2. The filter with wrinkled side up is assembled along with cleaned filtration apparatus and vacuum is applied. The filter is seated by a small volume of DI water.
3. During the previous sample processing, record the volume of sub-subsample split by cone splitter in the graduated cylinder as accurately as possible. Pour the sub-subsample into the filtration apparatus.
4. Use successive aliquots of DI water to wash down all the retaining particles, which are in the sub-subsample graduated cylinder and on the inner wall of filtration funnel, onto the filter. Remove the funnel holder (clamp) and hold the funnel on the top of the filter by hand. Use successive DI water rinses again to wash the filter contact edge of funnel carefully to make sure that all the visible particulates that stick on the contact edge are flushed down to the filter.
5. The filter is washed by a small volume of continuous DI water. Keep vacuuming until no visible trace of drainage.
6. The filter is then carefully removed from filtration support by tweezers and placed into previous aluminum weighing dish. The filter with dish is then placed into the drying oven at 103 to 105 ˚C for at least 24 hours.
7. The filter with the weighing dish is cooled to room temperature in the desiccator and then weighed on the analytical balance. Repeat weighing at least twice until no variation is shown on the mass indicator. The mass of filter with dish after filtering is recorded.

Suspended Solids Concentration (SSC) is calculated based upon the following equation:

Suspended Solids Concentration (SSC) (mg/L)

= [Weight of clean filter with dish (mg) – Weight of filter with dish after filtering (mg)]/

Sub-subsample Volume (L)

3.4.5.3 Analyses Procedures of Volatile Suspended Solids (VSS)

Volatile Suspended Solids (VSS) is analyzed at the UA lab, using test method in accordance with Standard Methods 2540E (Standard Method, 1999). The following section lists the procedures of VSS analyses conducted in UA lab:

1. The mass of filter with dish after filtering and drying is known from previous step of TSS analyses by weighing.
2. Preset the muffle furnace and wait until its internal temperature is constant at 550˚C.
3. The filter with dish for TSS is then placed into the furnace by tweezers and ignited for about one hour.
4. The filter with dish after ignition is cooled to room temperature in the desiccator and then weighed on the analytical balance. Repeat weighing at least twice until no variation is shown on the mass indicator. The mass of the filter with dish after ignition is recorded.

Volatile Suspended Solids (VSS) is calculated based upon the following equation:

Volatile Suspended Solids (VSS) (mg/L)

= [Weight of TSS (mg) – Weight of TSS after 550˚C ignition (mg)]/ TSS Subsample Volume (L)

3.4.5.4 Analyses Procedures for Total Dissolved Solids (TDS)

Total dissolved solids (TDS) are analyzed at the UA lab using test method in accordance with Standard Methods 2540 C (Standard Method, 1999). The following section lists the procedures of TDS analyses conducted in UA lab:

1. A cleaned crucible is carefully transferred from the desiccator to the analytical balance by tweezers. Repeat weighing at least twice until no variation is shown on the mass indicator. The initial mass of crucible is recorded.
2. After the TSS analyses using the nominal 0.45 µm MF-Millipore™ membrane filter are completed and the filter is removed from the filtration support, successive DI water rinses are used to wash the ground glass sealing with applied vacuum.
3. Pour the filtrate from the flask to the crucible. A small volume of DI water (about 20-30 mL) is used to rinse the flask twice, and then also poured into the same crucible.
4. The crucible with filtrate is transferred to the drying oven at 103 - 105 ˚C for at least 24 hours.
5. The crucible is cooled to room temperature in the desiccator and then weighed on analytical balance. Repeat weighing at least twice until no variation is shown on the mass indicator. The mass of crucible after the filtrate evaporates is recorded.

Total Dissolved Solids (TDS) is calculated based upon the following equation:

Total Dissolved Solids (TDS) (mg/L)

= [Weight of cleaned crucible (mg) – Weight of crucible after filtrate evaporates (mg)]/ TSS

Subsample Volume (L)

3.4.5.5 Analyses Procedures for Particle Size Distribution (PSD)

Particle size distribution (PSD) is necessary for evaluating the solids treatability of the Up-Flo® Filter. PSD analyses are conducted at the UA lab using combined measurements from sieving, filtering, and finally using the Coulter Counter. The following are the two parts of the PSD analysis procedures, consisting of sieving and filtering, and then the Coulter Counter analyses, respectively:

1. Sieving and Filtering:

i. The mass of the 1,180 µm opening nylon screening material and clean crucible are measured by analytical balance. The cleaned screening is then secured to the top of cone splitter while the initial sample is split. A graduated cylinder is used to receive and measure the volume of water subsample each time from the churn splitter until the whole initial sample is split by the cone splitter. Retain a small volume of water sample (measure the volume also) in the churn splitter so that the particles that stick on the churn splitter can be flushed into the cone splitter easily by swirling and pouring. Measured amounts of additional DI are then added to the churn to continue to rinse it into the cone splitter, noting the additional water volume added. The nylon screening with the screened debris is then transferred into the previously weighed clean crucible and placed into the drying oven at 103 to 105 ˚C for more than 24 hours. After that, it is moved into the desiccator and cooled to room temperature. Weigh the screening and screened debris with crucible on the analytical balance. The concentration of solids greater than 1,180 µm can be determined from the known mass and water volume.

ii. The initial mass of the cleaned and dried stainless steel sieve having 250 µm openings is measured on the analytical balance. A water subsample from the cone splitter prepared in a previous step, which is proportional to the total sample volume, is selected (The number of proportional subsample depends on the volume of the total initial sample). A funnel is used to support the sieve and prevent the water from spilling out. Pour the subsample through the 250 µm sieve to a graduated cylinder so that the water volume can be measured. Successive DI water is applied to wash the sieve and funnel. The additional water volume does not matter because it contains no particles. The sieve is placed into the drying oven at 103 to 105 ˚C for at least 24 hours. After it is cooled to room temperature in the desiccator, weigh it on the analytical balance. The solids concentration which is from 250 µm to 1,180 µm can be determined by known mass and water volume.

iii. The mass of nominal 3 µm MF-Millipore™ membrane filter with aluminum weighing dish is recorded by analytical balance. Assemble the filter with filtration apparatus. Pour the water subsample that was sieved by the 250 µm sieve in the previous step into the filtration apparatus. Wash the inner wall of the funnel, the filter contact edge of the funnel and the filter by successive DI water. The filter is then removed from the filter support carefully and transferred to the drying oven along with its aluminum weighing dish at 103 to 105 ˚C for over 24 hours. The filter with dish is weighed on the analytical balance after it is cooled in the desiccator. The solids concentration which is from 3 µm to 250 µm can be determined by known mass and sieving water volume.

iv. The mass of the nominal 0.45 µm MF-Millipore™ membrane filter with aluminum weighing dish is measured by the analytical balance. Assemble the filter with filtration apparatus. Pour the water subsample that is in the filtration flask and filtered by the 3 µm filter in the previous step into the filtration apparatus. The flask is washed using several times using small volumes of DI water in order to recover the very fine particulate onto the 0.45µm filter. Again, wash the inner wall of the funnel, the filter contact edge of the funnel and the filter by successive DI water rinses. The filter is then carefully removed from the filter support and transferred to the drying oven along with its aluminum weighing dish at 103 to 105 ˚C for over 24 hours. The filter with dish is weighed on the analytical balance after it is cooled in the desiccator. The solids concentration which is from 0.45 µm to 3µm can be determined by known mass and sieving water volume.

2. Coulter Counter Analyses:

The Beckman® Multi-Sizer III™ with two aperture tubes (100 µm and 400 µm diameter tube orifices) is used for Coulter Counter analyses in the UA lab. For each aperture tube, the size distribution can be measured over the range between 2% and 60% of the diameter of tube orifice, and the range of measured particle diameters overlap using these two orifice tubes. These aperture tubes are therefore used to create a composite high-resolution particle size distribution from 3 µm to 250 µm.

i. Either of the subsamples from the cone splitter can be selected for Coulter Counter analyses. The selected subsample is stirred on the stir plate with magnetic stir bar. Pipette a specific volume, based on expected dilution, at an approximate both mid-depth and midway point between bottle wall and vortex.

ii. Pre-sieve the pipetted subsample into the beaker in order to minimize the clogging problem of the aperture tube. The selection of opening size of the pre-filter sieve is based on the smallest size that still exceeds the maximum analytical range of the aperture tube. For example, the analysis range of the 400 µm aperture tube is from 8.0 µm to 240.0 µm, which are 2% and 60% of the orifice diameter, respectively, so the opening size of the sieve for pre-filtering is selected as 250 µm. Similarly, the pre-filtering size when using the 100 µm aperture tube is 75µm. The distribution results are reported as particle volume (directly correlated to mass) for each detected particle size. This particle volume and the previously determined particle concentration in this size range can be used to calculate the particulate density.

Consequently, using a combination of sieving, filtering, and Coulter Counter analyses, the overall particle size distribution (PSD) is integrated by filtering mass from 0.45 µm to 3µm, sieving mass from 250 µm to 1180 µm and screening mass for >1180 µm, with high resolution mass distributions from 3 µm to 250 µm by the Coulter Counter analyses based on corresponding filtering mass in this size range.

CHAPTER 4

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) METHODS

4.1 Quality Assurance Project Plan (QAPP)

QA/QC methods are required and documented by the Up-Flo® Filter Field Verification Testing Quality Assurance Project Plan (QAPP). As discussed in section 3.2, the QAPP was prepared in accordance with Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations (TARP, 2001, updated July 2003). The goal of the QAPP is to document standard procedures used for data collection, processing, and analysis, in order to reduce the variation and bias introduced during the sample collection, and ensure the validity and significance of the analytical results. These methods mainly consist of field and laboratory activities, including equipment maintenance and calibration, preparation of laboratory supplies, blank analysis, samples handling and preservation, duplicate analysis, laboratory flow chart and field note, etc. These elements and procedures will be discussed in this chapter.

4.2 Data Quality Indicators

Data Quality Indicators (DQIs) have been identified as key components in evaluating the quality and validity of data and supporting the verification process. These indicators include: precision, accuracy, representativeness, comparability and completeness. Performance data of

Up-Flo® Filter are discussed in Chapter 5 using multiple statistical analyses for the quantitation of the DQIs. If any QA objective is not met during the tests, an investigation of the cause will be initiated. Corrective action will be taken as needed to resolve the difficulties. Data failing to meet any of the QA objectives will be flagged in the technical evaluation report, and a full discussion of the issues impacting the QA objectives will be presented.

4.2.1 Accuracy

Accuracy is defined for water quality analyses as the difference between the measured sample value and the true value of the sample. Method accuracy for a targeted constituent can be determined and monitored depending on the specific analytical method, using a combination of matrix spikes and laboratory control samples with known concentration. Accuracy is usually expressed as the percent recovery of a compound from a sample. The following equation will be used to calculate percent recovery:

$$\text{Percent Recovery} = [(A_T - A_i) / A_s] \times 100\%$$

Where: A_T = Total amount measured in the spiked sample

A_i = Amount measured in the un-spiked sample

A_s = Spiked amount added to the sample

During the monitoring period of the verification tests, laboratory control samples with known concentrations (but unknown to the labs), called “blind” QC samples, were analyzed twice for TSS and SSC concentrations. The accuracy objectives defined by the QAPP, require percent accuracies for both TSS and SSC to be within 75 to 125% of the actual constituent concentrations. The analyses results of the laboratory QC samples are presented in Section 4.4.5.

4.2.2 Completeness

Completeness is a factor evaluating the ratio of the number of valid samples (sampled and qualified events) and the number of total measurements during the monitoring period. Completeness can be calculated by the following equation:

$$\text{Completeness} = (V / T) \times 100\%$$

Where: V = number of valid measurements (qualified events)

T = total number of measurements planned and obtained in the test

The goal of this qualification in this research is to reach a minimum 85% completeness for the total measurement that is obtained, required by the QAPP based on the requirement of TARP / NJCAT protocols. Both compiled demonstration protocols indicate that the minimum number of sampled events is 15 to 20, while 30 storm events have been sampled during this thesis research (added to the prior 20 storms previously evaluated), which means that the qualification is achieved. All of the 30 sampled events have fulfilled all the event eligibility criteria discussed in Section 3.2, except for one event having less than 0.1 inch of rain depth. The percentage of completeness is therefore measured as about 97%, meeting the qualification of 85%.

4.2.3 Precision

Precision is the agreement among measurements of the same constituent under similar conditions. It is expressed quantitatively as the measure of variability of a group of measurements compared to their average value, measuring the reproducibility of the sampling and analytical methodology. Generally, precision can be quantified as the relative percent difference (RPD) between duplicate samples analyzed from field and laboratory replicates. Relative percent difference is calculated by the following formula:

$$\%RPD = \left(\frac{|x_1 - x_2|}{\bar{x}}\right) \times 100\%$$

Where: x_1 = concentration of constituent

x_2 = duplicate concentration of constituent

$\bar{x}$ = average value of x_1 and x_2

Over the monitoring period, evaluations of laboratory precision were always conducted for each storm event sample by analyzing laboratory duplicates (splitting the sample by cone splitter through the sample preparation and analysis process). The constituents evaluated include TSS, SSC, TDS, VSS, bacteria and turbidity. These duplicate analyses results are attached in the QC tables of each event summary in Appendix F.

4.2.4 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition. For obtaining representative stormwater samples, proper system design, sampler selection, flow meter selection, location of inlet tube, mixing sample container handling, and splitting are the key factors in both field and laboratory evaluations.

For this research, representative field samples are expected to be collected by flow-weighted composite samples from cascading influent and effluent flow which are considered to be homogenous for the automatic sampling intake. The influent sampling intake (the strainer) needs to be secured as shown in Figure 14 in order to obtain representative influent samples of the (hopefully well-mixed) inflowing water. The representative laboratory data is achieved by following standard sample handling procedures, including a thorough mixing of the composite sample by churn splitter and equal splitting for individual subsamples by USGS/Dekaport cone splitter, including rigorous rinsing of equipment and redundant analyses. These set procedures are critical to ensure that the subsamples for any subsequent analyses are proportional and representative to the initial sample, as described by Clark and Pitt (2008) and Clark and Siu (2008).

Representativeness was also monitored through independent QA/QC audits by CFM Group LLC. for both field and laboratory activities, including review and observation of the laboratory procedures for sample handling, review and observation of the sample recovery, and observation of the field equipment operating and maintenance at the test site. Field and laboratory independent audits were performed several times during the research.

4.2.5 Comparability

Comparability is the parameter evaluating the extent of which one data set can be compared directly to another data set from the current project. In this research, comparability is achieved by using consistent and standardized sampling and laboratory analytical methods. All analyses are performed using Standard Methods or other published methods as discussed previously. All standards used in the analytical testing are traceable through the availability of verifiable standards, and standards working flow charts are maintained over the process of sample handling and analyses. Comparability is also ensured through independent QA/QC audits and review of the applied processing procedures and all reference materials used in the laboratory.

4.3 Field Quality Assurance

Field quality assurance methods include the pre-storm site setup, monitoring and sampling equipment maintenance and calibration, field blanks, field data management, samples handling, identification and labeling and field sheet. The goal of these control methods aims at detecting and reducing the external contamination due to the sample bottles, equipment or operation of sample collection.

4.3.1 Pre-Storm Field Cleaning and Sampling Setup

Sampling personnel arrive at the test site before any targeted storm event. All the sampling appliances and monitoring equipment are checked to make sure it is in good status. Both cascading plastic trays at the influent and effluent locations are cleaned thoroughly and put back to the sampling positions, while the retained material in the influent plastic tray from previous storm event are poured into the filter sump for the total mass balance at the end of the monitoring period. The YSI water quality sonde probes are cleaned and inspected for any damage. Both sondes and plastic trays are secured using clamps in order to prevent them being bounced around during the rigorous hydraulic conditions during the events. The totalizing rain gage is recorded and emptied immediately after each event, while the trigger rain gage is checked that the rain gage funnel is not clogged which would lead to sampling failure. Preliminary site inspections are conducted during every site visit, and any undesirable activity around the site (i.e. considerable sand exposure due to soil insects (such as fire ant hills), obvious vehicle oil leaking, massive pollen during pollination season and etc.) is recorded on the field sheets for traceability and comparability of the storm sample conditions under notable special site conditions.

4.3.2 Equipment Maintenance and Calibration

The activities of equipment maintenance and calibration are listed as follow:

1) Both automatic samplers are pumped through laboratory phosphate-free detergent and then hot tap water prior to each sampling event for decontamination. The cleaned 15 liter sample bottles are also rinsed by laboratory phosphate-free detergent and air dried and well-sealed in the UA laboratory before being brought to the field.
2) Internal sampling tubes of the peristaltic pump of the samplers are inspected in case of any leakage due to wearing.
3) Battery status for all monitoring equipment is checked to ensure that sufficient power will be available over the expected period of the event.
4) The ISCO 4250 flow meters were calibrated during the hydraulic flow tests, while 674

tipping bucket rain gage and the ISCO 6712 automatic samplers are inspected and checked for clogging before each targeted event.

5) The elevation of the pressure transducer in the filter sump is inspected and calculated periodically to detect any slipping.
6) Both YSI water quality probes are cleaned during every site visit.
7) The trigger rain gage is calibrated using standard documented calibration procedures based on the recorded water volume from the calibration burette corresponding to the tipping. In addition, the rain depth for each event also is recorded by the totalizing rain gage and compared to the tipping bucket rain gage.

4.3.3 Field Blanks

Field blanks are important for assessing whether there is any significant contamination introduced during the complete process of field sampling, sample transportation and laboratory analyses activities. The source of any errors may include contamination of samplers' suction lines, contaminated sample bottles, or other unpredictable issues. Field blanks are accomplished by pumping deionized water through the automatic samplers, and sent to UA laboratory for further analyses. The field blanks were used periodically during the sampling period. Any sampling or analytical sources of contamination were documented and corrected. Five sets of field blank analyses were conducted through the monitoring period and the assay results of these field blank samples are summarized in Appendix G.

The field blank results indicate that there was minimal contamination found during the whole monitoring period. The only issues were related to some total phosphorus and total coliform results during the blank analyses on June 28, 2012. The possible source of these contaminations might be from the Teflon sampling tubes or 15 liter sample bottles. Therefore, further cleaning and re-analyses was conducted for these constituents, and their results are labeled as “correction analyses”, as shown in Appendix G.1. The cleaning procedures were as follow: during the correction analyses, both Teflon sampling tubes were pumped through the hot soapy tap water (using phosphate-free lab detergent) and then the laboratory DI water. The samplers were left overnight and the blank samples were collected by pumping through the laboratory DI water on the next day for immediate laboratory processing.

4.3.4 Field Maintenance Logs

Field maintenance logs (field sheets), as shown in Table 5, describe and record the actions taken during any test site visit. The sheet includes the inspection and maintenance of equipment, such as retrieving data from equipment, measuring the sump sediment depth, cleaning the rain gage, measuring the elevation offset and checking the batteries, etc. Any special observation about the test site environment and Up-Flo® Filter system should also be included in the field sheet. Chain of Custody (COC) forms (Available on the website of Stillbrook Environmental Testing Laboratory in Fairfield, Alabama) were also used for samples being submitted to certified third-party independent laboratory for nutrient and metal analyses.

Table 5: Bama Belle Full-Scale Up-Flo® Filter Testing Project Field Sheet

Project Name:	Bama Belle up flow filter full-scale test	Field Conductor:	Yezhao Cai
Date/Time:		Weather Condition:	
Event Information			
✧ Start of the event: ✧ End of the event: ✧ Total Rain Depth (ISCO Rain gage) (inch): ✧ Approximate Runoff Volume of the site (gallon): ✧ Programmed flow/subsample for the event (circle): 120 gal (Small) 480 gal (Moderate) 2000 gal (Large) ✧ Number of subsamples collected: Influent: Effluent: ✧ Approximate Sample volume: Influent: Effluent:			
Inspection and Maintenance (check mark)			
☐ Retrieve data from the flow meters, water quality probes and scour sensor ☐ Review detail sampling information in the automatic samplers (for confirmation and comparison) ☐ Replace two large sample bottles ☐ Clean the ISCO rain gage ☐ Record/Check the totalizing rain gage for rainfall data comparison ☐ Measure/check the elevation offset of the filter sump ☐ Check/Change the batteries for flow meters, automatic samplers, water quality probes and scour sensor ☐ Clean/Inspect the inlet and outlet (plastic trays)			
Observation or Notice (check mark and explain)			

4.4 Laboratory Quality Assurance

A series of laboratory quality control actions are applied to meet the QAPP requirements, including standardized lab procedures, laboratory blank and duplicate, analyses of QC samples, etc. The standardized analytical information, including the analyzing methods, units, preservatives, holding time and Method Detection Limit (MDL), are tabulated in Table 3. All analytical results are also tabulated and summarized in Appendix F and Appendix G. Once any problem was identified, the data was highlighted and corrective actions were implemented immediately if results warrant changes to procedures. QA problems and corrective actions are summarized in the field and laboratory notes and QA appendices of the final performance report.

4.4.1 Samples Handling, Preservation and Identification

After each sampled storm event, the conductivity, temperature and pH of the samples were recorded immediately on the field notes using portable meters, and then the sample bottles were transported to the UA laboratory as soon as possible. The samples were not left unattended and were well sealed and preserved in the refrigerator at 4 ˚C, with the field notes safely stored inside if immediate processing is not possible. The USGS/Dekaport cone splitter and churn splitter were used to split the samples in the lab, as previously described. The split subsamples were preserved according to the requirements for the different constituents, as listed in Table 3. The sample bottles were labeled by waterproof mark with the project name, field ID (influent/effluent), collection date, constituent analysis requested, preservative type and note (i.e. filtered or unfiltered).

4.4.2 Preparation of Sample Processing and Solids Analyses

Before the samples processing and solids analyses (TSS, SSC, VSS, TDS and PSD) are started, a series of preparations are necessary for achieving the quality assurance of the analytical data. These include the QA/QC aspects associated with used filters, filter disks, filtration apparatus, analytical balance, cone splitters and churn splitters, etc. The following sections list these preparations:

a) Preparation of filters and filter disks. Different kinds of filter were used for different analyses. Whatman® 934-AH™ Glass Fiber Filter were used for SSC and TSS/VSS paired analyses, while the nominal 0.45 µm and 3 µm MF-Millipore™ membrane filters were used for TSS/TDS paired and PSD analyses. The filter is inserted into filtration apparatus by tweezers with wrinkled side up. Vacuum is applied and the filter is washed by laboratory DI water (reagent-grade water) at least three times, and continuous vacuum is kept until no visible trace of water. The washed filter is then transferred to pre-cleaned aluminum weighing dish by tweezers. The filter with dish are dried in the drying oven at 103˚C to 105˚C for at least 24 hours and then placed into the desiccator allowing to cool down to room temperature and preventing moisture from affecting the dried samples.

b) Preparation of filtration apparatus. In this research, Millipore 47mm All-Glass Vacuum Filter Holder was used for all necessary filtration steps. The flask, filtration support with ground glass sealing and funnel were first soaked and washed with hot soapy tap water using non-phosphate laboratory detergent and then respectively rinsed by laboratory DI water. The filtration device is then assembled and connected to a vacuum, and successive rinse of laboratory DI water is applied to wash the interior of ground glass sealing, along with the inner wall of flask and funnel. Air-dry and preserve the filtration device. Repeat the cleaning procedures above before and after the filtration apparatus is used.

c) Preparation of analytical balance. Ohaus Adventurer Pro™ analytical balance was used during this research. The location of the balance is on a firm and steady surface where there is no excessive air current or vibration. Before the balance was used, its leveling feet were adjusted so that the bubble in the level bubble indicator is in the central of the circle. The balance was also cleaned as needed, checked, and periodically calibrated.

d) Preparation of other tools. The other tools used in sample processing and solids analyses, including HDPE pipettes, graduated cylinders, HDPE subsamples containers, magnetic stir bars, 1,180 µm opening nylon screenings with crucibles, cone splitters and churn splitters, were washed in hot tap water with laboratory non-phosphate detergent and then DI water before each use.

4.4.3 Laboratory Blanks

Laboratory blanks were used to identify contamination during the laboratory procedures. Source of errors could include contamination of sample processing bottles, solvents and reagents, and any processing instrument or tools (i.e. cone splitter and churn splitter). Laboratory blanks are processed along with field blanks using the same methods as the event samples analyses, except that deionized water from the University of Alabama laboratory is used instead of the event samples.

4.4.4 Laboratory Duplicates

The purpose of laboratory duplicates is to evaluate the variability and precision of laboratory analytical methods. The general procedure for sample duplicate analyses is that the initial sample is split evenly into two sets of subsamples using the cone splitter and they are analyzed using the same methods for the same constituents. Laboratory duplicates are conducted for every paired storm event samples for solids (TSS, SSC, TDS and VSS), bacteria (Total Coliform, *E. Coli* and Enterococci) and turbidity, and the duplicate results are tabulated in the QC tables of every event summary as attached in Appendix F for quantifying the variations of analytical methods through the laboratory analyses.

4.4.5 Analyses of Blind QC Samples

Blind QC samples were used to test the accuracy of laboratory analytical method under unknown concentrations of certain analytes. The blind QC samples were analyzed like the field event samples and the concentration used to calculate the errors compared to the actual concentration. Results may be higher or lower than the actual concentration if interferences are present during the sample processing or analysis. These interferences were estimated and documented as necessary based on the significance of the errors. The blind QC samples were also submitted with the field samples to the third-party independent laboratory (Stillbrook laboratory in Fairfield, Alabama) using the same label with event samples such that the laboratory does not know they are QC samples. The results were tabulated and compared to the results of UA laboratory and the actual concentration with calculated precision. Two sets of blind QC samples were analyzed and the results are shown in Tables 6 and Table 7.

Table 6: July, 2012 Blind QC Sample SSC Analysis Results

Replicate #	1	2	3	4	5
Subsample Volume (mL)	107	110	100	106	105
Subsample Conc. (mg/L)	30.84	30.00	29.00	30.19	30.48
Average Conc. (mg/L)			30.10		
Certified Value[1] (mg/L)			31.9		
Analytical Verification[2] (mg/L)			30.9		

Note: 1. the actual "made-to" concentration confirmed by ERA analytical verification;
2. mean value reported by laboratories in Proficiency Testing Study compared to the Certified Value.

The standard QC sample analyzed as shown in Table 6 was from ERA (Golden, Colorado) and the SSC analytical method used for the analysis was in accordance with procedures discussed in Section 3.4.5.2. The range of the measured SSC values were from 29.00 to 30.84 mg/L, with an overall average of 30.10 mg/L and a standard deviation of 0.69 mg/L, and a coefficient of variation of 0.023. The subsample volume was also indicated for verifying the splitting variability of the cone splitter. The average measured value had a very small difference compared to the reported certified value, demonstrating excellent recovery and reliability of the laboratory analytical method and procedures used, especially considering the relatively low constituent concentration.

A set of blind TSS QC samples containing large particles are shown in Table 7. The analytical method was in accordance with the TSS method discussed in Section 3.4.5.1.The samples were analyzed at both UA and Stillbrook laboratory and the results were compared to the actual concentrations.

Table 7: November, 2012 Blind QC Samples TSS Analyses Results (blind samples prepared by Hydro International)

Sample #	Test Sand Used	Actual Conc. (mg/L)	Stillbrook Lab Results (mg/L)	Stillbrook Lab Accuracy	UA Lab Results (mg/L)	UA Lab Accuracy
A	SCS 250	60	45	75%	53.5	89%
B	SCS 250	140	79	56%	121.5	87%
C	SCS 250/F-100 blend	45	31	69%	28.5	63%
D	SCS 250/F-100 blend	170	60	35%	100	59%

Samples A and B have finer particle size distributions (Sil-Co-Sil® 250 has 90% of particles less than 150 µm in diameter and 50% less than 45 µm), while samples C and D have larger particle sizes, being representative of the particulate scenario found in typical stormwater runoff. As shown, the overall accuracy from the both labs varied from 35% to 89%, but the results from the UA lab indicate better recovery rates than those of Stillbrook lab. The recoveries for the finer particles are also better than for the larger particles, as expected for TSS methods. Since these test mixtures were made using coarse ground silica materials, the TSS testing methods would not be expected to be able to predict the SSC values that have large particles beyond the range of the TSS test method. As an example, Figure 17 is a plot of these known SSC concentrations with the measured TSS concentrations, as conducted at the UA laboratory. The TSS yield of the SCC concentrations were about 70%, indication that about 30% of the SSC sample was not detected using the standard TSS method. Figure 18 is a plot of the measured TSS concentrations as measured at the UA laboratory compared to the measured TSS concentrations as measured at the Stillbrook Environmental laboratory. The correlation between these two sets of data is excellent, but it is clear that the recovery of the two laboratories was significantly different. The Stillbook reported TSS concentrations that were about half of the UA reported TSS concentrations, and the Stillbrook method had a significant intercept (indicating a potential bias or a calibration error of about 18 mg/L, or about 0.2 mg (0.0002 g) associated with a 100 mL sample size).

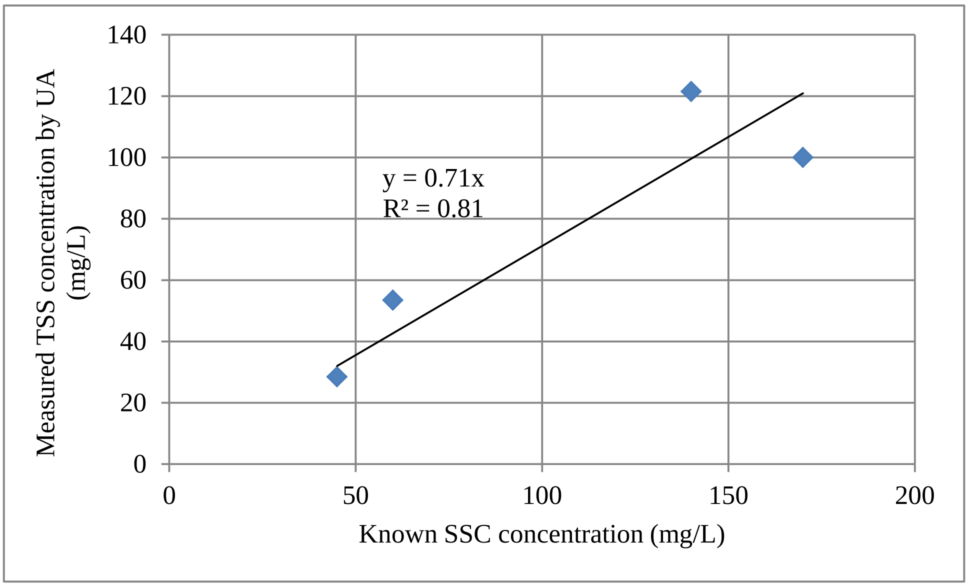


Figure 17: Comparison of Known SSC Concentrations and Measured TSS Concentrations

As noted above, the blind QA SSC samples were closely measured by both labs. It is expected that the initial sets of blind QA samples did not have appreciable amounts of larger particles and both SSC analytical methods indicated excellent recoveries with no significant errors. Potential laboratory problems therefore arise when samples having large particles are measured using TSS analytical methods.

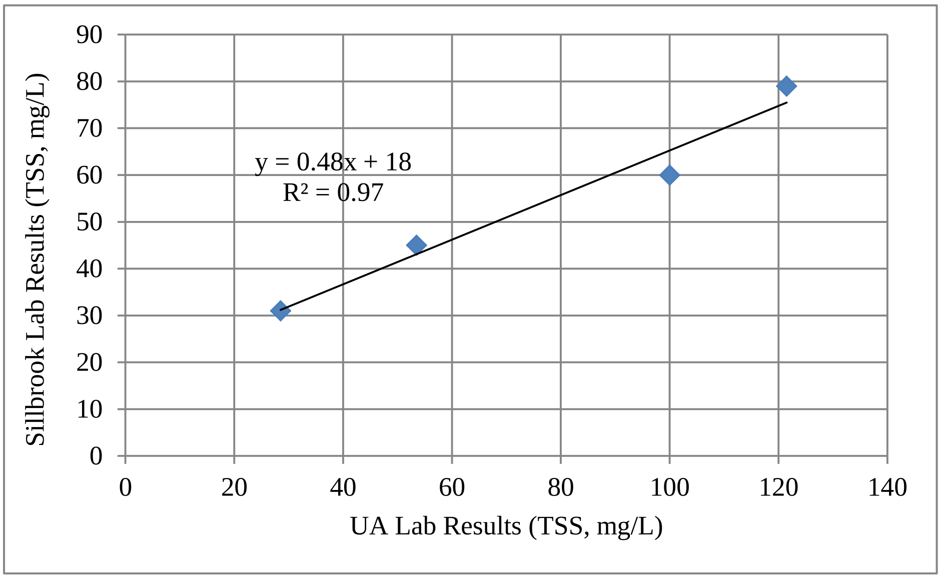


Figure 18: TSS Measurement Comparison of Different Laboratory

4.4.6 QC Flow Chart

A step-by-step laboratory quality control flow chart was developed and employed strictly during the process of laboratory sample analyses, as shown in Figure 16. This flow chart was created as a guide to ensure consistent sample handling and minimize the chance of losing the data due to laboratory mishandling.

4.5 Electronic Data Management

All analytical and hydrologic related event-based data for the project was stored electronically in a retrievable spreadsheet database. The electronic data, from flow meters, automatic samplers, water quality probes and scour sensor, were transferred directly into the database for the subsequent analyses and archiving purposes. These data were reviewed for any equipment malfunction or other operational problem. The database was used to produce event based hydrologic summary statistics.

Laboratory raw analytical results were also transformed and presented in suitable formats in individual storm reports. The report include an event hydrograph, laboratory analytical results, and all associated sampling, flow, and precipitation characteristics, and are included in Appendix F.

4.6 Quality Assurance Audit

Quality assurance audits were conducted to detect any potential deficiencies in field sampling and water quality analyses during the project. The audits included both field and laboratory audits conducted by an external independent observer (CFM Group LLC.). The field audits consisted of witnessing the pre-storm field cleaning and equipment setups, sample recovery and handling at the site, operation of the instruments, and reviewing the documentations, while the laboratory audits examined samples handling, processing, analyzing and preserving. Eleven independent observations of field and laboratory activities were conducted covering the whole monitoring period of this thesis research.

4.7 Quality Assurance Report

The final QA report for this research (included as part of this thesis) contains a continuation of the full-scale Up-Flo® Filter field performance verification conducted by Togawa (2011). As well as previous research, the report includes field and laboratory analytical results and statistical analyses, inspections and maintenance records and written documentation over the whole monitoring period. Specifically, the report will clearly indicate the experimental designs, samples collection and handling processes and the relative QA/QC methods. All the working efforts are based on the fulfillment of Up-Flo® Filter field testing QAPP protocol.

CHAPTER 5

PERFORMANCE DISCUSSIONS AND EVALUATIONS

5.1 Discussion Summary

The series of field performance verification tests of the Full-Scale Up-Flo® Filter has been conducted during a one-year long monitoring period at the Bama Belle parking area, Tuscaloosa, Alabama, adjacent to the Black Warrior River. The testing efforts consisted of field hydraulic flow tests and actual storm event monitoring. These hydraulic and water quality analytical results were evaluated using a series of statistical and graphical analyses to determine the performance significance. These recent field testing data were also combined and compared to the results from previous monitoring at the same test site, verifying the consistency and repeatability of the performance for a broad range of rainfall and runoff characteristics. The storm event performance data was also compared to the results of the controlled sediment and flow tests conducted by Togawa (2011) which examined different particulate concentrations, particle size distributions and flows.

5.2 Hydraulic Flow Tests Performance Analyses

Figures 19 shows the relationships of head vs. influent flow rates, and head vs. effluent flow rates for the installed CPZ™ Mix filter media bags. The last recorded data point during each steady flow test are shown on these plots as they represent the most steady flow conditions (there were slight creeps of the stage values during the observations as equilibrium conditions were reached). These regression equations indicate that the media bags basically have linear dependence with stage below the bypass weir. The differences in these two plots indicate the bias of the effluent flow monitor (Figure 22 compared the metered influent pumped rate with the monitored effluent flow rate). When replacing the media bags, it is critical that they are placed very carefully with no obvious folding of the mesh bag material. The flow distribution matala also needs to be compressed when the top lids are installed to control the media fluidization.

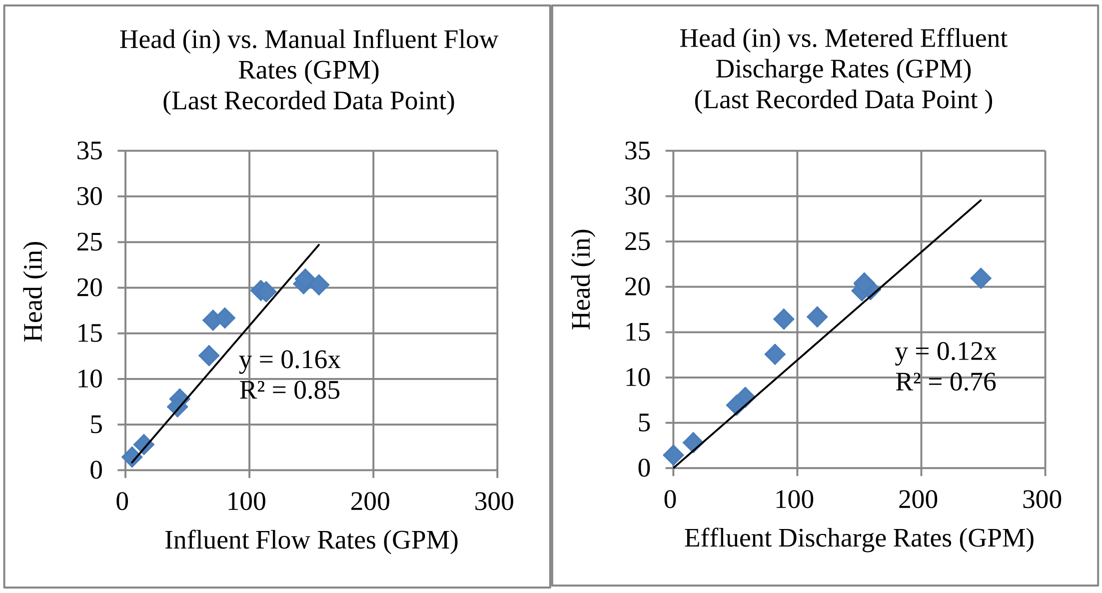


Figure 19: Head vs. Flow rates of Influent and Effluent during Flow Test

Figure 20 is a scatterplot indicating the composite stage-discharge rating curve for the flows vs. head in the main filter chamber along with showing multiple Up-Flo® filter outlet elevations. The curve reflects that the CPZ™ Mix media bags have reasonable effluent flow rate as expected (about 150 GPM before the flows entered the bypass weir for the 6 filter modules), which indicates no conspicuous leakage or gap existing in the filter modules or filter media bags.

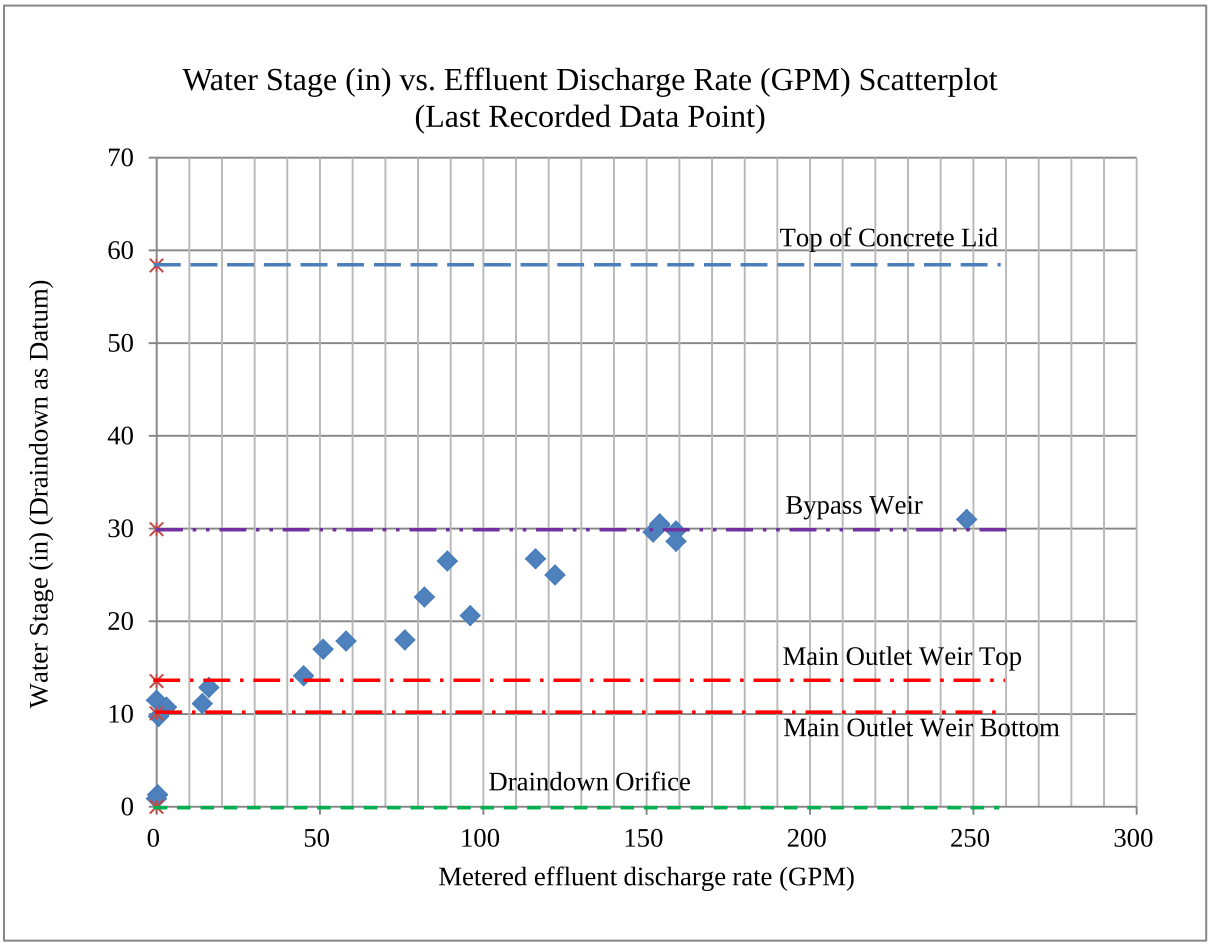


Figure 20: Sump Water Stage vs. Effluent Flow Rate with Multiple Outlets

Figure 21 shows the relationship between draindown time, sump water stage, and effluent flow rate during the maximum flow rate tests. The flowrates for these tests were between 250 and 300 GPM with the pump operating at maximum power to fill that sump as much as possible. The pumps were then shut off and the time, stage, and flow were recorded as the water elevation receded. The time needed for the water stage to drop from the bypass weir depth to the bottom of main outlet weir (with water passing through the media bags) was about 23 minutes. The time needed for the water level to drop from the main outlet weir bottom to the draindown orifice was about three hours.

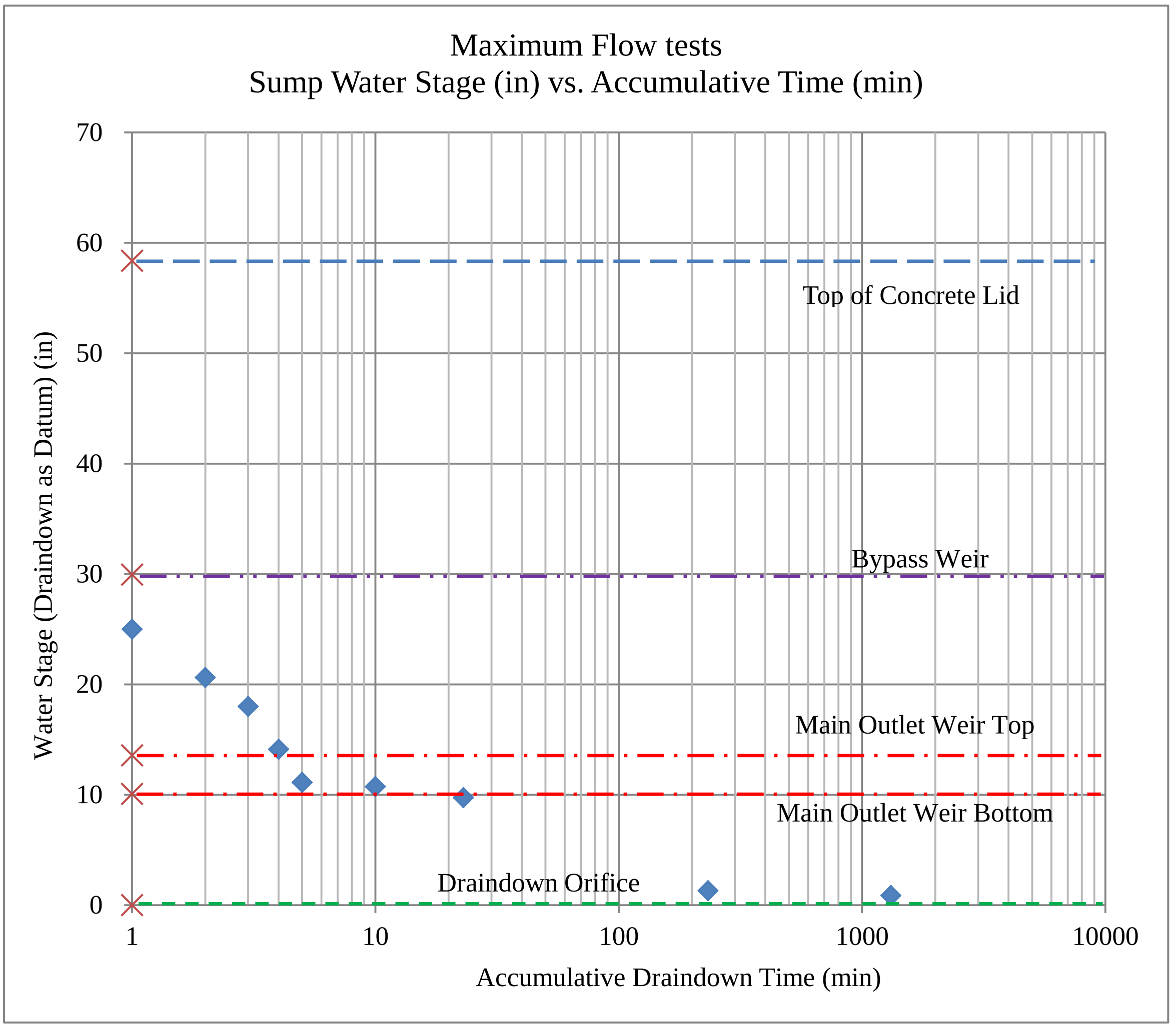


Figure 21: Maximum Flow Test Monitoring

Figure 22 shows the relationship between the calibrated influent flow rates and the ISCO area-velocity metered effluent flow rates. This shows that there is about a 29 percent average positive bias in the area-velocity effluent discharge rate compared to the calibrated influent flow rate. The variation in this calibration curve is greater for larger flows than for lower flows. This level of variability is not unusual for velocity sensors because the flow monitor obtains data frequently during a runoff event, there will be many available observations of flow in relatively short periods that will tend to even out these flow fluctuations. The flow sensor is being used to control the sampler and the reasonably consistent bias does not affect that function.

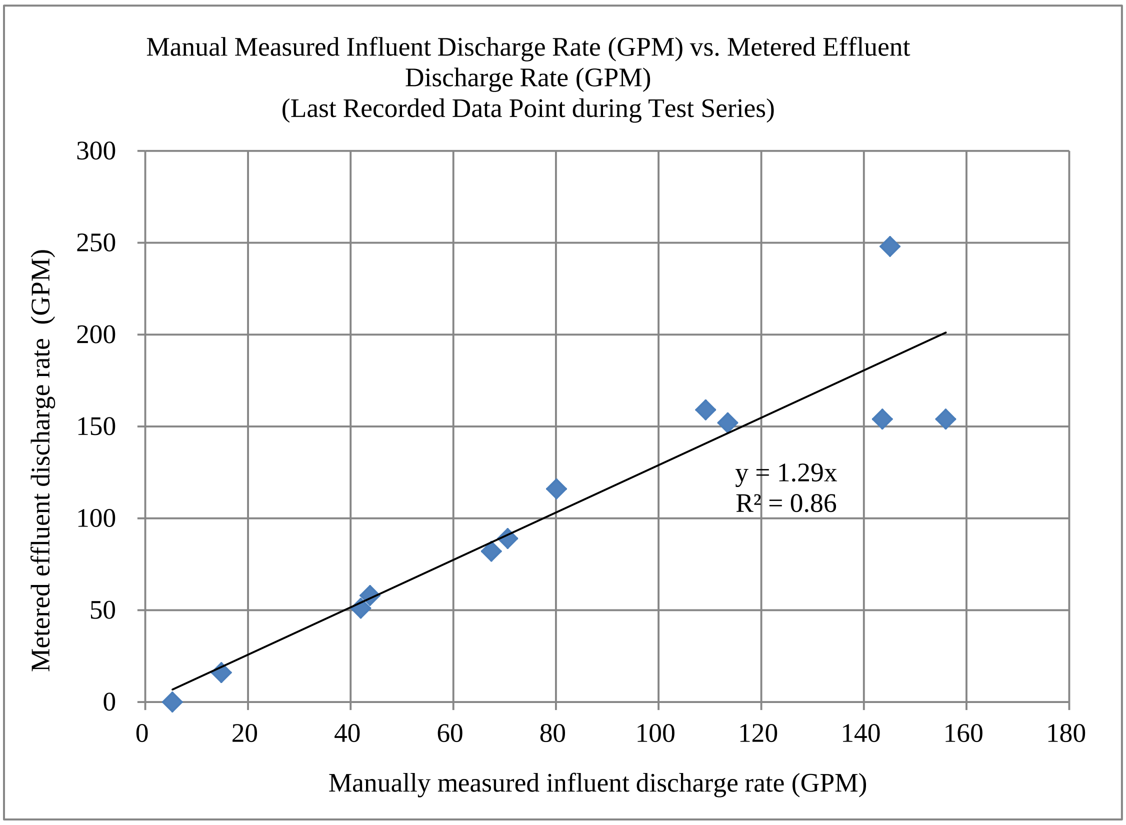


Figure 22: Manual Measured Influent Flow Rate vs. Metered Effluent Flow Rate

Figure 23 indicates that the manually measured sump water stage values were very closely correlated to the monitored stage values by the 4250 area-velocity flow sensor in the filter main chamber (used only to measure stage, not velocity in this location).

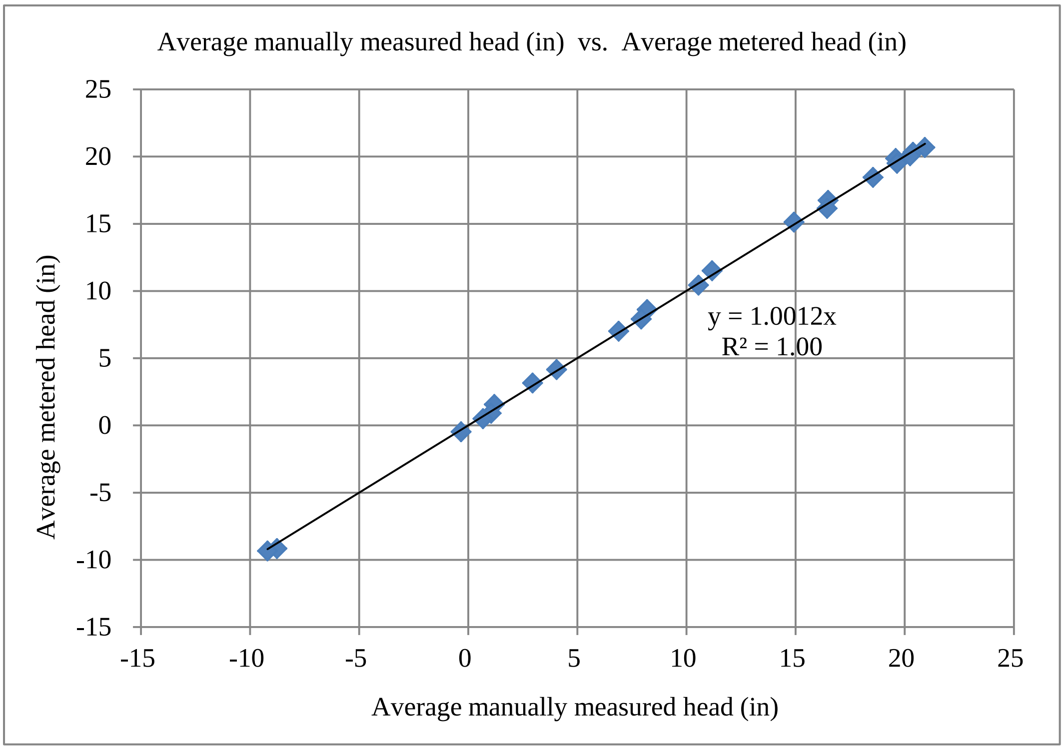


Figure 23: Manually Measured Head vs. Metered Head Values

Figure 24 shows the relationship between the effluent discharge rate and the depth in the effluent pipe. The area-velocity sensor uses an acoustical sensor to directly measure the water velocity while also measuring the water depth above the sensor to calculate the cross-sectional area of the flow (based on the diameter of the pipe). The sensor then multiplies these two values together to obtain the discharge value. The sensor requires at least one inch of water above the sensor for accurate measurements. Therefore, a small plate was placed across the bottom of the outlet pipe, forming a dam (as show in Figure 25) which results in the relatively consistent stage-discharge vs. rate scatterplot as shown in Figure 24. The minimum effluent stage is therefore about four inches as the dam exists. The discharge rate increases with a relatively small increase in the water depth, because it is acting as a rectangular weir with irregular sides.

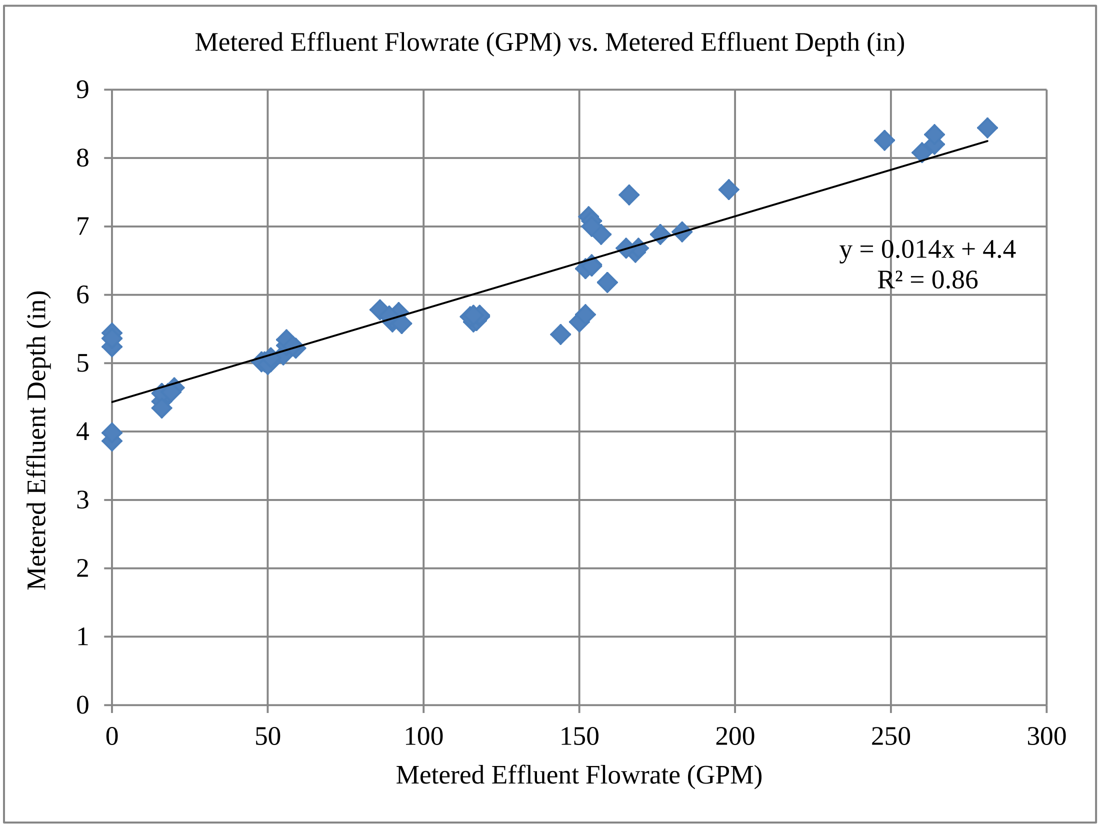


Figure 24: Effluent Flowrate vs. Effluent Depth

Figure 25: Outlet Monitoring Location Showing Small Plate Across Pipe to Ensure Sufficient Depth above the Velocity Sensor

5.3 Hydraulic Performance During Actual Storm Monitoring

The hydraulic performance of the Up-Flo® Filter during actual storm events provides much valuable information about the treatment flow rate capacity changes with time. These hydraulic performance evaluations focused on the filter behavior under a broad range of storm conditions, the time-series durability of the filtration rate, and the resulting bypass performance. All storm events during the monitoring period, including the non-sampled storms, were included in these evaluations in order to generate a complete time series scenario of the hydraulic performance of the Up-Flo® Filter system.

5.3.1 Rainfall and Runoff Characteristics during the Monitoring Period

Beginning at the end of March 2012, this thesis research included a one-year period of monitoring during actual storms conducted at the Riverwalk parking area near the Bama Belle dock in Tuscaloosa, Alabama. Over half of the storms occurring during this period were completely monitored, while rain and flow data were collected for all storms. Table 8 summarizes information for the rain events during the monitoring period. A total of about 49 inches of rainfall and about 980,000 gallons of runoff were monitored at the test site during this period (including both sampled and un-sampled rains). The rainfall data was collected by the trigger ISCO tipping bucket rain gage on the top of the monitoring station. Trees were located closer to the rain gage than desired (a distance of about half the tree height), but this was the only location suitable for the sampling. As noted previously, the rain gage was used mainly to trigger the samplers, with the rain data being of secondary importance. Monitored flow data was more critical, which was directly measured. In addition to the tipping bucket rain gage, a small totalizing rain gage was used to verify the recorded rain depth. Figure 26 compares these two rain sensors, and indicates excellent agreement (R^2 of 0.94 with a 5% average bias; paired Wilcoxon sign rank tests did not detect any significant differences at the 95% confidence level).

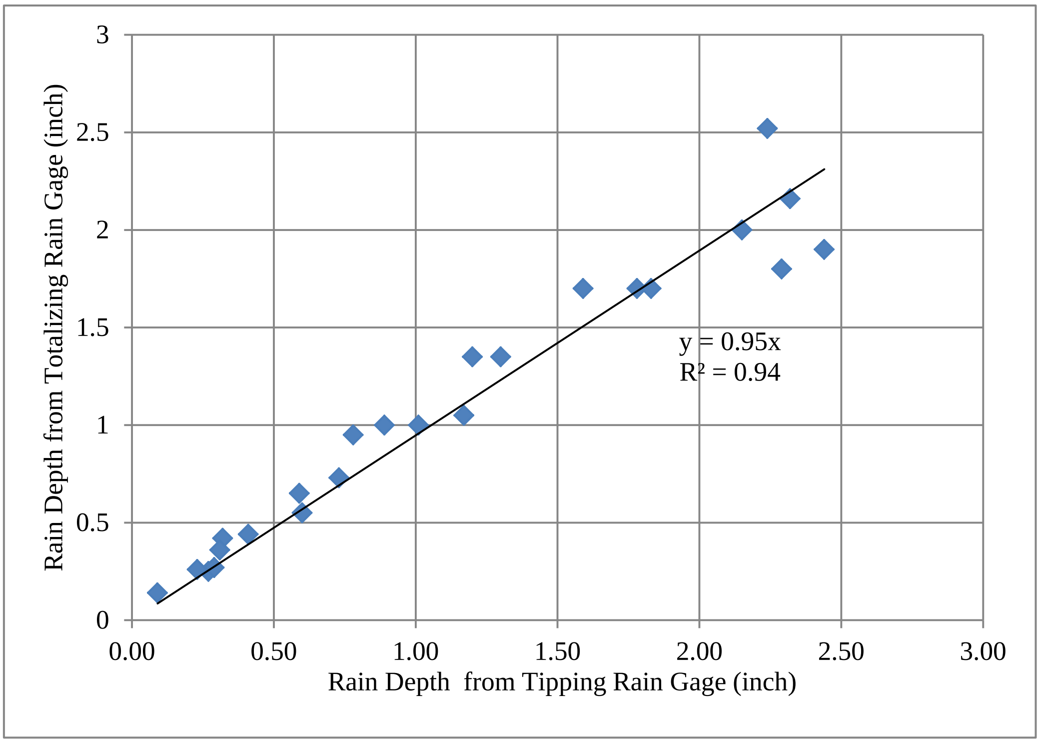


Figure 26: Comparison of Tipping Bucket and Totalizing Rain Gages at Bama Belle Site

Table 8 shows the fraction of the flow treated. About 730,000 gallons of runoff, (about 74% of the total annual flow), was treated by the media filter system without bypass. The bypass flows were partially treated by sedimentation. This treatment fraction is lower than the expected 90% because the monitoring extended several months past when the media bags decreased in their filter flow rate, causing increased bypass. Normally, the media filter bags would have been replaced before then, but one of the objectives of the research was to quantify performance beyond the media life.

Table 8: Summary of Rain Events Characteristics for All the Storms during the Monitoring Period

	Rain Depth (inch)	Runoff Volume (gallon)	Runoff Depth (inch)	Fraction of all flow fully treated by media filters
Sum	49.01	982,234	39.16	731,186 gallon / 74.4%
Average	0.71	14,235	0.57	83.4%
Median	0.41	8,468	0.33	95.4%
Maximum	3.53	83,630	3.13	100%
Minimum	0.02	267	0.01	36.9%
Std. Dev.	0.76	17,475	0.71	20.0%
COV	1.07	1.23	1.25	0.24
Percentage of Storms Sampled	30.16 inch / 61.5%	624,623 gallon / 63.6%	25.85 inch / 66.0%	446,987 gallon / 71.6%

Figure 27 is a scatterplot of the relationship between rain depth and runoff volume at the Bama Belle test site. This plot includes all the data points from the previous project phase that monitored 20 storm events and the current project phase that monitored 69 storm events, for a total of 89 events evaluated. This plot demonstrates a strong linear relationship between the rain depth and the runoff volume at the test site, with excellent regression characteristics (R^2 = 0.95).

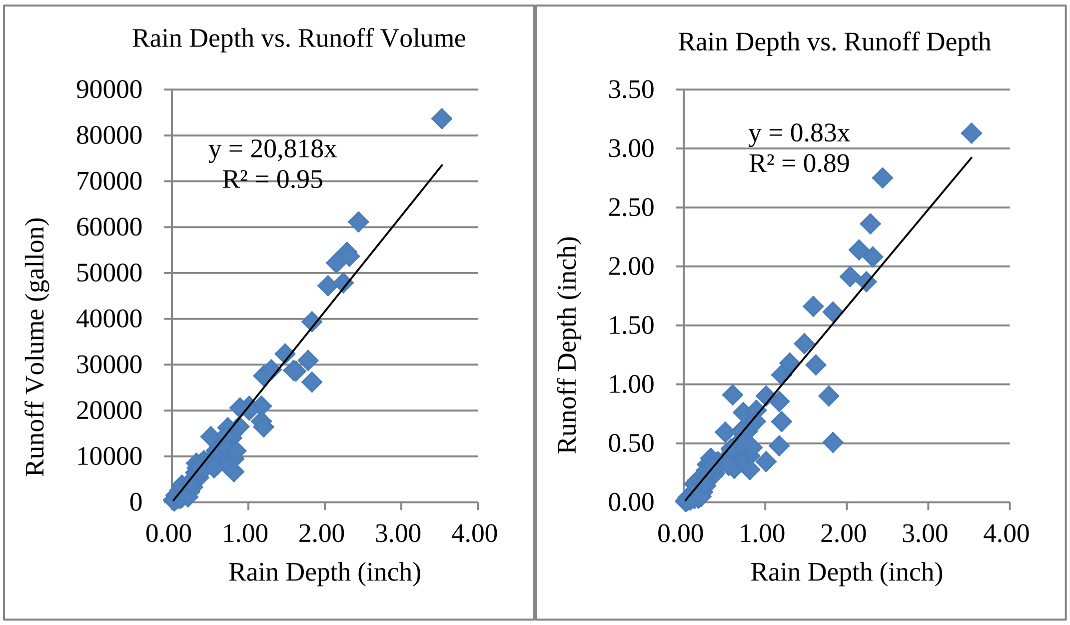


Figure 27: Relationship between Rain Depth and Runoff Volume and Runoff Depth of Bama Belle Site

For the purpose of evaluating the water quality performance of the Up-Flo® Filter more reliably, storm events occurring during the monitoring period were sampled as many as possible (couldn't monitor all events due to very long time required to process samples and analyze for the targeted constituents) and finally about 62% of storm events by rain depth (or about 64% of storm events by runoff volume) were sampled and analyzed for verification. The 30 events sampled and their hydrological information is tabulated in Table 9. As shown, an extensive range of rainfall and runoff conditions occurred during the monitoring; the rain depth ranged from 0.09 to 2.24 inch while the runoff volume ranged from 1,750 to 61,131 gallons. The COVs of the percent of flow treated by the media for the 30 sampled events is a low 0.28, being consistent with and verifying the overall COV value in the Table 8.

Table 9: Rainfall and Runoff Characteristic Summary of Sampled Storm Events during the Monitoring Period

Event/Sample Date	Rain Depth (in)	Runoff Volume (gallon)	Runoff Depth (in)	Runoff Coefficient (Rv)	Rain Duration (hr)	Peak Runoff Rate (GPM)	Average Runoff Rate (GPM)	Treated Fraction (%)
2012/5/31	0.27	3267	0.14	0.50	16.87	67	3	100.00
2012/6/10	0.60	8240	0.91	1.00	15.25	962	24	75.07
2012/7/11	0.29	4464	0.32	1.00	9.17	83	14	100.00
2012/7/12	0.28	5062	0.27	0.96	5.75	77	19	100.00
2012/7/21	1.78	30884	0.90	0.50	13.07	1009	27	51.68
2012/8/3	0.18	2065	0.09	0.49	4.75	128	7	99.36
2012/8/4	0.75	11535	0.40	0.54	0.67	850	240	52.16
2012/8/13	1.01	20903	0.90	0.89	2.22	1023	164	49.43
2012/9/1	0.70	10402	0.41	0.59	3.58	390	46	75.90
2012/9/3	0.41	8509	0.34	0.83	5.62	239	24	96.30
2012/9/30	1.83	39335	1.61	0.88	35.68	206	18	99.99
2012/10/14	1.01	20062	0.34	0.34	3.13	784	44	51.72
2012/10/18	1.17	17650	0.48	0.41	2.40	299	80	58.53
2012/11/27	0.32	8510	0.31	0.98	1.90	134	66	100.00
2012/12/4	0.59	10693	0.44	0.75	8.85	273	20	73.59
2012/12/8	0.09	1750	0.04	0.49	0.72	71	25	100.00
2012/12/10	2.24	47830	1.87	0.84	8.50	325	88	89.57
2012/12/16	1.20	27550	1.08	0.90	10.00	166	44	98.43
2012/12/28	0.73	16242	0.76	1.00	12.55	112	24	100.00
2013/1/1	1.30	28886	1.18	0.91	16.80	130	28	84.38
2013/1/13	2.15	52199	2.14	0.99	53.50	332	16	73.92
2013/1/30	1.59	28721	1.66	1.00	15.22	297	44	49.76
2013/2/10	2.44	61131	2.75	1.00	64.48	290	17	76.20
2013/2/21	2.29	54490	2.36	1.00	35.88	353	26	70.37
2013/2/25	0.31	6432	0.26	0.85	9.50	98	11	79.14
2013/3/5	0.23	2492	0.11	0.47	1.87	217	23	40.41
2013/3/11	2.32	53629	2.08	0.90	11.20	299	74	36.97
2013/3/22	0.41	7129	0.31	0.75	23.52	265	5	63.15
2013/3/23	0.89	20583	0.78	0.87	7.68	299	41	54.51
2013/3/30	0.78	13978	0.60	0.76	22.78	340	11	67.08
Sum	30.16	624623	25.84	-	-	-	-	71.56
Maximum	2.44	61131	2.75	1.00	64.48	1023	240	100.00
Minimum	0.09	1750	0.04	0.34	0.67	67	3	36.97
Std. Dev.	0.74	17882	0.76	0.22	15.29	286	50	20.96
COV	0.74	0.86	0.88	0.28	1.08	0.85	1.17	0.28

The Up-Flo® Filter was expected to have different levels of performance under different hydrological conditions, Figures 28 through 31 show the filter's hydraulic performance for the August 13, 2012 event, which is a typical summer Tuscaloosa rain having a high rain intensity and short duration (about 1 inch total rain, peak 5-minute peak intensity of more than 3 in/hr, and drain duration of slightly more than 1 hour). Figure 28 is the hydrograph for this event. The peak flow rate was about 1,000 GPM and the sump water level submerged the bypass. The sump water stage (shown on the right side of the figure), uses the elevation of the draindown orifice as the datum which, is also the lowest water elevation between events (except for any evaporation or leakage, which was minor at this installation). The depth sensor (pressure transducer) in the sump was always below this datum and the offset between the depth sensor and water level was inspected periodically during site maintenance, making sure the correct offset for the stage values were used by the depth sensor.

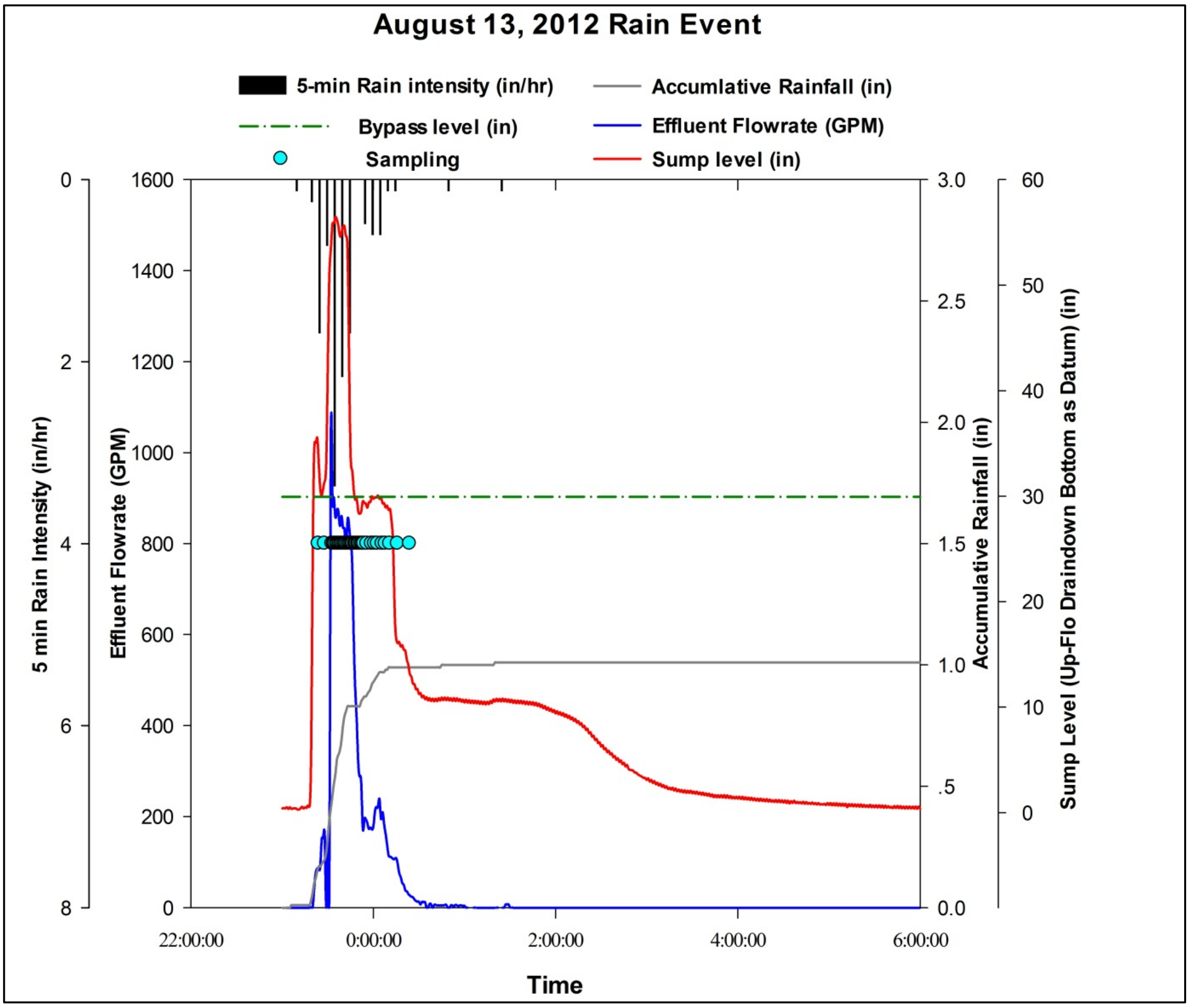


Figure 28: August 13, 2012 Rain Event Hydrograph

Figure 29 is a scatter plot of the effluent flow rate vs. sump water stage showing the multiple filter outlet levels. During this event, the maximum treatment flow rate (the point just below the bypass weir) was about 150 GPM, as expected based on the controlled flow tests. The water elevation stayed near the bypass level for some time, but then increased to the top of the sump during the peak flow period. The bypass performance at this installation was lower than the capacity measured during Hydro International's laboratory testing (not published), which was about 2,200 GPM. This difference was due to the narrower siphon cap (about 1.5 inch high) needed for this installation.

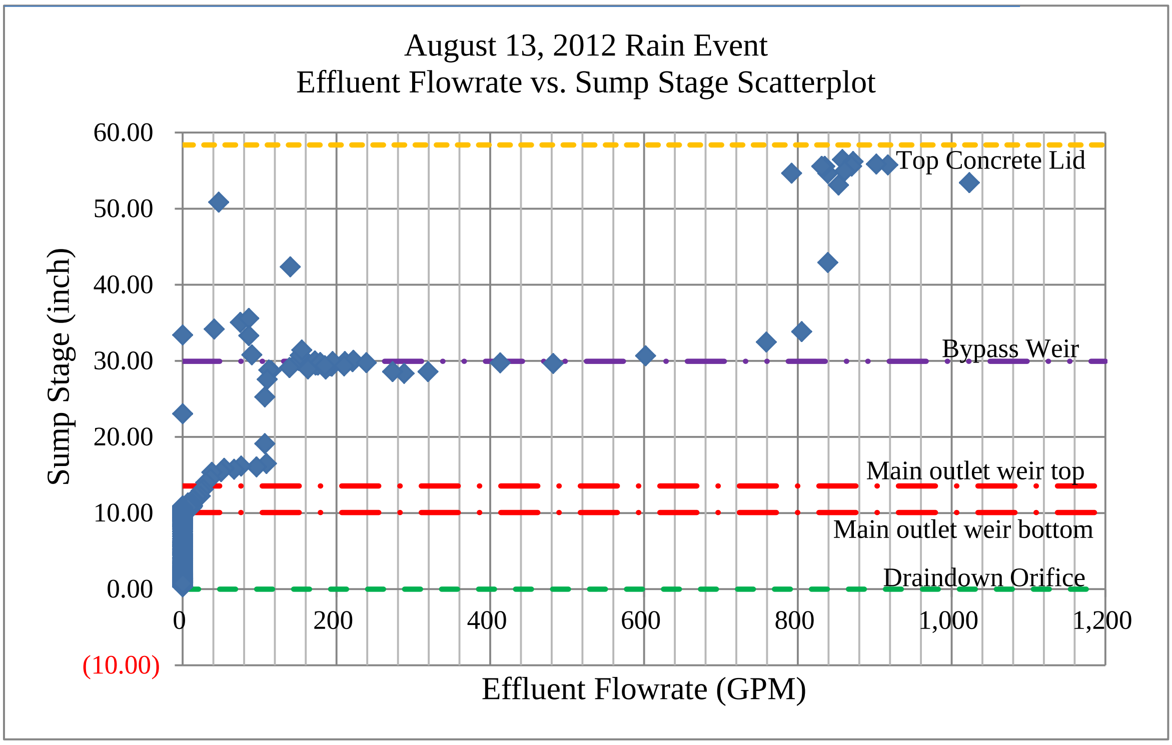


Figure 29: August 13, 2012 Rain Event Effluent Flowrate vs. Sump Water Stage

Figure 30 shows the rate of sump water drainage by the draindown system. After the event, the sump stage kept dropping down to the bottom of main outlet weir in the filter module just within several minutes and then to the level of the draindown orifice within about 3 hours. Lowering the water beneath the media is important, as that prevents media degradation and anaerobic conditions. The draindown also provides a backwashing benefit removing some of the captured pollutants in the media to the sump, resulting in longer media life. Figure 31 is the flow-duration curve for the August 13, 2012 event. The median flowrate for this event was about 150 GPM while 100% of the flow was less than about 1,000 GPM. All these hydraulic performance evaluations for each sampled storms are attached in Appendix F.

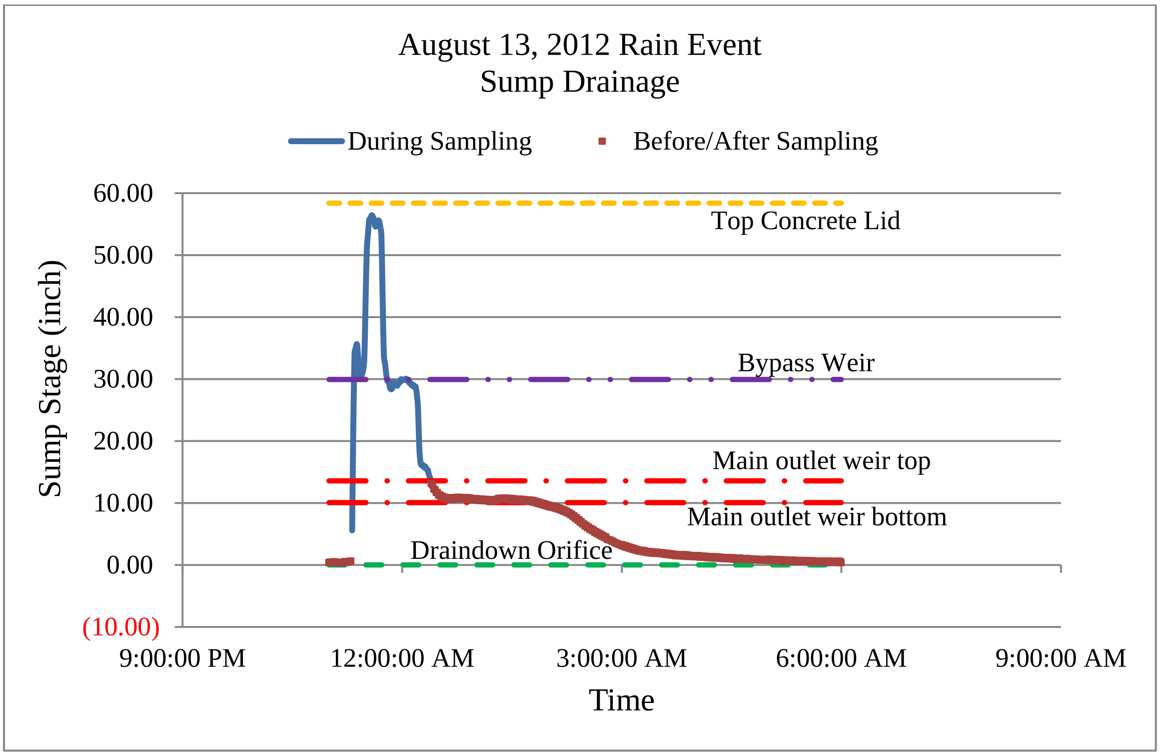


Figure 30: August 13, 2012 Rain Event Effluent Sump Drainage

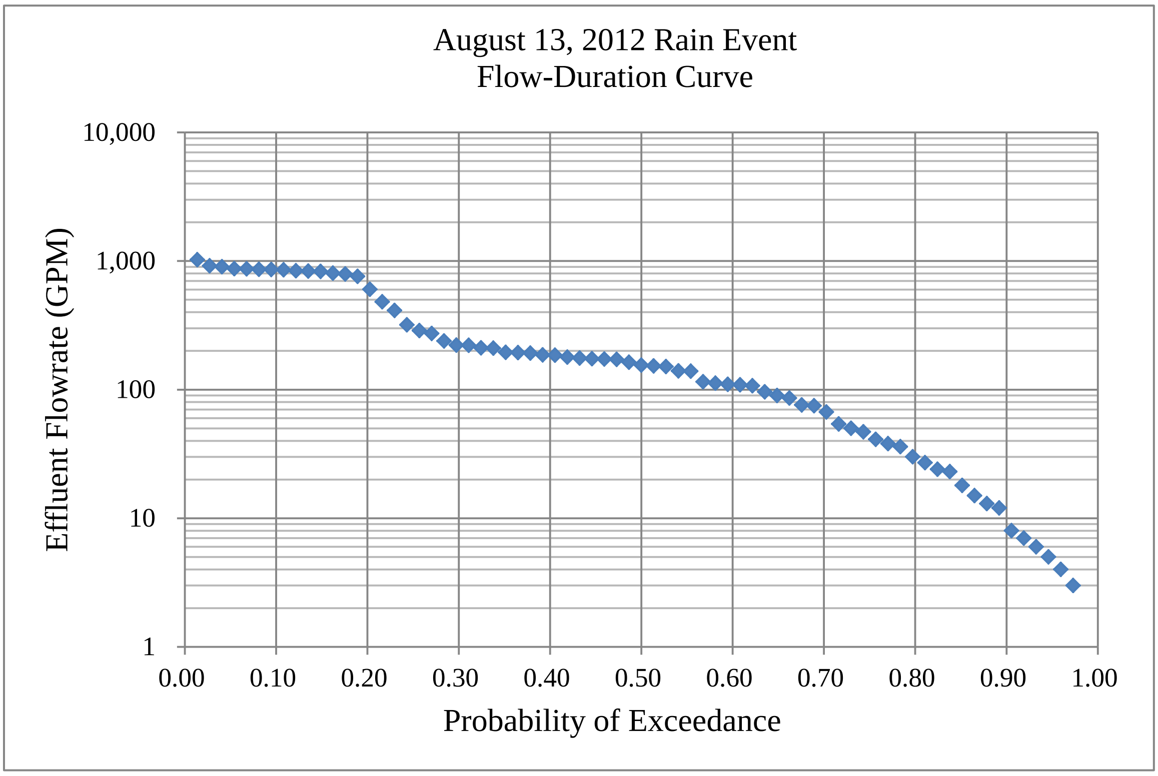


Figure 31: August 13, 2012 Rain Event Flow-Duration Curve

5.3.2 Monitoring Treatment Bypass

Bypass of flows around the treatment media of the Up-Flo® Filter occurs when the water elevation in the sump rises above the bypass siphon overflow. The bypass water is therefore partially treated through sedimentation when in the sump along with floatable control by the bypass hood, but the bypass water does not receive full treatment of the media filtration. Bypass is therefore a key factor affecting the overall hydraulic capacity and treatment filtration effectiveness of the filter system. A siphon-activated bypass weir with hood is employed on the top of the outlet module for the excessive flows. The bypass frequency and amounts occur during periods of peak runoff rates (which are highly dependent on the peak rain intensity) which exceed the treatment flow rate capacity of the media filters. The sump volume provides limited storage for very short periods of peak flows. In a larger vault system having upflow modules, the greater storage volume reduces the bypass. Fewer bypasses occur in moderate rainfall conditions. The bypass frequency and amounts are expected to increase with time as the filter becomes partially clogged and the treatment flow rate decreases with use. The media bags are therefore replaced when this becomes excessive.

Figure 32 is a time series plot of the accumulative average treatment percentage of total flows over the one-year monitoring period. The variations shown on this plot are affected by random and seasonal rainfall and runoff conditions (theoretically, higher treatment with less intense storms in the winter and lower treatment with, more intense storms in the summer in the Tuscaloosa area). The trend shown during the later periods mainly follow the operating life of the filter media decreasing treatment flow capacity with time. The final average treatment percentage was holding around 83% after the one year period, somewhat less than the designed 90% treatment capacity. This difference is likely due to the rain characteristics during the monitoring period being different than the long-term conditions upon which the design was based. In addition, the treatment flow rate substantially decreased in January of 2013, indicating when media bag replacements were needed. Monitoring continued beyond this time as it was desired to measure performance during this sub-optimal period, as described below.

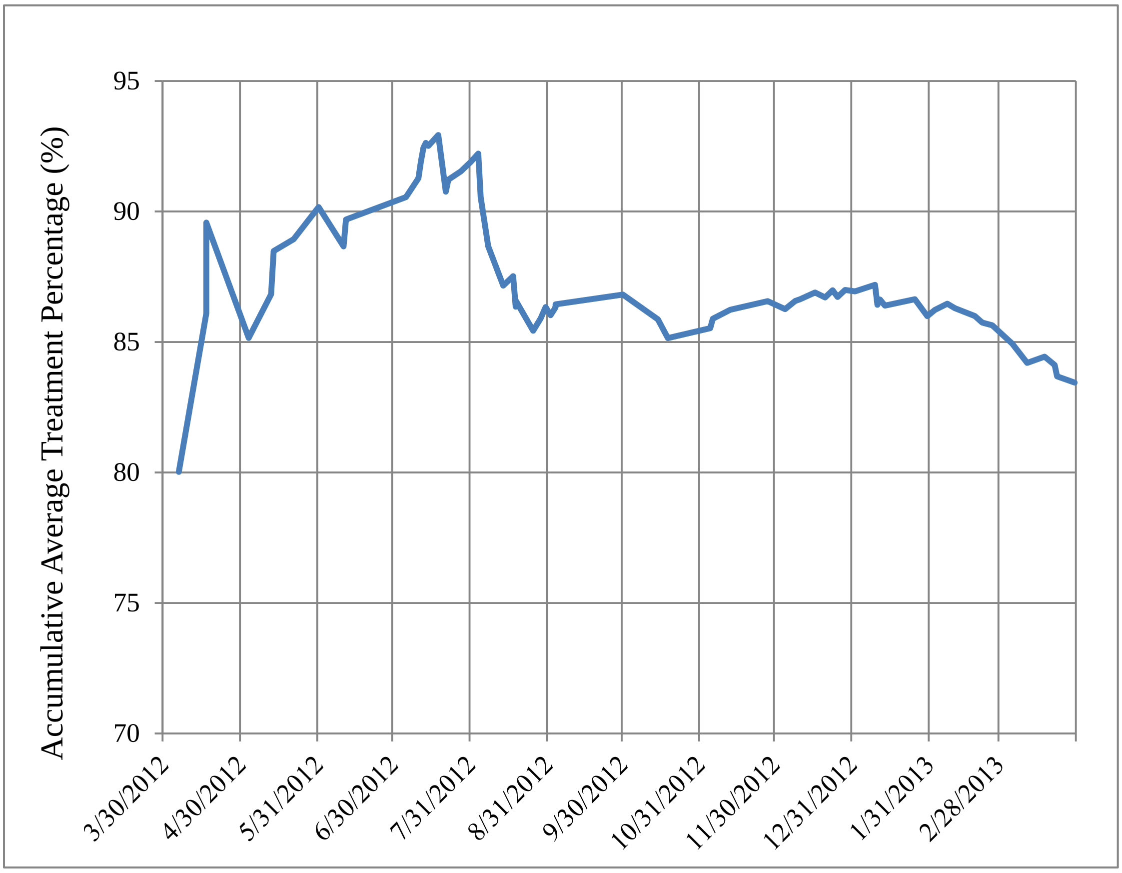


Figure 32: Time Series of Accumulative Total Flow Treatment Percentage over Monitoring Period

Figure 33 is a time series plot of the treatment flow rates observed (the maximum flows associated when the sump water stage dropped back down to the level of the bypass weir). This was considered as the level maximum operational maximum treatment flowrate of the Up-Flo® Filter. The flow rate when the sump elevation was dropping was used instead of rising was because the sump stage increases were very unsteady and greatly fluctuated as the influent flow rates varied. The sump levels dropped as the flow rates were steadier on the recession limb of the hydrographs and better represent the stage and flow conditions when bypassing occurred. The blue line in the plot verifies the water stage corresponding to the bypass rate, which is shown as the pink line. High treatment flow rates (with large variations) occurred at the beginning of the study period, with maximum treatment flows ranging from about 100 to 250 GPM. The treatment flow rates dropped dramatically after about nine months in the middle of January, 2013 (around the 20th sampled event at about 34 inches rainfall and 650,000 gallons runoff). These reduced flow rates were about 50 GPM and were quite stable during the last several months of the monitoring period. The system was not monitored beyond the end of March 2013, and it is therefore unknown when complete clogging and 100% bypassing would have occurred in the absence of any site maintenance. At the end of the project monitoring period, these old media bags were removed and new bags replaced.

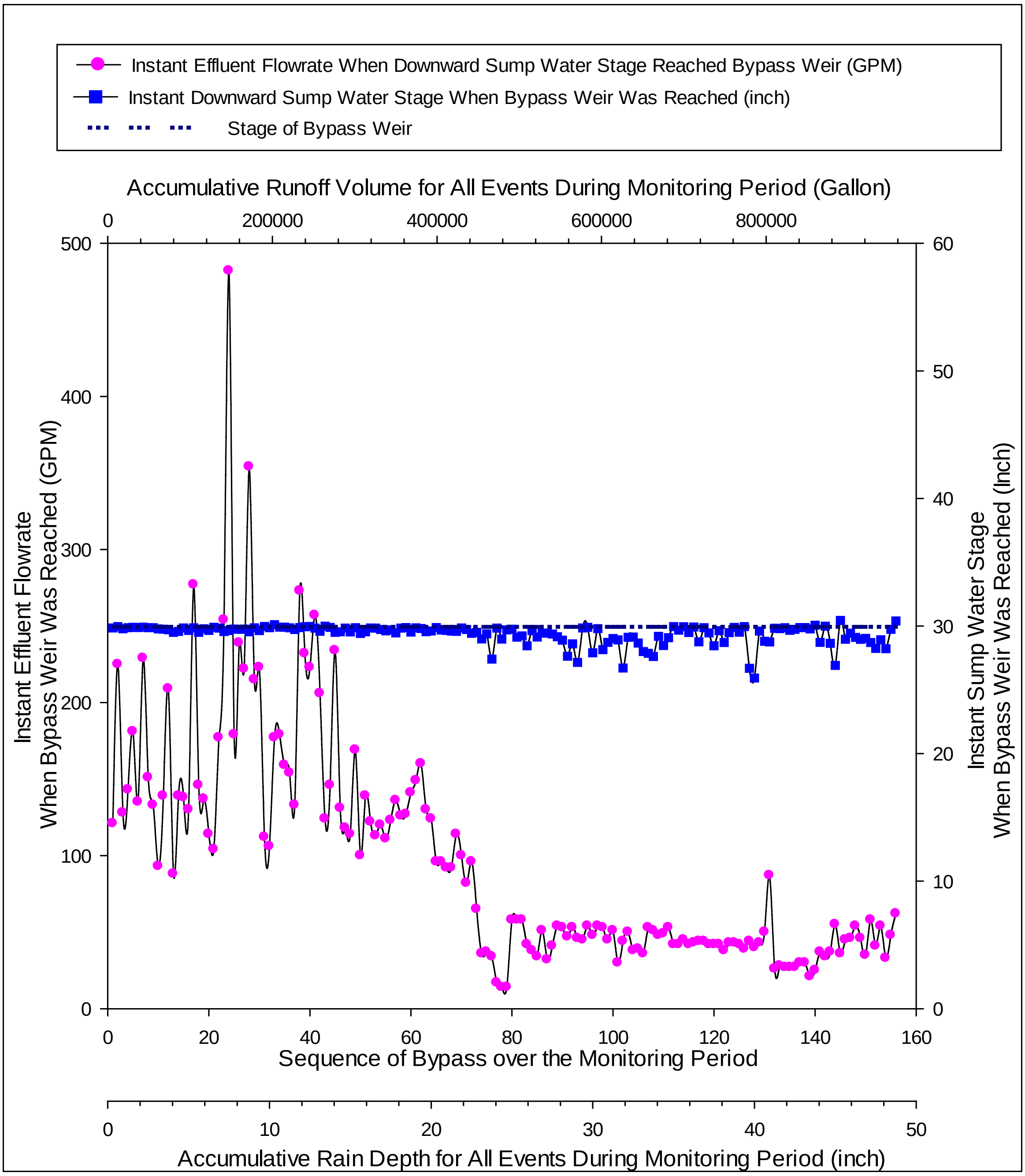


Figure 33: Time Series Relationship of Effluent Flowrate and Sump Water Stage at Bypass Weir

Figures 34 and Figure 35 are scatterplots of the treated flow percentages associated with peak 5-minute rain intensities. At least 90% of the total flows were treated for events which had peak rain intensities up to about 1.2 in/hr (or peak flow rates of up to about 150 GPM). At least 50% of the runoff flows were treated, even when the peak rain intensity was as high as about 5 in/hr (or about 1,000 GPM of peak runoff rate). Some other relatively high treatment percentages also occurred with high peak rainfall conditions. Starting in January 2013, the measured treatment flow rates were found to be consistently lower than the design flow rate, and the following storms were therefore expected to have a higher bypass percentage, even under relatively less intense storms, as shown in Figure 35.

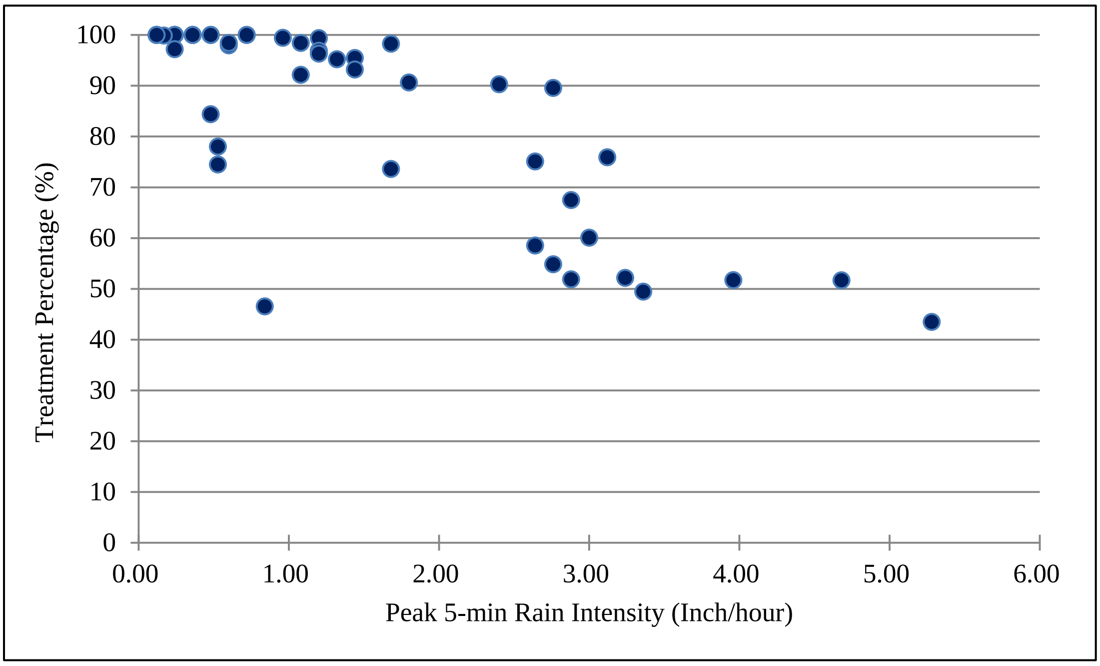


Figure 34: Scatterplot of Treatment Percentage vs. Peak 5-min Rain Intensity (Considering All Events before January, 2013)

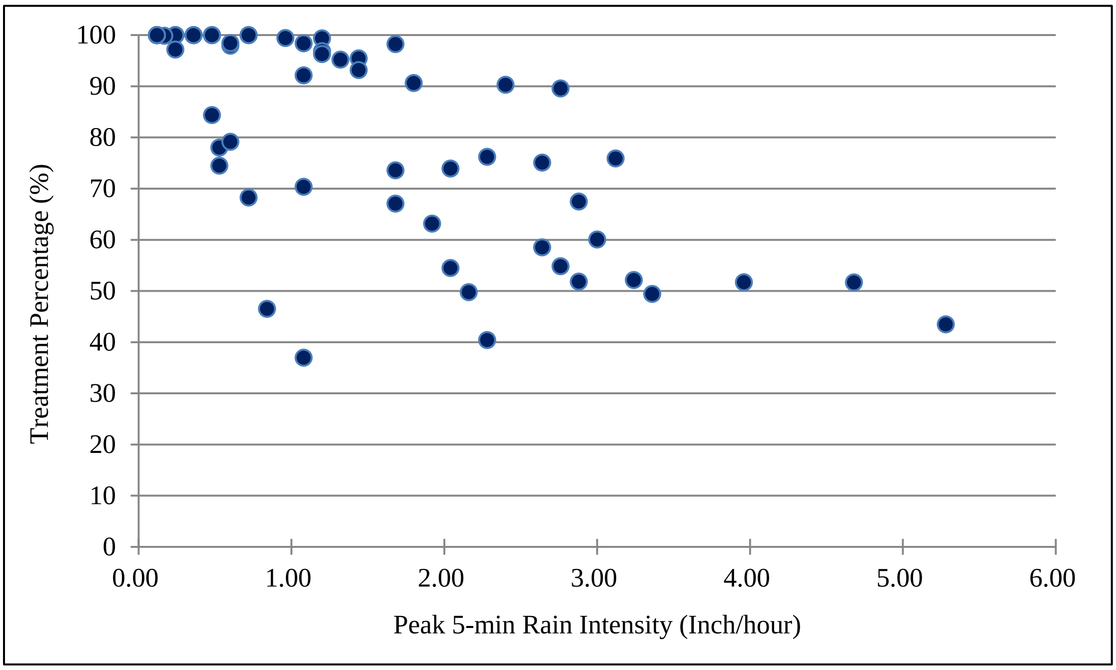


Figure 35: Scatterplot of treatment percentage vs. peak 5-min rain intensity (Considering All Events during Monitoring Period)

Figure 36 is a time series plot of the percentage of the total event volume that was bypass. The large variation shown on the plot mostly depends on the rainfall characteristics, especially the summer thunderstorms (around July and August) in Tuscaloosa area typically have short flow durations but can have very high rainfall intensities which will generate large portions of bypass. The last few months of tests do show an increase in the bypass percentage, likely associated with the decrease in treatment flow rate capacity due to clogging.

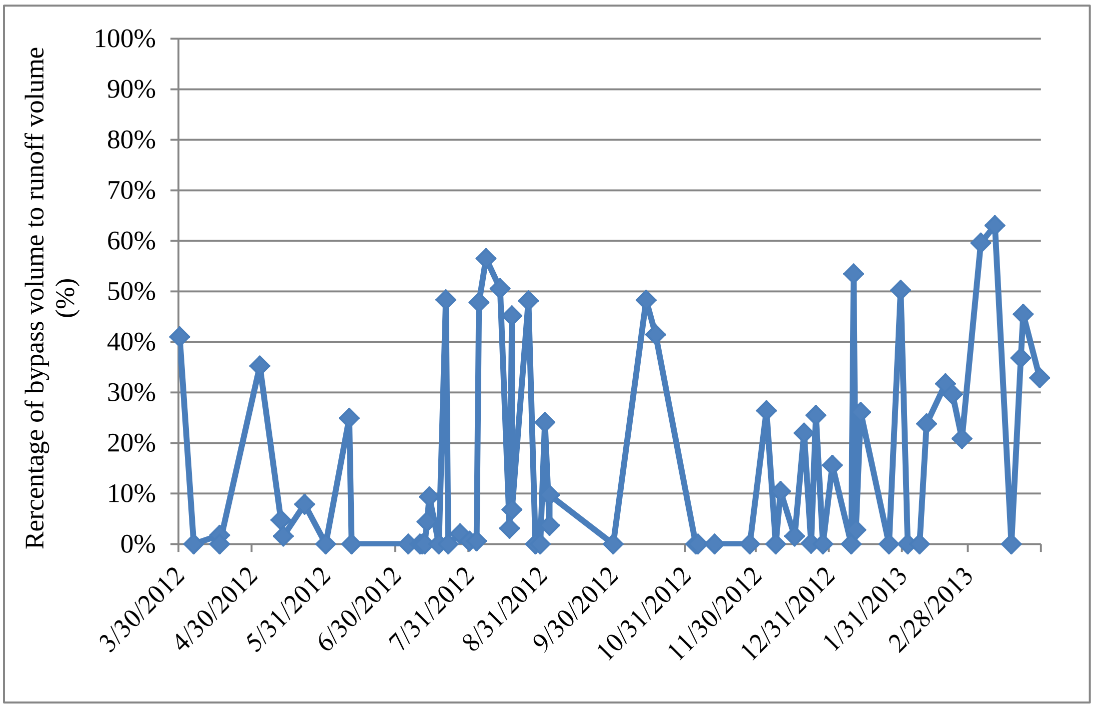


Figure 36: Time Series Plot of Percentage of Bypass Volume to Runoff Volume

5.4 Performance Evaluations of Solids Removal

Solid constituents, including suspended fine particulates and settleable sediments, are critical pollutants in stormwater and are therefore a common key parameter when evaluating the water quality performance and treatability of a stormwater runoff treatment device. Solids not only affect the visually apparent water quality, such as color, hardness, and turbidity, but many pollutants, including heavy metals, nutrients, PAHs, and microorganism, are often closely associated with the solids in the stormwater (Clark and Siu, 2008). Therefore, the capability of removing large fractions of the solids constituents at a stormwater treatment facility also reflects the secondary ability for treating other associated pollutants. During this thesis research, the overall water quality performance of the full-scale Up-Flo® Filter primarily focused on the removal of solids constituents, as measured by total suspended solids (TSS), suspended solids concentration (SSC) and solids concentrations for several specific size ranges. The other solids-related compounds, including volatile suspended solids (VSS), total dissolved solids (TDS), and turbidity, were also measured. In addition, the solids removal performance during actual storm monitoring was also compared to the removal of solids during the controlled sediment removal tests, and compared based on their known particle size distributions and specific gravities. Also, many conventional constituents (heavy metals, nutrients, and bacteria) were also monitored during the project.

5.4.1 Up-Flo® Filter Treatment Performance for Solids Constituents

During the one-year monitoring period (March 2012 through March 2013), a total of 30 storm events were sampled during this project, out of a total of 69 rains that occurred during the full monitoring period that were greater than 0.1 inches), covering a complete range of annual rainfall and flow conditions. The other storms that were not sampled for water quality analyses did have measurements of rain depth and flow to help interpolate the mass of pollutants measured in the sump at the end of the project. “All” of the storms in the year were not monitored due to the time needed to process and analyze the samples (which required one to two weeks per storm event). The storms that were monitored represented the range of conditions that occurred during the sample year.

Table 10 below lists the summary treatment performance and influent and effluent concentrations for the of solids constituents, while Figure 37 are line plots showing the influent and effluent quality changes for the 30 sampled storms, illustrating the irreducible concentrations for the Up-Flo® Filter. The TSS results are shown using two alternative filters (both acceptable); a glass fiber filter and a nominal 0.45 µm membrane filter. The glass fiber filter resulted in the largest recovery, compared to the SSC results. As shown in the table and the plots, the effluent solids concentrations, measured as TSS and SSC, averaged about 3 mg/L (with about 0.75 COV values). The average removal rates for TSS and SSC were 80 and 85% respectively (glass fiber filters), indicating excellent solids control capability of the Up-Flo® Filter. The measured turbidity, which is correlated with the concentration of fine suspended particulates, had an average effluent concentration of about 12 NTU, and an average reduction of about 56%. As expected, the TDS removals were smaller. The effluent TDS concentrations were about 46 mg/L and the average removal rate was about 11%. The filterable solids that comprise TDS are very small (<0.45μm, and mostly dissolved salts and major ions) and are difficult to control using either conventional or advanced stormwater treatment.

Table 10: Summary of Solids Constituents Analyses for 30 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
TSS (UA) (glass fiber filters) (mg/L)	Influent	162	122	571	11	147	0.91
	Effluent	23	21	56	3	17	0.75
	Removal Efficiency	79.9%	85.1%	98.1%	40.9%	15.2%	0.19
TSS (UA) (membrane filters) (mg/L)	Influent	150	118	495	5	131	0.87
	Effluent	22	18	59	2	16	0.73
	Removal Efficiency	82.7%	87.3%	95.8%	52.8%	14.0%	0.17
SSC (UA) (mg/L)	Influent	778	127	6231	23	1372	1.76
	Effluent	26	22	68	3	18	0.71
	Removal Efficiency	85.4%	89.2%	99.4%	52.9%	14.2%	0.17
VSS (mg/L)	Influent	35	33	124	3	25	0.72
	Effluent	9	8	25	1	6	0.70
	Removal Efficiency	69.2%	72.0%	93.9%	28.6%	16.2%	0.23
TDS (mg/L)	Influent	52	47	135	17	24	0.45
	Effluent	46	39	124	14	23	0.50
	Removal Efficiency	11.4%	9.1%	45.7%	-17.5%	17.9%	1.57
Turbidity (NTU)	Influent	32.5	22.9	117.5	4.5	28.5	0.88
	Effluent	11.7	8.3	33.2	3.1	9.7	0.83
	Removal Efficiency	55.7%	58.2%	83.0%	17.5%	21.3%	0.38

Figure 37 illustrates how large influent concentrations are reduced by the greatest amount, while low influent concentrations may only have small removals. Generally, most stormwater treatment devices have an irreducible concentration below which the effluent concentrations are not able to be further reduced. In most cases, the percentage reduction values may not be very indicative of overall performance of the device. Errors are especially likely if these values are applied for a wide range of influent concentrations. It is likely that most stormwater managers will find that final effluent concentrations are more useful, especially in the time of numeric effluent limits.

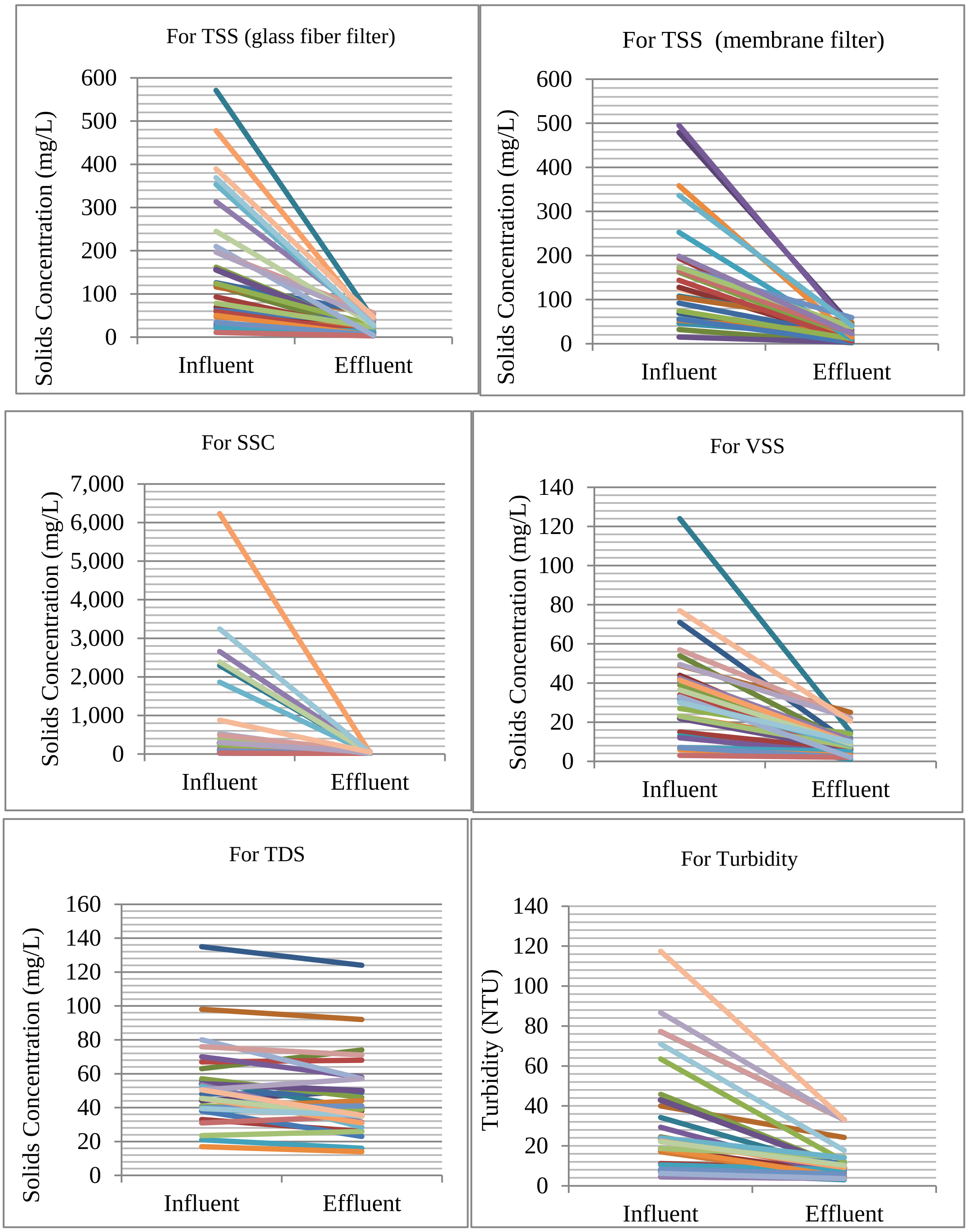


Figure 37: Solids Performance Line Plots of 30 Sampled Events

Replicate Analyses for TSS were conducted in the laboratory at the University of Alabama using different filters, as discussed in Section 3.4.5.1. Figure 38 shows the correlation plots of TSS analyses using glass fiber or membrane filters. The TSS results from both filters had strong correlation relationships with R^2 values about 0.82 and 0.86. The solids recoveries using the glass fibers were greater than when using the membrane filters (the membrane filters were about 20% low for influent samples and about 8 % low for effluent samples). The effluent samples had few large particles and lower concentrations than the influent samples, which likely resulted in the difference in recoveries between the two filter types.

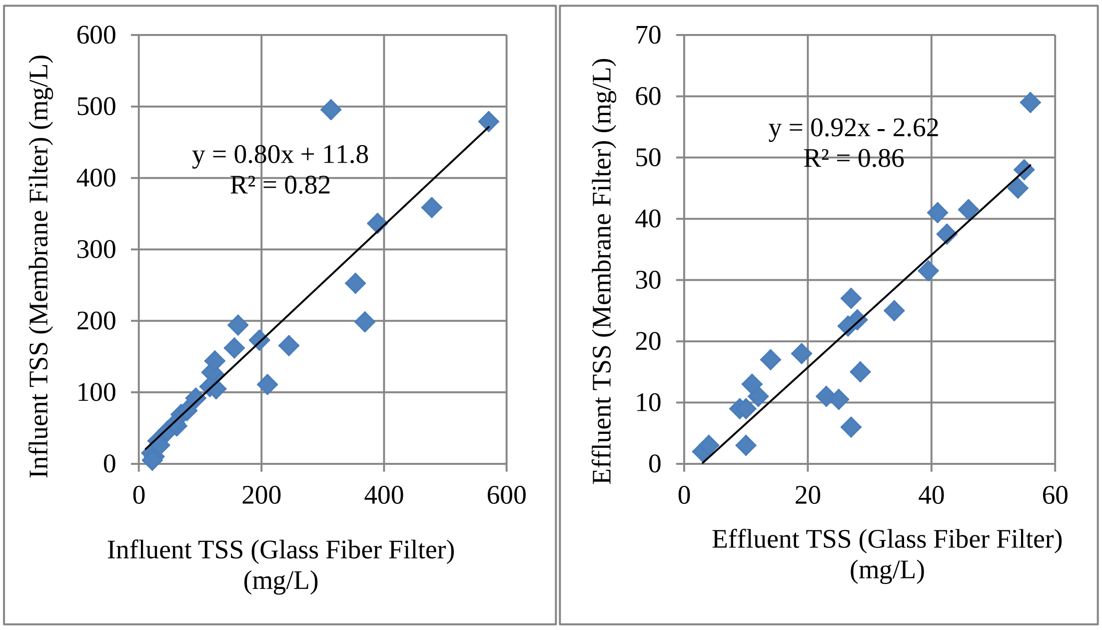


Figure 38: Correlation Plots of TSS Analyses using Glass Fiber and Membrane Filters

Figure 39 shows a time series plot of solids removal efficiencies for TSS, SSC, TDS, and VSS respectively, for each of the 30 monitored events. The percentage reductions contain large amounts of variability and no apparent pattern with time. For TSS and SSC, both plots follow a similar relationship with period, with some performance degradations occurred periodically, likely due to the low influent concentrations. However, the overall average removal performance was still about 80% for TSS and 85% for SSC, meeting the primary performance goal for the Up-Flo® Filter. Some of the TDS removals are shown to be negative. It is unlikely that the device produced dissolved solids, but these variations are likely associated with the analytical variations that are common for low TDS concentrations (little mass added to the large mass evaporating dish).

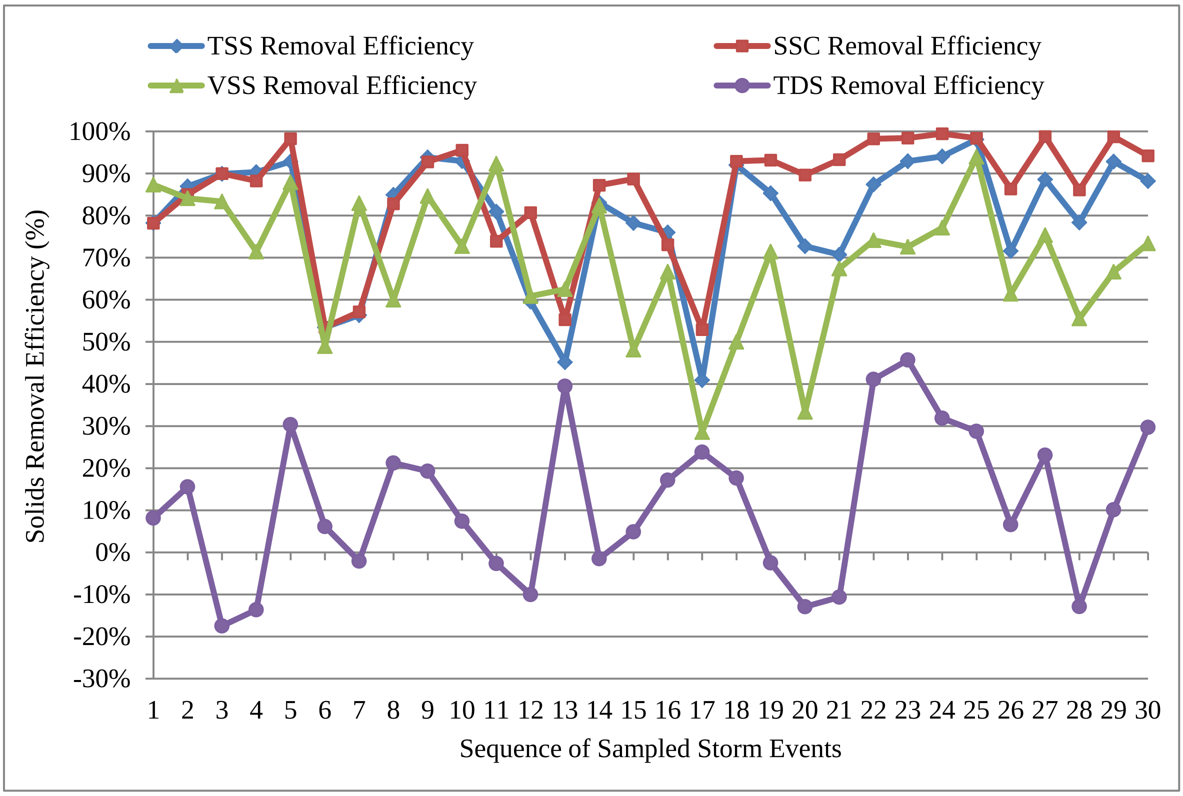


Figure 39: Time Series of Average Solids Removal Efficiency for Solids Constituents

SSC performance represents the overall particulate solids removal rate, ranging from fine particulates (0.45 µm) to large sediments (>1200 µm). Figures 40, 41 and 42 are scatterplots and probability plots of influent and effluent SSC concentrations. The regression line Figure 40 (calculated using log-transformed values to meet the regression requirements for this data set) is relatively flat compared to the red 45 degree equivalent concentration line, demonstrating that the effluent SSC concentrations were always less than the influent concentrations. Figure 41 plots the same data and plot with showing the 95% confidential intervals (CIs). As shown in Figure 42, the influent is normally distributed while the effluent concentrations are not, according to the Anderson-Darling test statistics shown on the figure, indicating the need for nonparametric statistical analyses. The two log-normal probability plots are not parallel, showing wider separations for the higher concentrations than for the smaller concentrations. The effluents have a smaller variation, while the influents have a large variation, as typical for a well behaved stormwater control device.

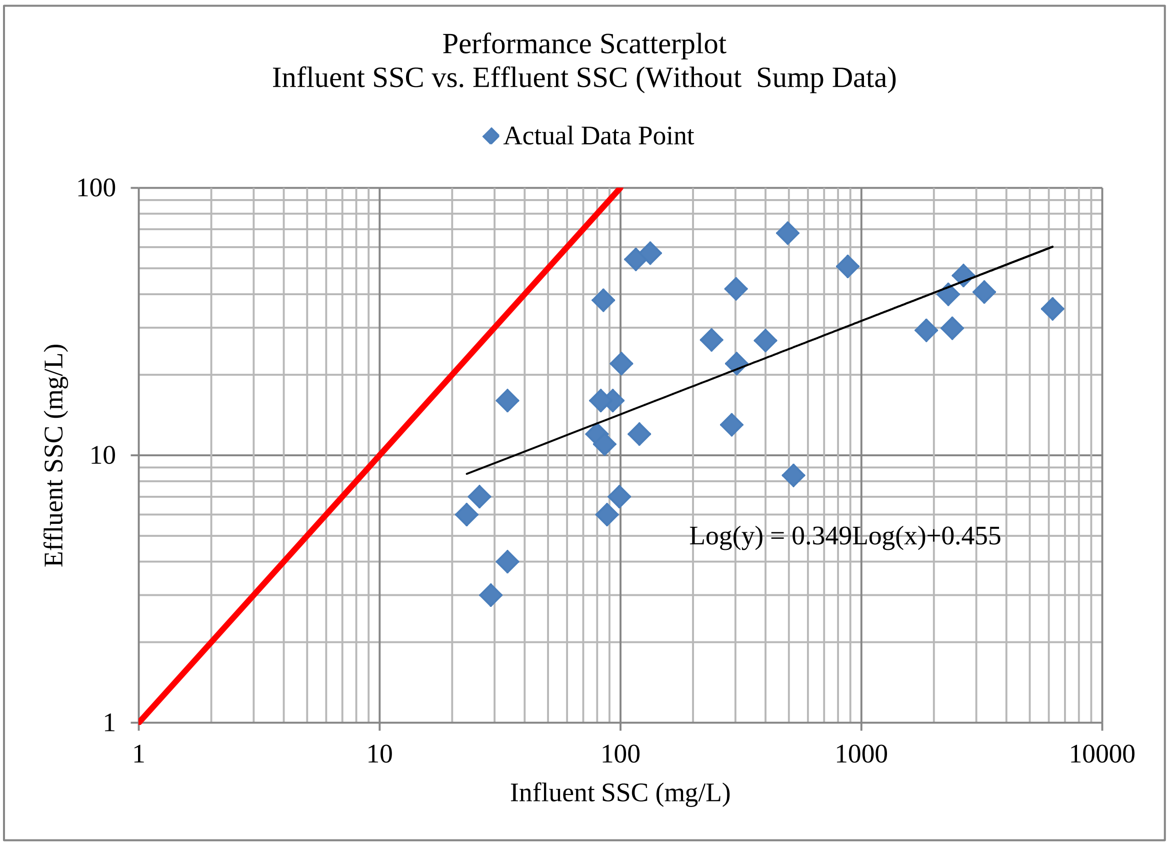


Figure 40: Scatterplot of Influent SSC and Effluent SSC for 30 Sampled Events

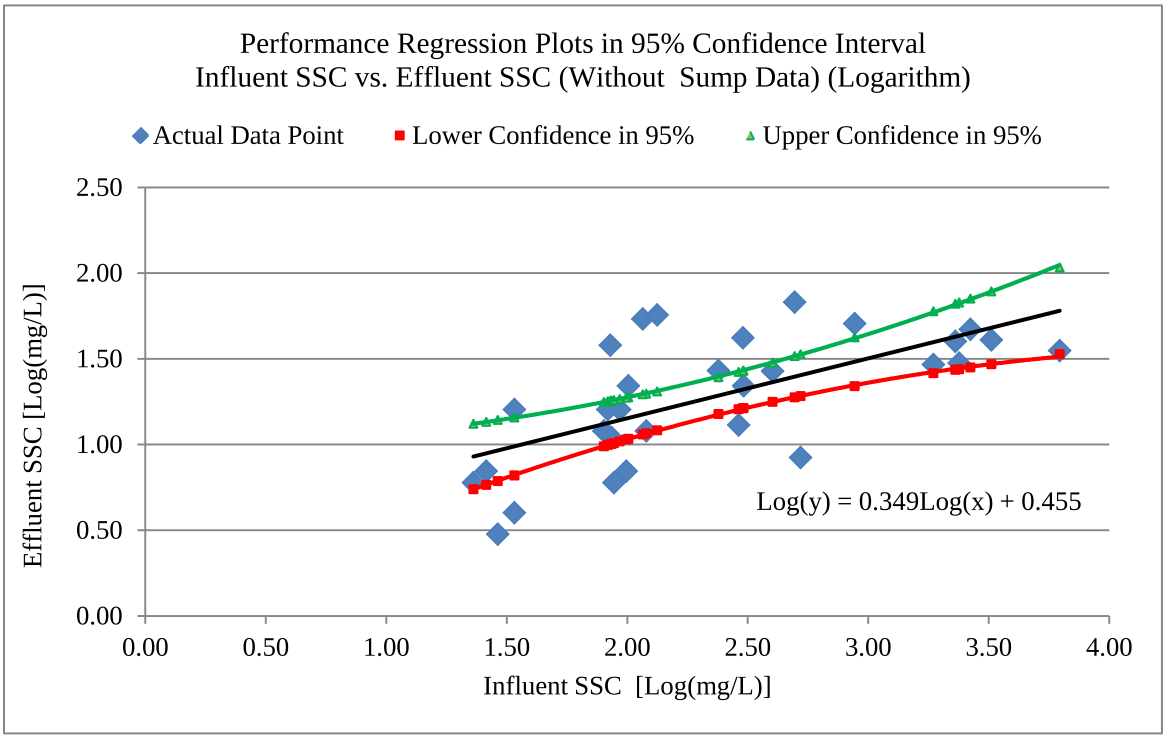


Figure 41: Scatterplot of Influent SSC and Effluent SSC for 30 Sampled Events With 95% Logarithm Confidential Interval (Logarithm10 Transformation)

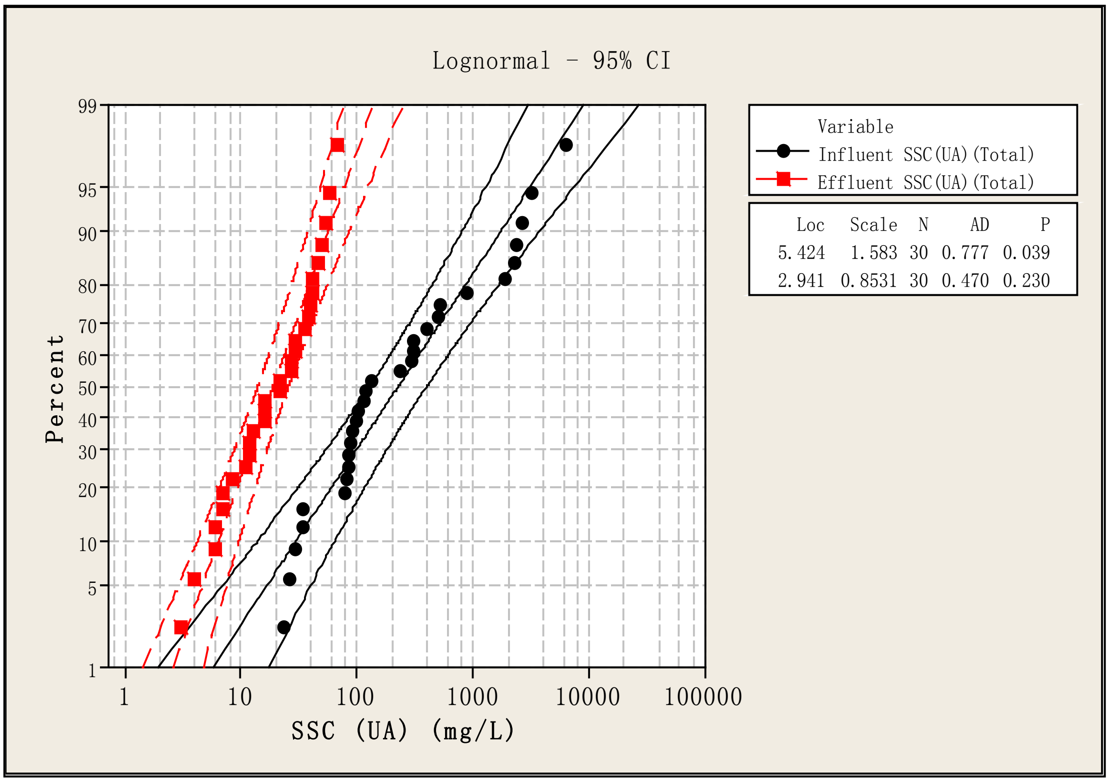


Figure 42: Probability Plots of Influent and Effluent SSC

Table 11 and Figure 43 describe the regression and ANOVA analyses and residual plots of SSC performance that correspond to the $\log_{10}$ regression equations in Figures 40 and 41. Table 11 shows that the significance of the regression with intercept and slope terms, and indicates that the overall regression model is statistically significant as the "Significance F" factor is much less than 0.05. Figure 43 presents the residual plots for the logarithm-transformed equation. The residuals are well-behaved, being randomly distributed around zero with no apparent trends.

Table 11: Regression and ANOVA Analyses of SSC Performance (Logarithm10 Transformation)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.65
R Square	0.42
Adjusted R Square	0.40
Standard Error	0.29
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.67	1.67	20.28	0.00
Residual	28.00	2.31	0.08		
Total	29.00	3.98			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.45	0.19	2.39	0.02	0.07	0.84
X Variable 1	0.35	0.08	4.50	0.00	0.19	0.51

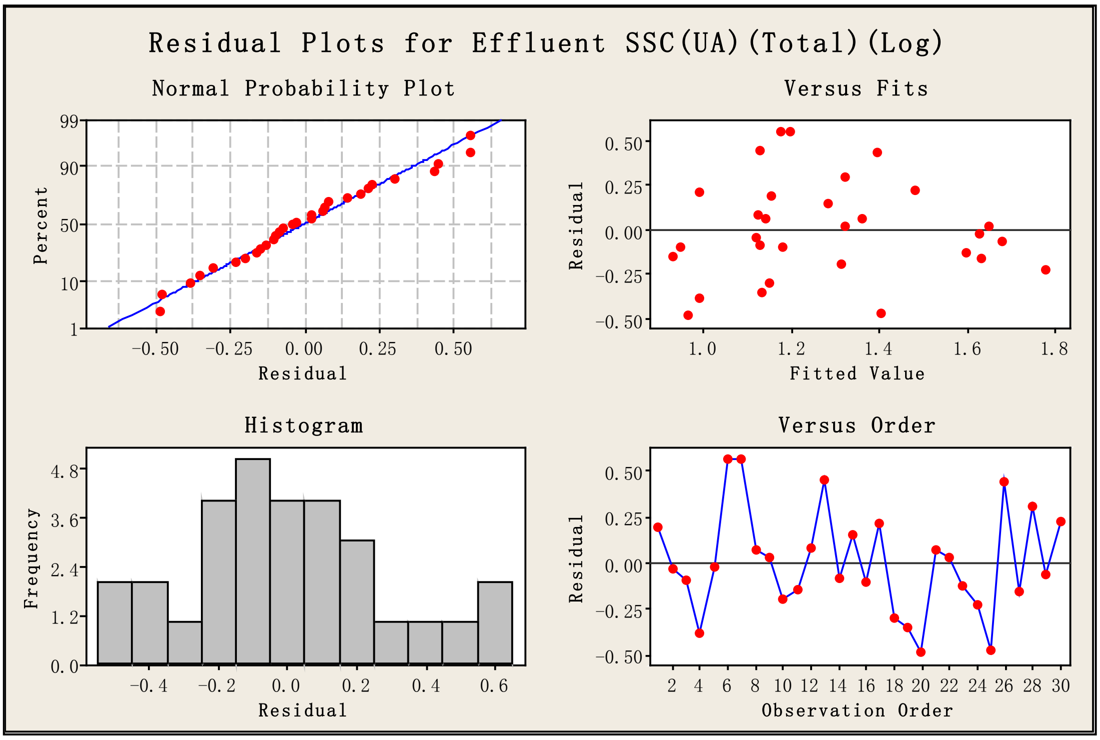


Figure 43: Residual Plots of SSC Performance (Logarithm Transformation)

Table 12 summarizes the regression equations describing the performance of all solids constituents for the 30 sampled storms. All regression equations were $\log_{10}$ transformed. The equations are all highly significant. The Wilcoxon Signed Rank Test (non-parametric) was used for hypothesis testing (influent = effluent), and the p-values for all constituents show significant differences between the influent and effluent values.

Table 12: Summary of Regression Performance of Solids Constituents for 30 Sampled Events

Particulate Constituents	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value that Influent Equals Effluent
TSS (UA)	Log(y) = 0.5968 Log(x)	0.91	0.00	NA	0.00	<0.001
TSS (UA) (Membrane Filter)	Log(y) = 0.5748 Log(x)	0.89	0.00	NA	0.00	<0.001
SSC (UA)	Log(y) = 0.3493Log(x) + 0.4546	0.40	0.00	0.02	0.00	<0.001
VSS	Log(y) = 0.5997 Log(x)	0.90	0.00	NA	0.00	<0.001
TDS	Log(y) = 0.9635 Log(x)	0.96	0.00	NA	0.00	0.003
Turbidity	Log(y) = 0.6994 Log(x)	0.94	0.00	NA	0.00	<0.001

5.4.2 Analytical Method Issues for Stormwater TSS and SSC Measurements

As described in previous sections, ASTM D 3977-97B (ASTM, 1997, Reapproved in 2002) was used for the SSC analyses, while Standard Methods 2540D (Standard Methods, 1999) was used for the TSS analyses during this research. The fundamental difference between the SSC and TSS analytical methods is how the subsampling is conducted (Gray et al., 2000). The SSC method is much more efficient in detecting large particulates that are in the sample. The TSS analysis methodology was developed to focus on “suspended” solids that would likely remain in a wastewater after simple primary treatment, and was never intended to include the large particles that are easily removed from the waste stream. Stormwater can include large particulates (if the sampling is suitable) so the analytical results may indicate SSC values much larger than TSS values. Treated stormwater is likely to have much closer SSC and TSS results.

This discussion describes some of the issues relating to TSS and SSC analytical methods addressed during this research applicable to stormwater. Paired sample analyses for TSS and SSC by Gray et al. (2002) showed that TSS results were typically between 25 to 34 percent less than SSC results. The bias of the TSS method is largely due to the subsampling technique (magnetic stirrer and pipetting) in the non-homogenous samples for TSS (or shake and pour subsampling), compared to the use of a cone splitter that divides the complete sample to obtain the SSC subsample. Another result found by Gray et al. (2000) was that TSS results were close to the SSC results when most of the particles were finer than 62 μm. Therefore, the correlation between TSS and SSC can vary greatly for different conditions. Observations during this thesis research, in combination with findings from with previous work, found that:

1) TSS results are affected by subsampling location in the sample container. Standard Methods requires subsampling at mid-depth and midway between the bottle wall and the stirring vortex, assuming the sample are being well-mixed. However, this sampling location may not retrieve a representative fraction of the larger particles which tended to slide along the bottom of container (Clark and Pitt, 2008), especially for those samples where the fraction of large particles is considerable. Settleable sand particles tend to move around the bottom of the bottle in a clump, away from any mid-depth pipetting; if subsampling includes the clump, the TSS results would be substantially influenced (Clark and Siu, 2008);
2) TSS results are affected by aliquot volumes. Typically, each pipetted aliquot is 10 mL, and 10 aliquots, totally 100 mL, are obtained from a one liter stirred sample. A larger number of aliquots will generally result in better representativeness. In many cases, only

a single 100mL pipetted subsample may be obtained;

3) TSS results are affected by sample volume and the dimension of the sample container. Considering the subsampling technique listed by Standard Methods, the water column in the sample container needs to be deep enough to provide sufficient space between the mid-depth and midway and the bottom of the container in order to minimize the collection of non-representative amounts of large (heavy) particles around the bottom that will bias the result of the TSS method. Similarly, the height of the sample container needs to be high enough to allow the water column sufficient depth (i.e. wide and short sample containers can result in the capture of large particles on the bottom using the Standard Methods' pipetting method). Generally, the typical dimensions of typical HDPE 1 liter wide mouth Nalgene sample bottles are preferable for TSS analysis;

4) TSS results are affected by the speed of rotation of the magnetic stir bar. This is especially notable for large (heavy) particles. The rotation speed of the magnetic stir bar is usually not strong (fast) enough to keep the large (heavy) particles and sand suspended during pipetting. Furthermore, previous comparison research has indicated that, even for fine particulates ranging up to 106 um, differences between the true concentration and TSS-EPA and TSS-SM increased from less than 2%, to 36% as the particle size (correlated to mass) increased (Guo Q., 2006).

5) Recall that the TSS method was not originally intended to collect large particles that are easily removed with simple wastewater treatment. Upper particle size limits for TSS are usually in the range of 75 to 125 µm. Using a particle size distribution method, the TSS values can be modified according to whatever upper limit is desired.

6) The SSC method, ASTM D 3977-97B, has been shown to be more consistent and to represent a wide range of particle sizes (Clark and Siu, 2008). During this research, the observed main possible source of error introduced during SSC analysis is that the initial sample split is non-homogenous (especially if using a churn splitter) so that the difference of solids concentration in each subsample may occur (i.e., some subsamples may have more solids than others). When the sample is split using the USGS/Dekaport cone splitter, this problem is minimized. However, very large initial samples may make this method of subsampling impractical. Five liter sample increments have been shown to be easily handled, possibly requiring several pours in the cone. As noted in the methods discussion, the sample container is well rinsed to remove any remaining large particles (and the rinse volume noted which affects the concentration calculations). Previous repeatability tests for the cone splitter conducted in the UA lab indicated that the coefficients of variation (COV) of subsamples from cone splitter for different sediment types (Mix sediments, Sil-Co-Sil® 250 and Sieved Sand (9 to 250 μm)) were less than 5% (COV values of <0.05), although the splits for the larger particles had slightly greater variabilities than the splits for the smaller particles (Pitt, 2009). This level of is acceptable under controlled solids conditions (typically larger fraction of fine particulates compared to actual stormwater runoff). Another minor source of error is likely that the visual measurements of subsample volumes may not be accurate enough due to the low resolution of the scale of graduate cylinder that receives the split subsample from cone splitter (i.e. the resolution of the scale of 250 mL graduate cylinder used during this research is only up to 5 mL; volumetric flasks only have one indication and are not

suitable for measuring small flow increments). These volume measurement errors may also introduce small errors (usually <5% also).

5.4.3 Analyses of Particle Size Distributions (PSD)

The effectiveness of the Up-Flo® Filter for different particle size ranges is especially critical since it combines several analytical procedures and a broad range of particle sizes, and represents comprehensive solids performance, rather than being limited by one specific analytical method. It also provides valuable information for the treatability evaluation for narrow particulate size ranges than can be used to predict performance for sites having other PSDs.

Figure 44 contains line plots of influent and effluent concentrations for several particle size ranges. These line plots indicate that the Up-Flo® Filter has different removals for each particle range, generally being less for the smallest particles and more for the largest particles, as would be expected. However, even the smallest particle size range (0.45 to 3 µm) is shown to have statistically significant removals. Again, the removal rates are greater when the influent concentrations are larger. These plots also show that the Up-Flo® Filter retains almost all of the relatively large particles (>250 µm). Some reverse sloped lines occur occasionally, indicating an increase in concentration, likely due to analytical variability or possible sump scouring.

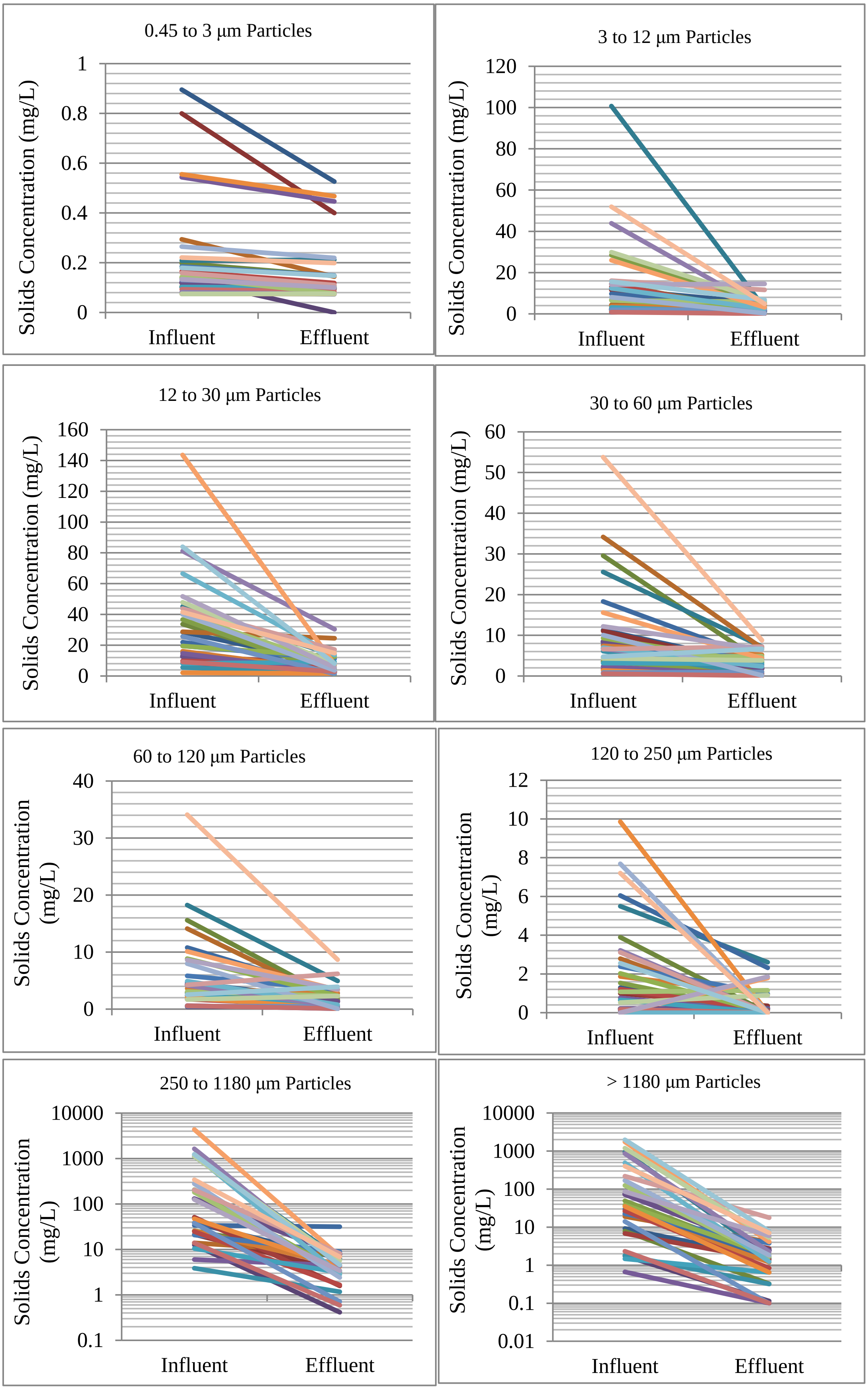


Figure 44: Performance Line Plots of Particle Ranges for 30 sampled Storms

Table 13, and Figures 45 and 46 summarize the particle size distribution performance for the influent and effluent samples collected during the 30 sampled storms. Table 13 shows that the Up-Flo® Filter removed about 97% of the total particulate loading observed during these sampled storms based on the sum of average solids concentration for each range, with greater removals for the large particles and lower removals for the smaller particles. A larger portion than expected of the sum of loads was associated with the unusually large loadings in the influent of particles larger than 250 µm, possibly due to nearby erosion of landscaped areas. Figure 45 shows that the median particle size (D_{50}) of the influent samples was about 460 µm and about 33 µm for the effluent samples. The influent D_{50} is quite large compared to most outfall stormwater samples as the source water was from an adjacent parking lot directly and the larger particles were effectively delivered to the influent plastic tray used for cascading the flow. Also, as noted above, nearby erosion of landscaped areas likely also contributed to these large particles. At outfalls in typical drainage areas, most of the large particulates (>100 µm) are trapped as semi-permanent bedload in the collection and storm drainage systems and are not discharged.

Figure 46 indicates that particle capture is effective for all particle size ranges, but is best for the larger particles. About 25% and 9% of the total particulate influent and effluent solids load, respectively (about 2,526 lbs and 13 lbs of calculated mass) are larger than 1180 µm. The absolute largest particle sizes are not known, as the largest separating screen used was 1180 µm. The sump sediment samples were analyzed at the end of the monitoring period for a wider range of particle sizes and the largest size can then be determined for the mass balance calculations, as discussed in Section 5.7.

Table 13: Summary of Particle Size Distribution of 30 Sampled Storms

Particle Size (um)	Average Mass Percentage (%)		Average Solids Concentration for the range (mg/L)		Calculated Total Mass of sampled storm events for the range (lbs)		Average Percentage Reduction by Solids Concentrations
	Influent	Effluent	Influent	Effluent	Influent	Effluent	
0.45 to 3	0.25	1.15	0.22	0.16	0.80	0.65	27%
3 to 12	5.18	13.02	15.28	3.19	94.22	16.27	79%
12 to 30	15.68	34.08	33.84	8.14	228.80	47.73	76%
30 to 60	7.07	11.84	10.61	3.23	44.88	17.29	70%
60 to 120	3.43	7.02	6.22	1.99	28.68	10.09	68%
120 to 250	1.47	1.44	2.29	0.45	9.65	3.21	80%
250 to 1180	42.18	22.33	424.62	5.23	4232.60	24.27	99%
>1180	24.74	9.12	287.04	2.74	2525.84	12.56	99%
Total	100	100	780	25	7165	132	97%

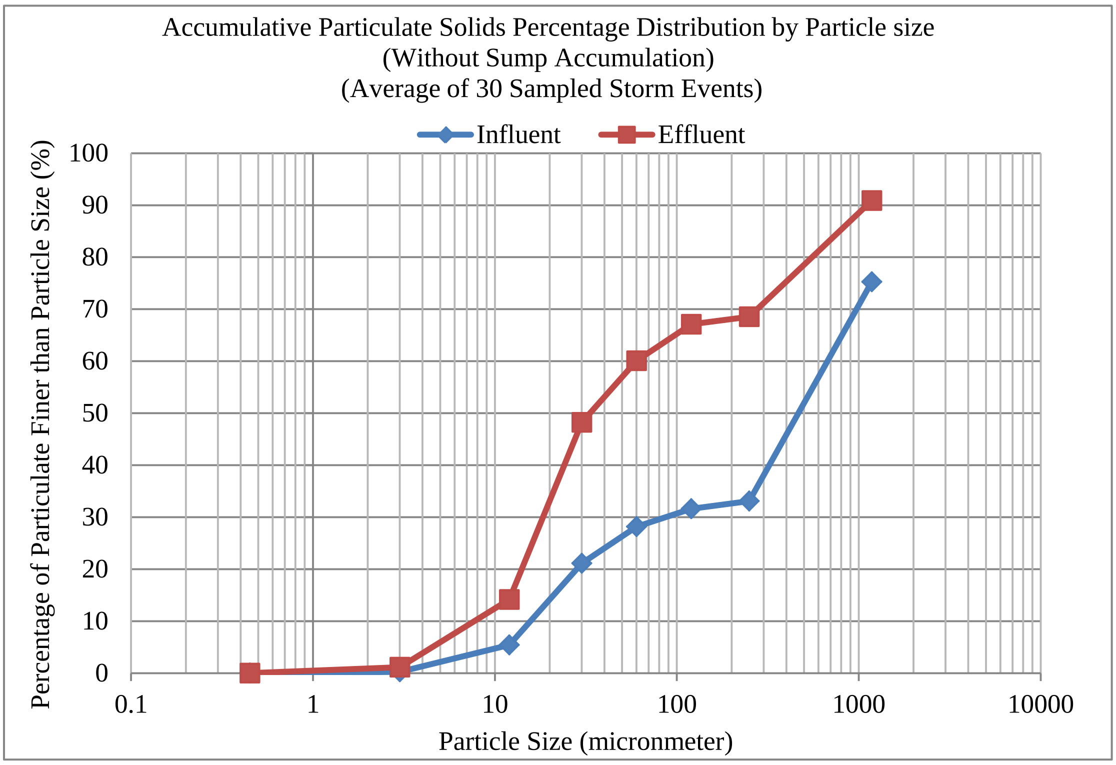


Figure 45: Accumulative Percentage Distribution by Particle Size for 30 sampled Storms

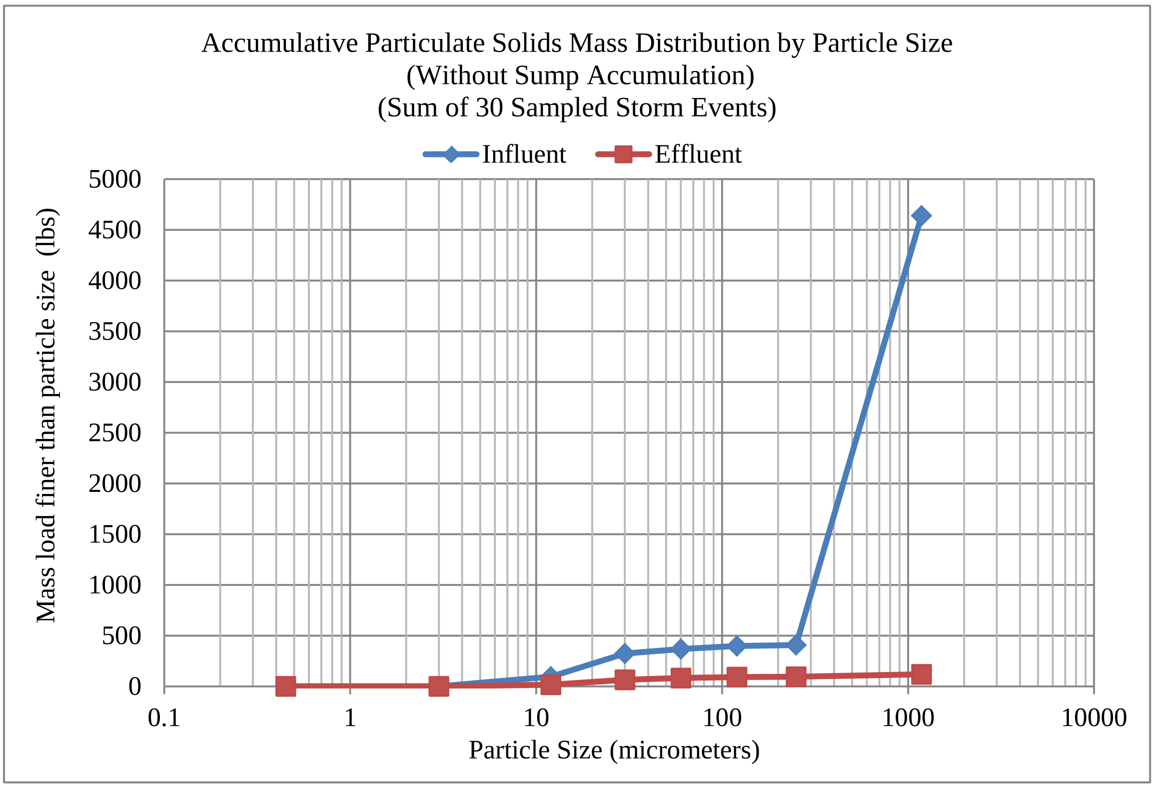


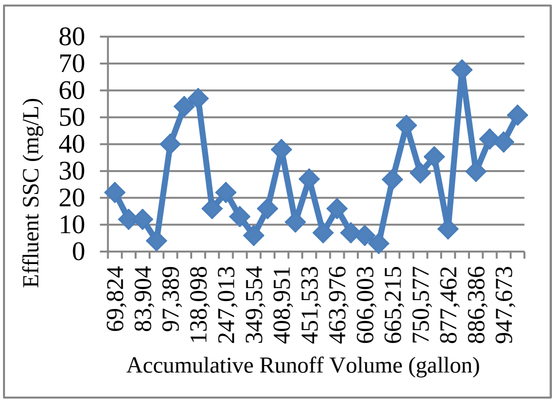
Figure 46: Accumulative Calculated Mass Distribution by Particle Size

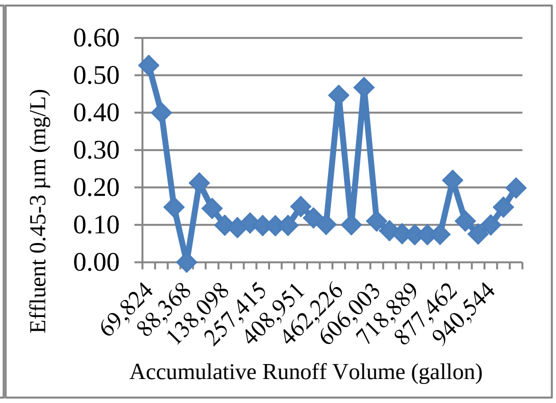
Table 14 summaries regression and ANOVA information describing the performance for each particle size range. All of these regression calculations were based on $\log_{10}$ transformed data, except for the particle size from 120 to 250 µm due to the large fraction of non-detectable effluent concentrations. These regressions and ANOVA summaries demonstrate that all of the size ranges had statistically significant reductions, as the p-values were all less than 0.001. Some of the R_2 values are low, corresponding to effluent concentrations that vary little.

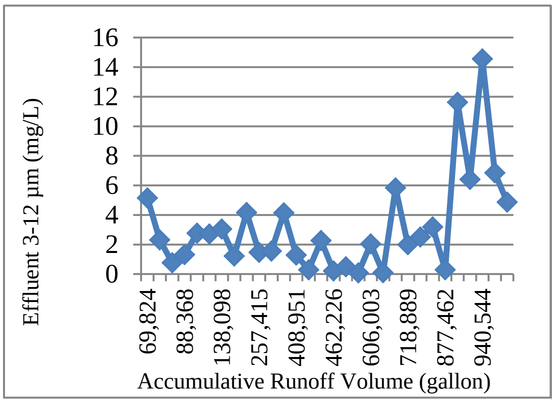
Table 14: Summary of Regression and ANOVA Performance for Particle Size Ranges (30 Sampled Storms)

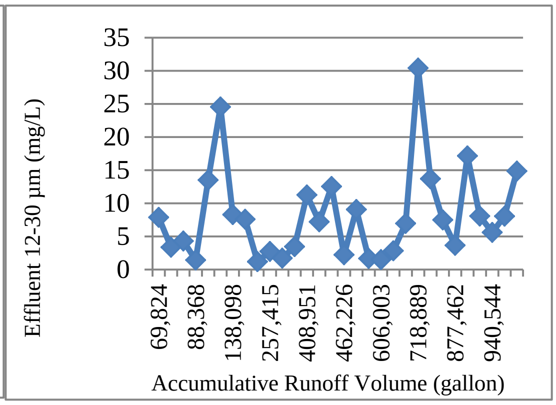
Particle Size (um)	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
0.45 to 3	Log(y) = 0.8129 Log(x) - 0.237	0.92	0.00	0.00	0.00	<0.001
3 to 12	Log(y) = 0.3562 Log(x)	0.33	0.00	NA	0.00	<0.001
12 to 30	Log(y) = 0.5498 Log(x)	0.82	0.00	NA	0.00	<0.001
30 to 60	Log(y) = 0.8654 Log(x) - 0.4454	0.41	0.00	0.02	0.00	<0.001
60 to 120	Log(y) = 0.7345 Log(x) - 0.4163	0.28	0.00	0.01	0.00	<0.001
120 to 250	y = 0.1008x	0.12	0.03	NA	0.03	<0.001
250 to 1180	Log(y) = 0.2681 Log(x)	0.65	0.00	NA	0.00	<0.001
>1180	Log(y) = 0.4435 Log(x) - 0.5918	0.52	0.00	0.00	0.00	<0.001

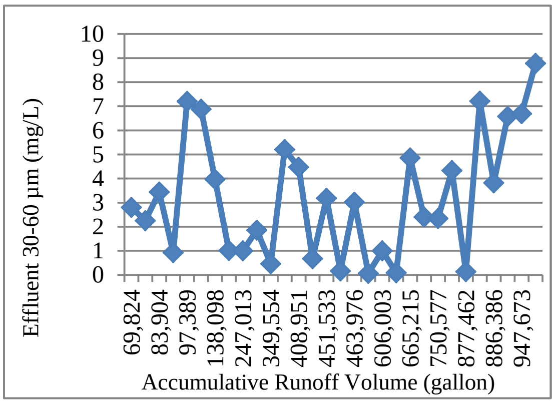
It was expected that the effluent solids characteristics and behavior of the filter were affected by multiple factors, such as the rainfall characteristics of each individual storm, the operating life of the filter media, and other random and uncertain reasons. Therefore, Figures 47 and 48 are plots of the performance of the Up-Flo® Filter as a function of total accumulative runoff treated and bypass fraction of the total flow. Figure 47 shows that the accumulative runoff volume that was monitored at the test site made a slight difference for the effluent solids quality of Up-Flo® Filter near the end of the monitoring period (after about 700,000 gallons were treated). There is substantial variability in effluent quality over these narrow ranges, but the last several events appear to have steadily increasing effluent concentrations, especially for the largest particle size range.

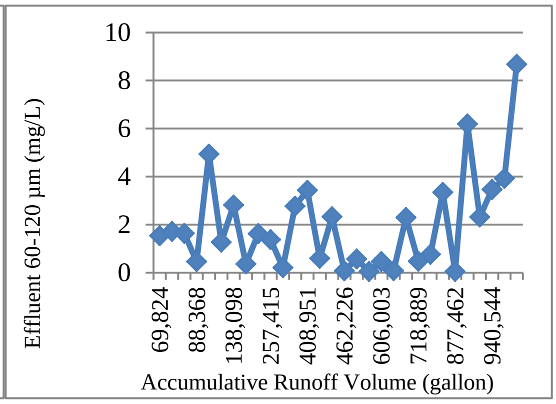

Effluent SSC (mg/L)
0
10
20
30
40
50
60
70
80
69,824
83,904
97,389
138,098
247,013
349,554
408,951
451,533
463,976
606,003
665,215
750,577
877,462
886,386
947,673
Accumulative Runoff Volume (gallon)

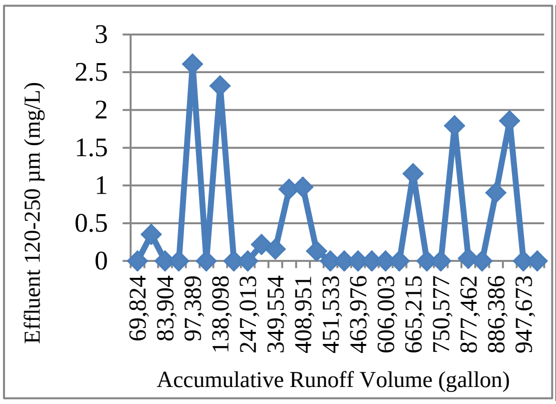

Effluent 0.45-3 µm (mg/L)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
69,824
88,368
138,098
257,415
408,951
462,226
606,003
718,889
877,462
940,544
Accumulative Runoff Volume (gallon)

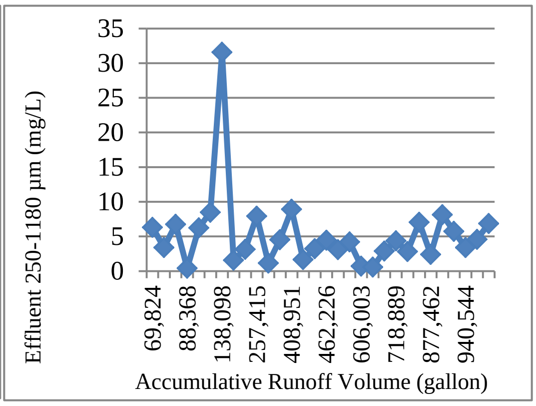

Effluent 3-12 µm (mg/L)
0
2
4
6
8
10
12
14
16
69,824
88,368
138,098
257,415
408,951
462,226
606,003
718,889
877,462
940,544
Accumulative Runoff Volume (gallon)


Effluent 12-30 µm (mg/L)
0
5
10
15
20
25
30
35
69,824
88,368
138,098
257,415
408,951
462,226
606,003
718,889
877,462
940,544
Accumulative Runoff Volume (gallon)


Effluent 30-60 µm (mg/L)
0
1
2
3
4
5
6
7
8
9
10
69,824
83,904
97,389
138,098
247,013
349,554
408,951
451,533
463,976
606,003
665,215
750,577
877,462
886,386
947,673
Accumulative Runoff Volume (gallon)


Effluent 60-120 µm (mg/L)
0
2
4
6
8
10
69,824
88,368
138,098
257,415
408,951
462,226
606,003
718,889
877,462
940,544
Accumulative Runoff Volume (gallon)


Effluent 120-250 µm (mg/L)
0
0.5
1
1.5
2
2.5
3
69,824
83,904
97,389
138,098
247,013
349,554
408,951
451,533
463,976
606,003
665,215
750,577
877,462
886,386
947,673
Accumulative Runoff Volume (gallon)


Effluent 250-1180 µm (mg/L)
0
5
10
15
20
25
30
35
69,824
88,368
138,098
257,415
408,951
462,226
606,003
718,889
877,462
940,544
Accumulative Runoff Volume (gallon)

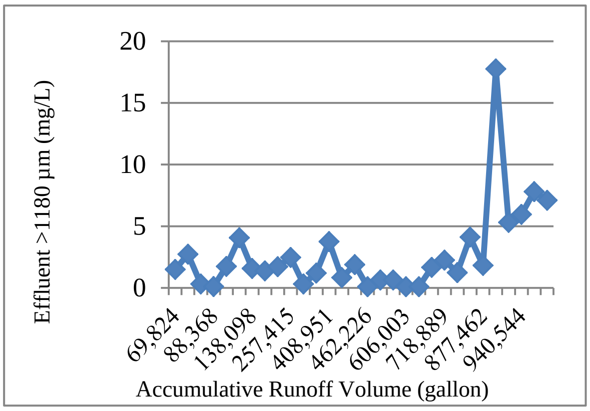
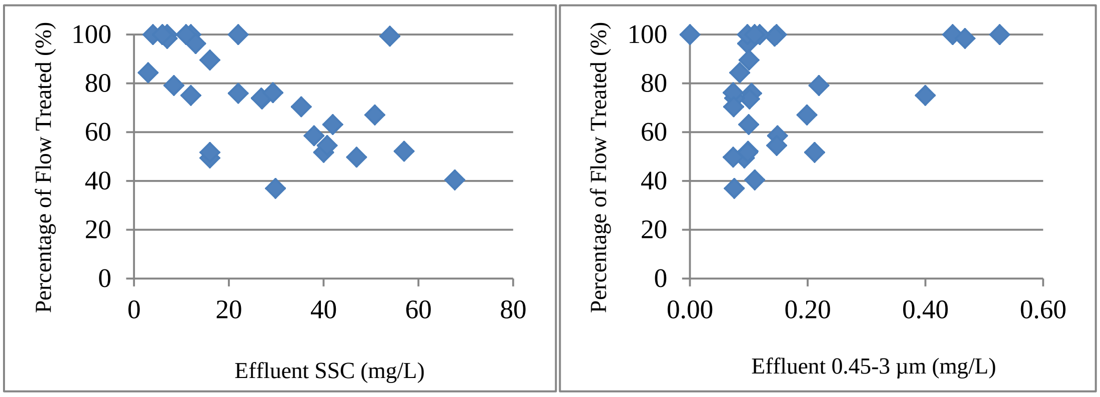


Figure 47: Effluent Solids Quality with Accumulative Runoff Volume

Figure 48 shows how the bypass percentage (the percentage of the total flow that was only partially treated and bypassed the media filters during periods of very large flows) influenced the effluent solids quality. As expected, the effluent solids concentrations for every particle size range increased as the treatment percentages decreased (or as the bypass percentage increased).



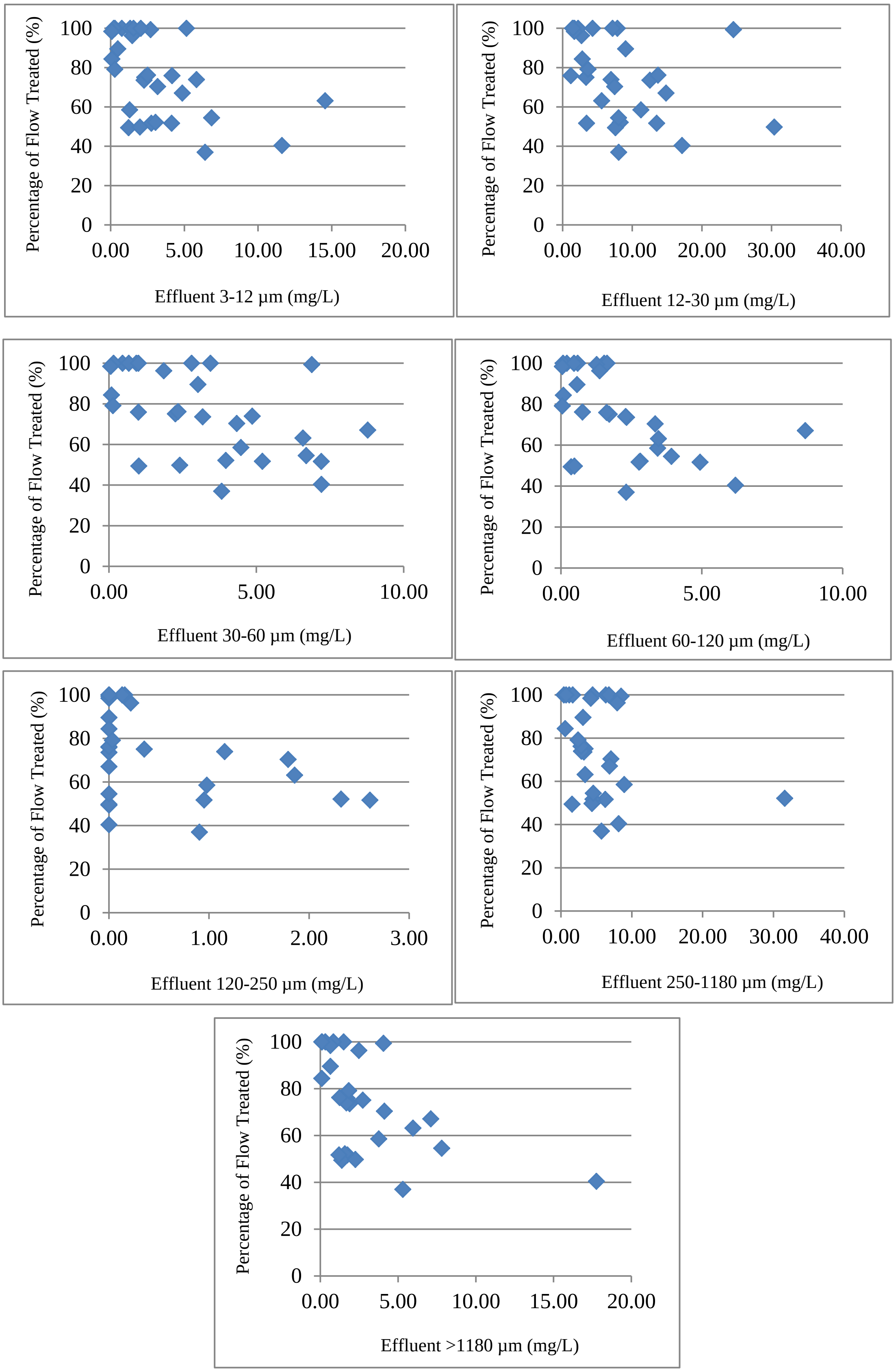


Figure 48: Effluent Solids Quality with Treatment Percentage of Each Sampled Storms

5.4.4 Impact of Sampling Technique on Solids Performance Evaluations

Auto-sampling techniques have been the major tool used to obtain representative stormwater samples for laboratory analysis during many years. It is too difficult and expensive to utilize manual sampling, especially when most of the hydrologic event must be sampled. Storm predictions have greatly improved in recent years, but these still results in uncertainties. Therefore, it is important to know the limitations of automatic samplers in obtaining representative samples of stormwater containing a wide range of particle sizes and concentrations. Automatic samplers have been shown to have significantly lower efficiencies in collecting large particles.

One of the primary short-comings affecting auto-sampling is the lack of sufficient turbulence at the fixed sampling point, such as the sampler intake in the storm drainage pipe (Clark et al., 2009). During this research, plastic trays were secured in the influent and effluent locations to capture cascading flows that completely mixed the samples at the point of sampling.

The effluent location needed a small dam to block some of the water before the sampling location for accurate flow measurements. This likely caused the accumulation of larger debris behind the obstruction before sampling. However, very little large material was discharged from the treatment device. However, during bypass periods, some larger particles were likely discharged. During the sampling, some debris was noted to accumulate at this location, but only small quantities, especially considering the very large flow volumes.

Another automatic sampler problem is associated with the ability of the sampler to pump large particles up the sampler line. The automatic sampler used during this research was the

Teledyne ISCO 6712 automatic sampler. The sample lines are Teflon™ lined polyethylene having about 10 mm diameters and have about 100 cm/sec water velocities in the sample line during sample pumping. Burton and Pitt (2001) stated that particles greater than about 250 µm in size are collected by autosamplers, but at low effectiveness. Previous laboratory experiments conducted by Clark et al. (2009) demonstrated that typical autosamplers for stormwater sampling are not sufficient to capture particles that are greater than 250 to 500 µm based on solids testing having 2.65 specific gravities (most stormwater has lower specific gravities of about 1.5 to 2.5 and therefore somewhat larger particles may be collected). A prior phase of this research conducted by Pitt and Khambhammettu (2006) also indicated that no sediment larger than 250 µm was collected by the influent autosampler at the pilot-scale sampling location. Bed load samples from the sump found that about 30% of the total influent particulate mass was greater than 250 µm.

During this research, the influent median particle size averaged about 460 µm, indicating possible biases of influent solids measurements. The location of the sampling intake probe has been found to affect the accuracy of sediment concentration captured by autosamplers (Roseen et al., 2011; Horowitz 2008; Eads and Thomas 1983). Specifically, during this research, the effluent probe location may have resulted in oversampling of the larger particles as some of these large materials accumulated in the sample tray near the intake.

Burton and Pitt (2002) recommended the use of bedload samplers to better represent the larger particles during a stormwater monitoring program. During this research, the filter sump acts as an effective bedload sampler and the accumulation of captured material was monitored, as described later in this thesis.

5.4.5 Solids Performance during Different Monitoring Periods

As mentioned in the previous sections, field performance verification testing of the Up-Flo® Filter during actual storms has previously been conducted by Togawa, (2011). An initial 20 storm events were sampled and monitored during an approximate one-year period. Recently, an additional 30 storm events were sampled and monitored at the same test site with the same test methodology as part of this thesis research. Overall, a total of 50 events have been evaluated to describe the performance of the Up-Flo® Filter under a wide range of rainfall and runoff conditions, resulting in increased confidence of the performance observations.

Table 15 lists the descriptive performance summary for the solids constituents, while Figure 49 includes the influent and effluent solids concentration line plots for all 50 sampled storms. As shown in the table and the plots, the effluent solids concentrations, measured as TSS and SSC, averaged about 21 and 25 mg/L, respectively. The TSS and SSC removal efficiencies averaged about 76 and 78%, respectively. TDS reductions averaged about 21%, while the measured (non-continuous) turbidity, which is another important indicator of water quality associated with fine particulates, had average reductions of about 54%, with effluent quality ranging from 3 NTU to 33 NTU.

Table 15: Performance Summary of Solids Constituents for 50 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
TSS (mg/L)	Influent	126	89	571	11	123	0.98
	Effluent	21	17	64	3	16	0.75
	Removal Efficiency	75.7%	80.0%	98.1%	22.2%	17.4%	0.23
SSC (mg/L)	Influent	521	93	6231	23	1143	2.19
	Effluent	25	20	69	3	17	0.70
	Removal Efficiency	77.8%	80.7%	99.4%	12.1%	18.6%	0.24
TDS (mg/L)	Influent	76	58	333	17	52	0.68
	Effluent	54	48	124	12	28	0.52
	Removal Efficiency	20.8%	17.3%	88.6%	-17.5%	24.6%	1.18
Turbidity (NTU)	Influent	26.8	18.8	117.5	4.5	24.4	0.91
	Effluent	10.0	7.7	33.2	2.7	8.1	0.81
	Removal Efficiency	53.6%	54.9%	86.6%	11.3%	20.6%	0.38

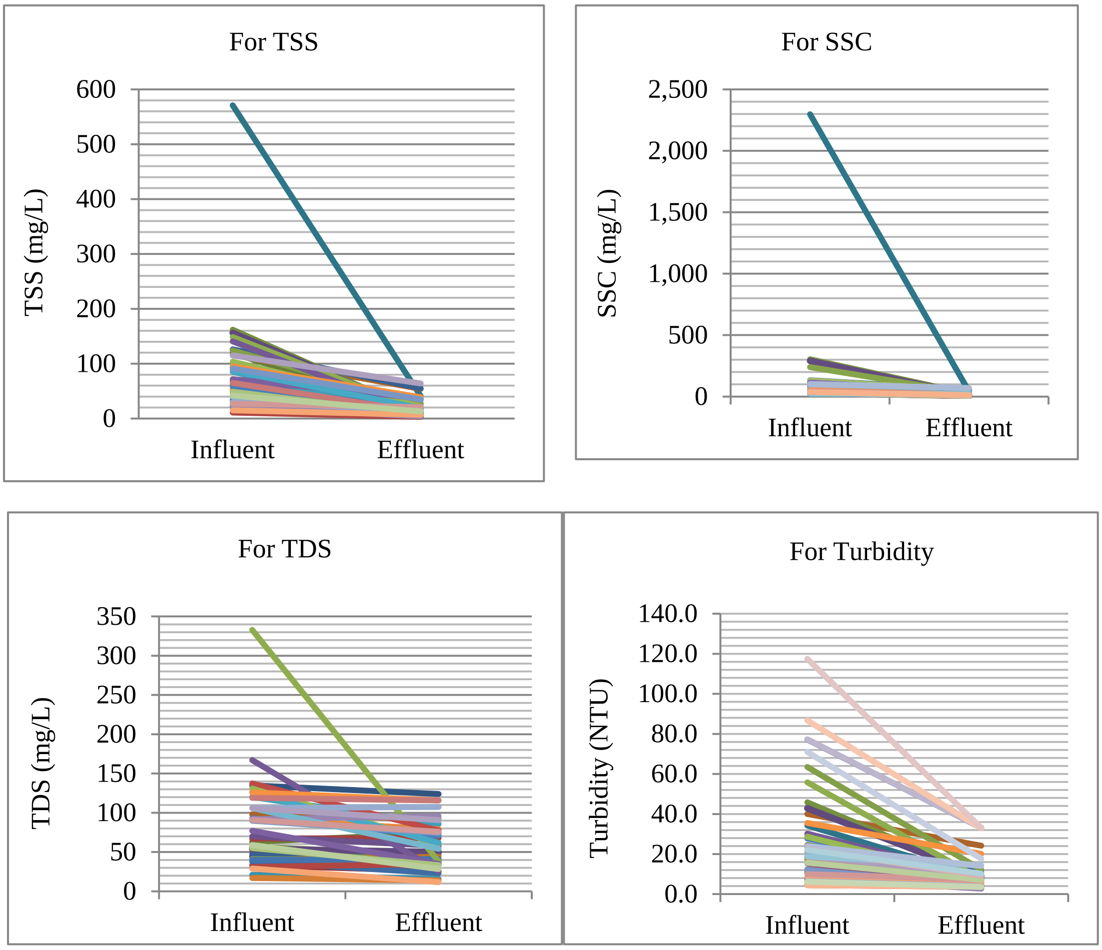


Figure 49: Performance Line Plots of Solids Constituents for 50 sampled Storms

Figures 50, 51 and 52 illustrate the scatterplots and probability plots of influent SSC and effluent SSC. The power regression plots in Figure 50 are much flatter compared to the red 45 degree equivalent concentration line, showing that the effluent SSC concentrations were always less than the influent concentrations (only one observation was close to the red line which had a low influent concentration). Figure 51 shows the plots for the data after $\log_{10}$ transformations along with the 95% confidential intervals. In Figure 52, the influent is normally distributed (p-value < 0.05), while the effluent concentrations are not, based on the Anderson-Darling test results shown on the figure. The two probability plots are separated with no overlaps, showing likely significant treatability under wide ranging influent concentration conditions.

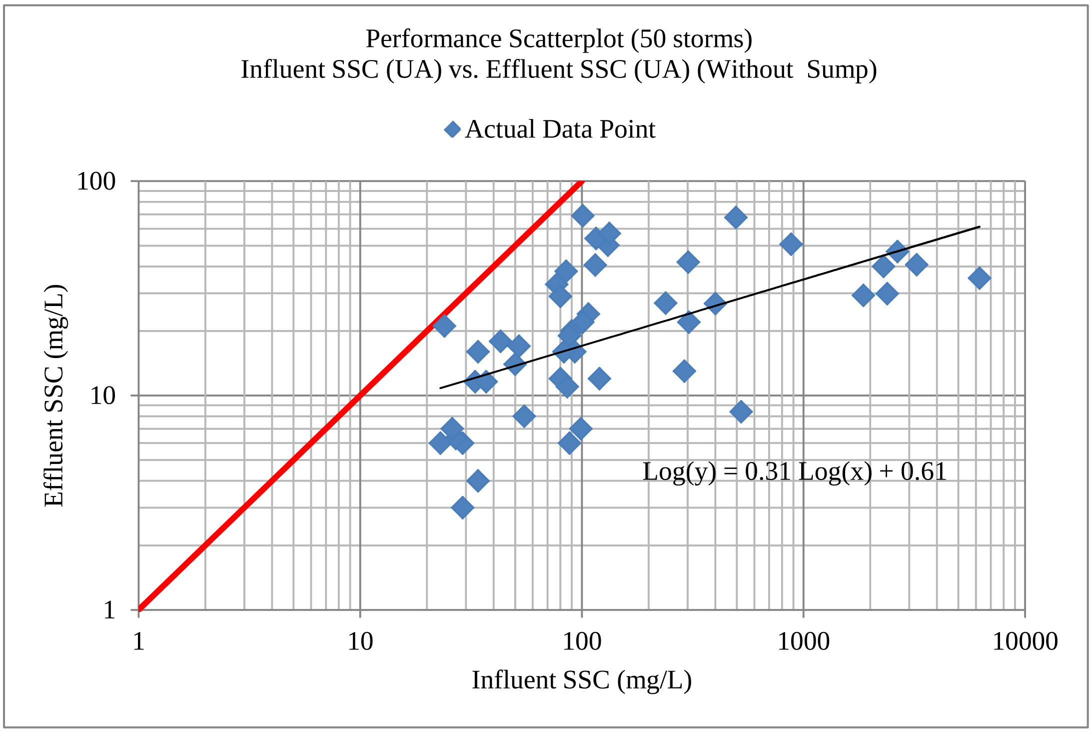


Figure 50: Scatterplot of Influent SSC and Effluent SSC for 50 Sampled Events

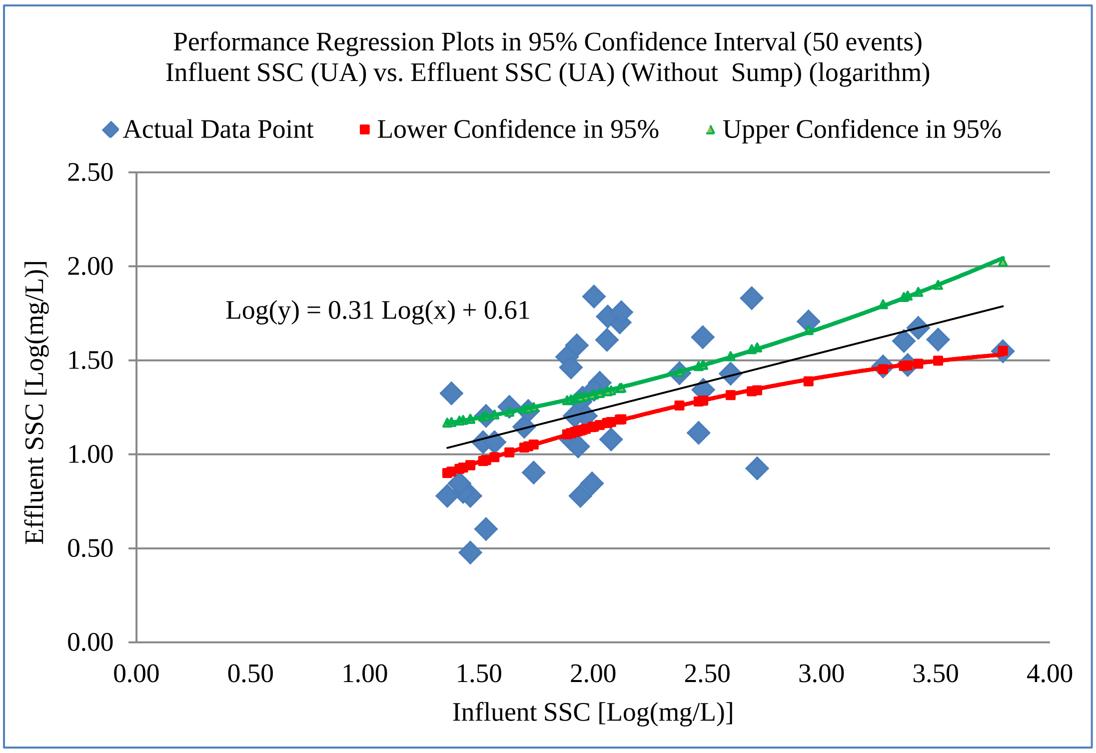


Figure 51: Scatterplot of Influent and Effluent SSC for 50 Sampled Events with 95% Confidential Intervals (Log10 Transformations)

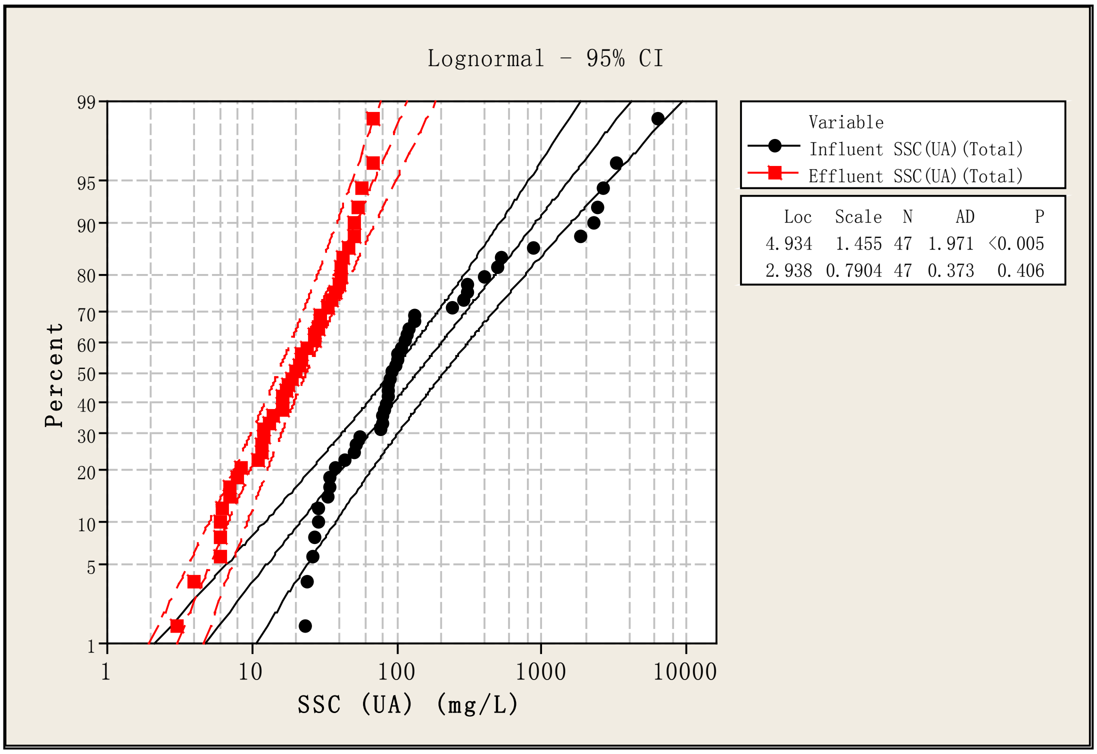


Figure 52: Probability Plot of Influent SSC and Effluent SSC (50 Sampled Storms)

Table 16 and Figure 53 describe the regression and ANOVA analyses and residual plots of for SSC performance for the combined 50 sampled storms. Table 16 shows the ANOVA conclusions for the regressions shown in Figures 50 and 51. The overall regression model is shown to be highly statistically significant since the "Significance F" term is much less than 0.05 with both significant intercept and variable terms. Figure 53 shows the corresponding residual plots of $\log_{10}$-transformed SSC values for the 50 sampled storms. The residuals are visually randomly distributed around zero and fit the normal probability plot, as required.

Table 16: Regression and ANOVA Analyses of SSC Performance (50 Sampled Storms) (Logarithm Transformation)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.57
R Square	0.33
Adjusted R Square	0.31
Standard Error	0.29
Observations	47.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.76	1.76	21.67	0.0000
Residual	45.00	3.66	0.08		
Total	46.00	5.42			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.61	0.15	4.13	0.0002	0.31	0.91
X Variable 1	0.31	0.07	4.66	0.0000	0.18	0.44

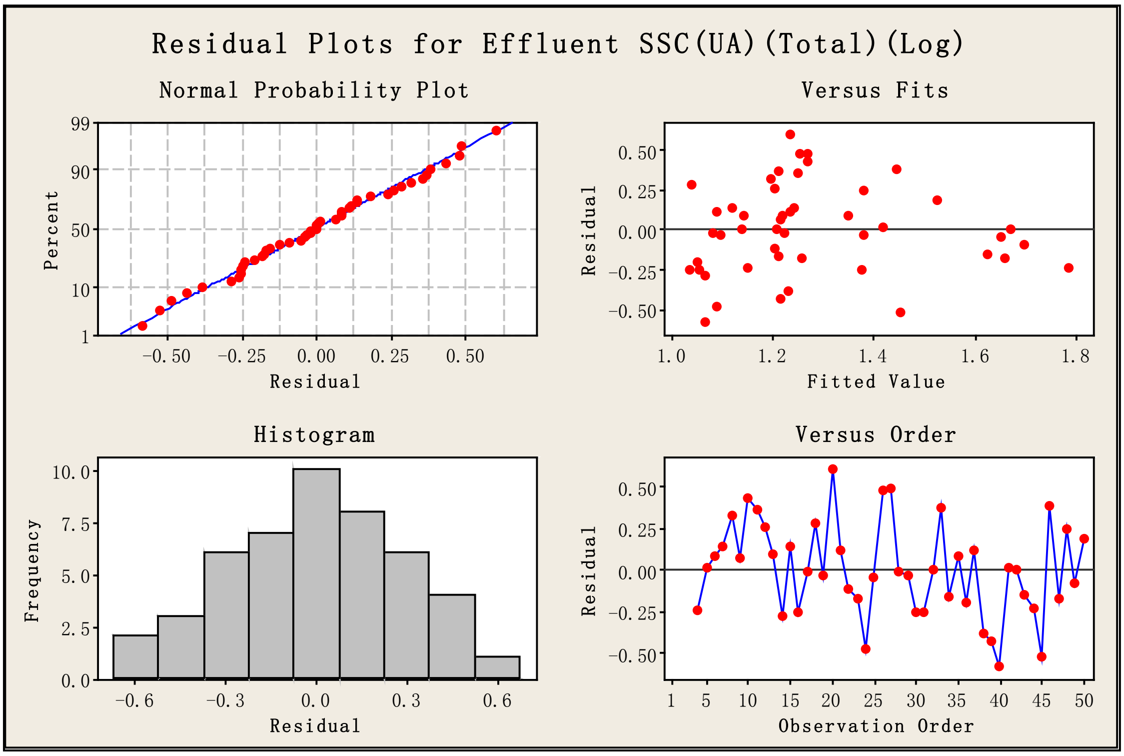


Figure 53: Residual Plots of SSC Performance (50 Sampled Storms) (Log10 Transformations)

Table 17 lists summaries for the regression equations describing the performance of the solids constituents for the 50 sampled storms. Again, all regression equations were $\log_{10}$-transformed. All equations indicate significant regression with all p-values for overall model, slope and intercept terms (if needed) being <0.001. The p-values from the Wilcoxon Signed Rank hypothesis test (non-parametric) also show significant differences between influent and effluent concentrations, as expected again.

Table 17: Summary of Regression and ANOVA Performance for Solids Constituents (50 Sampled Storms)

Solids Constituents	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
TSS	Log(y) = 0.6169 Log(x)	0.92	0.00	NA	0.00	<0.001
SSC	Log(y) = 0.3096 Log(x) + 0.6125	0.31	0.00	0.00	0.00	<0.001
TDS	Log(y) = 0.6448 Log(x) + 0.509	0.46	0.00	0.01	0.00	<0.001
Turbidity	Log(y) = 0.6981 Log(x)	0.95	0.00	NA	0.00	<0.001

Figure 54 shows line plots of influent and effluent concentrations for each particle size range. These line plots illustrate the overall removals of the Up-Flo® Filter for each specific particle range, even for particle sizes as small as 3 µm, regardless of the influent concentrations and hydraulic conditions. Also, relatively large particles (>250 µm) were almost completely retained in the Up-Flo® Filter with very few observed in the effluent. Some reverse sloped lines occasionally occurred, likely due to analytical variability, possible sump scouring, or particulate breakthrough, however, the number of these reverse plots is very small so that the treatability and performance stability of Up-Flo® Filter are not severely affected.

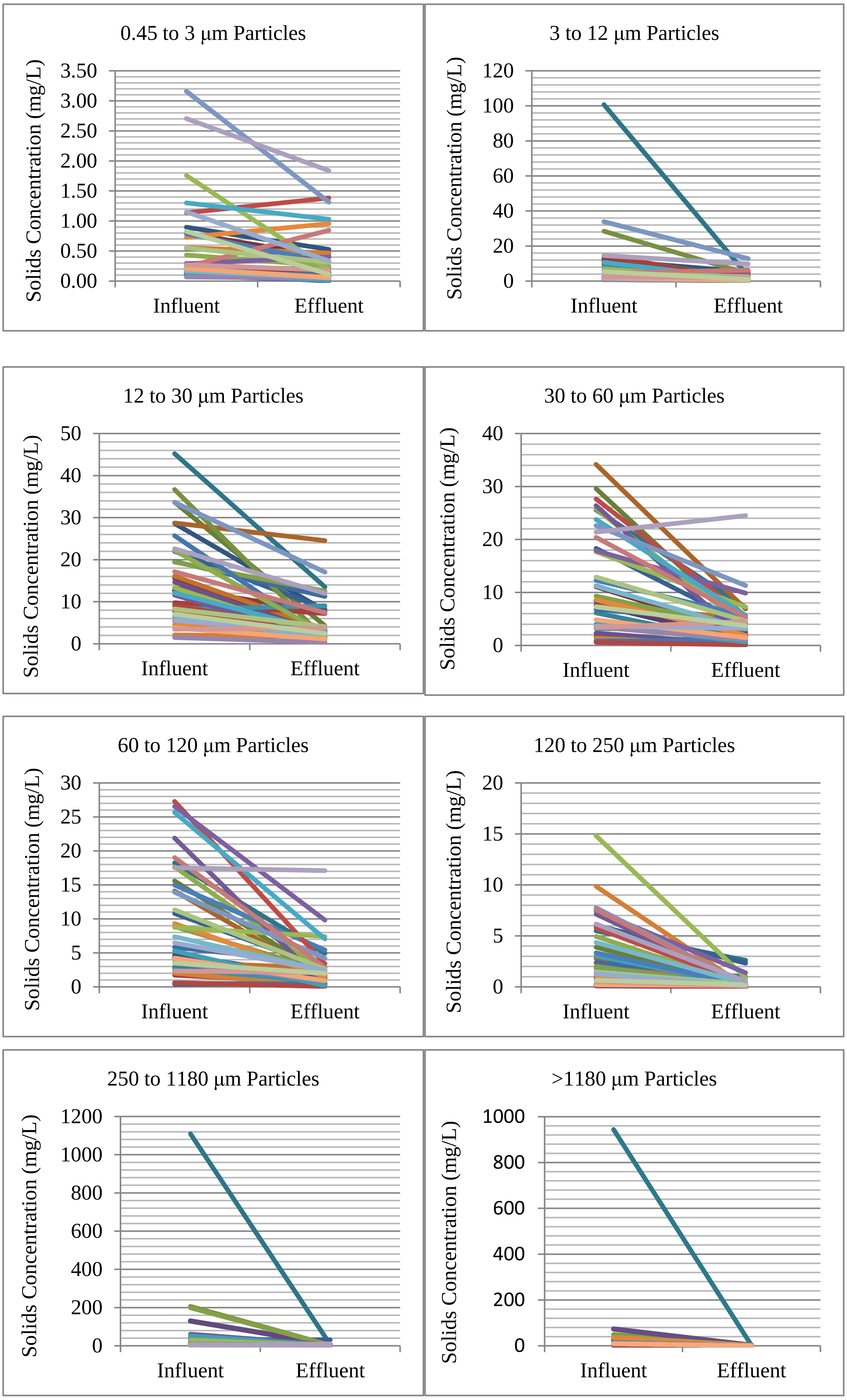


Figure 54: Performance Line Plots of Particle Ranges for 50 sampled Storms

Table 18, Figures 55 and 56 summarize the particle size distributions (PSD) for the influent and effluent samples for all 50 sampled storms. Table 18 shows that the Up-Flo® Filter removed about 95% of the overall solids loading for these sampled storms based on the sum of the solids loads with increasing removals with increasing particle sizes. Much of the influent mass area associated with the very large particles that are likely associated with nearby site erosion from landscaped areas and are not likely representative of typical conditions. Figure 55 shows that the median particle size (D_{50}) of the influent samples was about 750 µm and about 40 µm for the effluent samples. As mentioned, the influent D_{50} is quite large compared to most stormwater samples from drainage systems since the adjacent parking lot directly discharged the larger particles to the influent plastic tray, nearby erosion, and these particles were captured inconsistently by the sampler intake. Figure 56 indicates that particle removal is effective for all particle size ranges.

Table 18: Summary of Particle Size Distribution of 30 Sampled Storms

	Average Mass Percentage (%)		Average Solids Concentration for the range (mg/L)		Calculated Total Mass of sampled storm events for the range (lbs)		Average Percentage Reduction by Concentration
Particle Size (um)	Influent	Effluent	Influent	Effluent	Influent	Effluent	
0.45 to 3	0.6	1.6	0.5	0.3	2.1	1.4	34%
3 to 12	6.5	13.0	11.8	3.2	103.8	20.7	73%
12 to 30	14.9	27.1	24.6	6.5	243.4	53.6	74%
30 to 60	12.2	16.9	12.6	4.2	65.8	25.7	66%
60 to 120	9.5	11.1	9.4	2.8	48.2	16.4	70%
120 to 250	2.9	1.5	3.1	0.4	15.7	3.7	87%
250 to 1180	31.4	23.3	260.2	4.7	4240.8	29.1	98%
>1180	22.0	5.5	176.2	1.6	2539.5	12.6	99%
Total	100	100	498	24	7259	163	95%

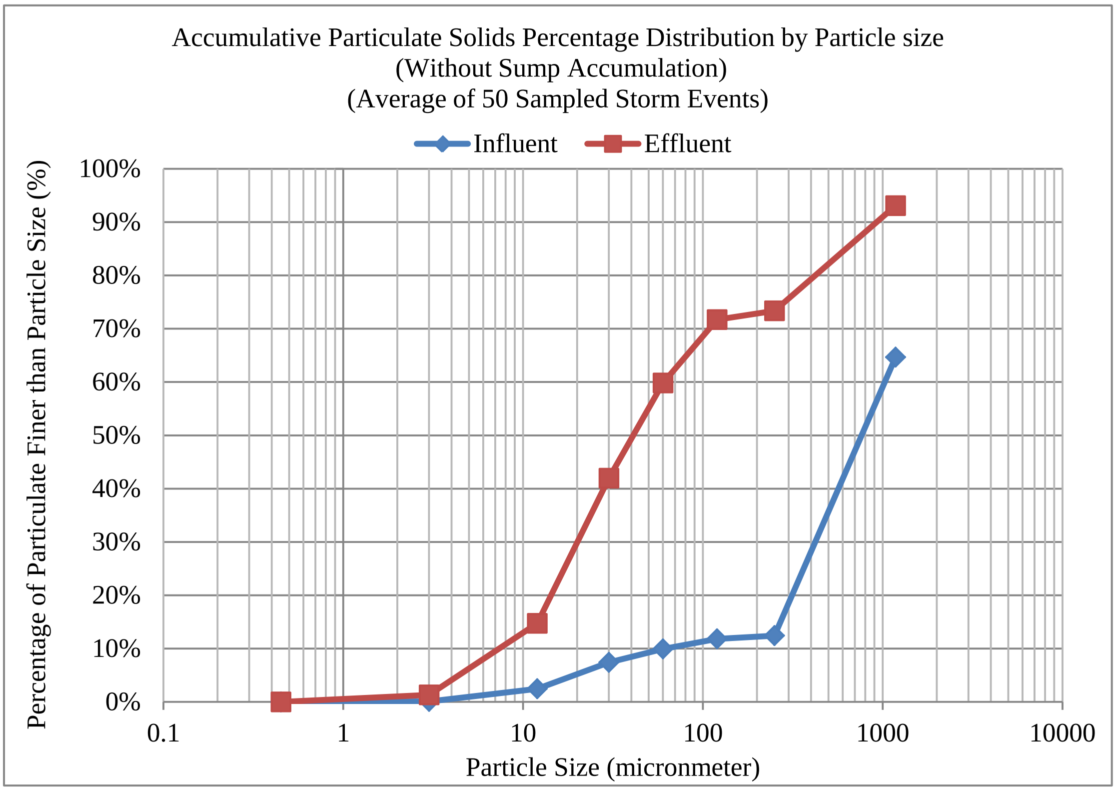


Figure 55: Accumulative Percentage Distribution by Particle Size for 50 sampled Storms

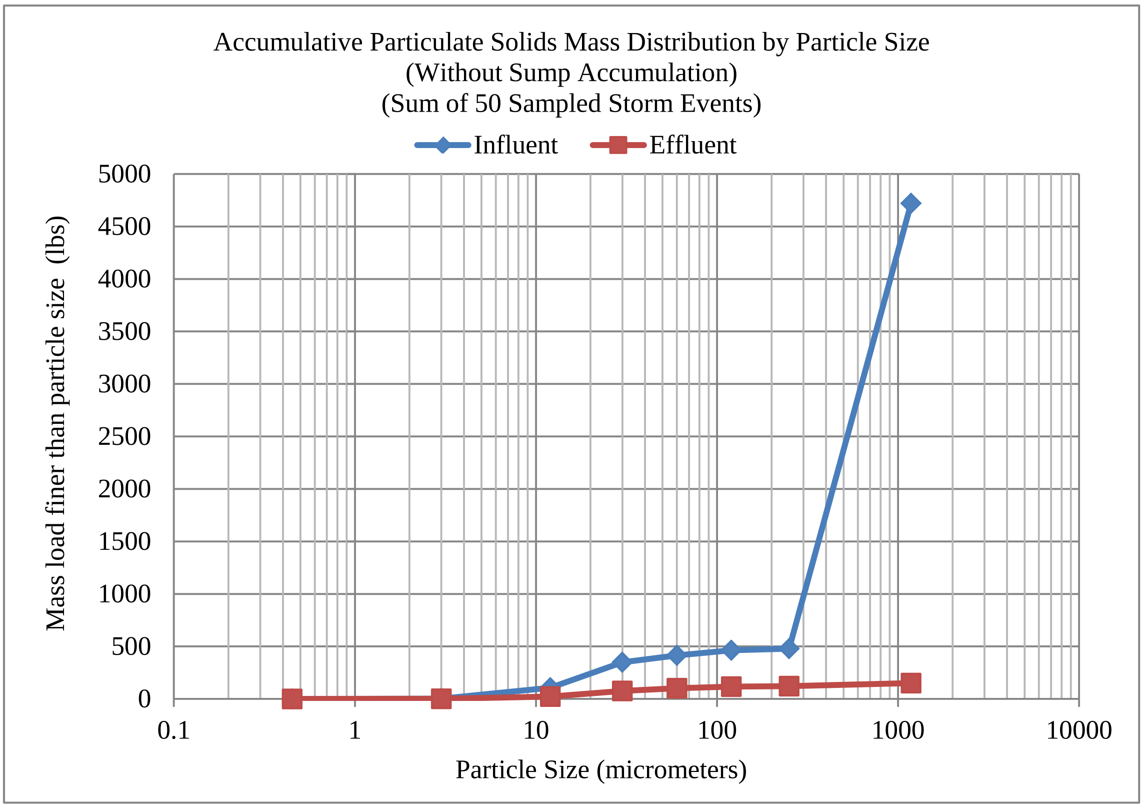


Figure 56: Accumulative Calculated Mass Distribution by Particle Size for 50 Sampled Storms

Table 19 summarizes the regression and ANOVA analyses for the particle size ranges for the 50 sampled storms. Again, all the regression calculations were $\log_{10}$ transformed, except for the particle size from 120 to 250 μm due to large fraction of non-detectable effluent concentrations. These regression and ANOVA results show that all removals were statistically significant (the p-values are all less than 0.001).

Table 19: Summary of Regression and ANOVA Performance for Particle Size Ranges (50 Sampled Storms)

Particle Size (um)	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
0.45 to 3	Log(y) = 0.8343 Log(x) - 0.2848	0.65	0.00	0.00	0.00	<0.001
3 to 12	Log(y) = 0.3957 Log(x)	0.38	0.00	NA	0.00	<0.001
12 to 30	Log(y) = 0.5389 Log(x)	0.80	0.00	NA	0.00	<0.001
30 to 60	Log(y) = 0.858 Log(x) - 0.3908	0.43	0.00	0.01	0.00	<0.001
60 to 120	Log(y) = 0.7403 Log(x) - 0.3972	0.32	0.00	0.00	0.00	<0.001
120 to 250	y = 0.0755x	0.19	0.00	NA	0.00	<0.001
250 to 1180	Log(y) = 0.2869 Log(x)	0.58	0.00	NA	0.00	<0.001
>1180	Log(y) = 0.4435 Log(x) - 0.5918	0.52	0.00	0.00	0.00	<0.001

5.4.6 Solids Performance Comparison during Actual Storm Monitoring and Controlled Sediment Tests

Controlled sediment tests were conducted before the previous phase of storm monitoring to quantify the solids removal performance under known steady flow rates and particle concentrations. Similar to the hydraulic flow test during this research, the controlled sediment tests were used influent water that was pumped from the adjacent Black Warrior River into a large plastic drum that has two outlets with valves to control the influent flow rate to the Up-Flo® Filter. Flows were calculated by timing how long it took to fill a container having a known volume.

Different influent flow rates and solids concentrations were conducted to examine the particle removal rate of the Up-Flo® Filter under steady hydraulic conditions. The solids mixture was made using fine sand: coarse sand: Sil-Co-Sil 106: Sil-Co-Sil 250 at 5: 17: 70: 8 mass rations. This resulted in particle size ranging from 20 to 2,000 µm at 50 mg/L, 100 mg/L, 250 mg/L, and 500 mg/L concentrations. The river water also contributed fine particles to the mixture. This thesis section compares the solids performance differences between the controlled tests and the actual storms monitoring, regardless of the runoff flow rates. Figure 57 shows the line plots of SSC performance for these two categories. Yellow, red, and black lines represent the results from the controlled tests, the previous 20 sampled storms, and the recent 30 sampled storms. The SSC is shown to have a smaller range of effluent quality, but the plots of controlled mixed solids are relatively flatter with fewer reductions. This is likely due to the controlled solids tests having different particle sizes with higher fraction of smaller particles (from the river water), which are much difficult to be retained by the filter media.

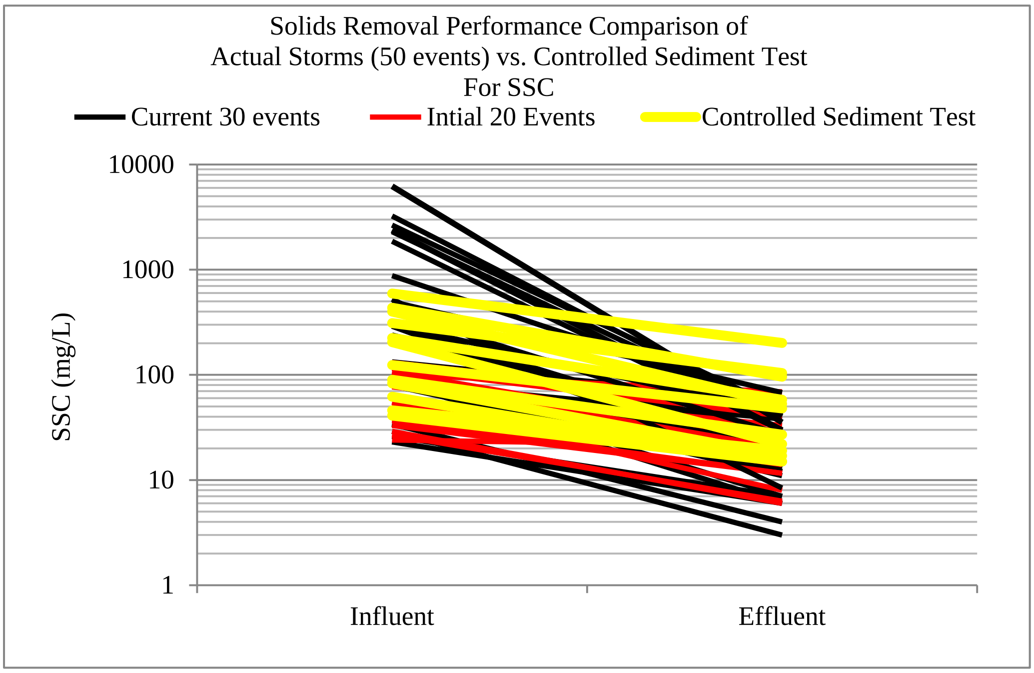


Figure 57: Line Plot of SSC Performance between Actual Storms and Controlled Test

The specific gravities of the different particles during the test phases also greatly differed that would affect the performance. The controlled tests had two sediment sources: the river water had very fine sediments having very high specific gravities (resulting in low removal rates) plus the ground silica (moderate and large particles) having high specific gravities (2.65), resulting in higher removal rates for those particles. The storm monitoring had specific gravities that were substantially less than the ground silica for the larger particles, but more than the river particulates for the finer particulates. Therefore, the controlled tests would have lower removals for the fine sizes and higher removals for the moderate and large particle sizes compared to the storm runoff.

Figure 58 contains a pair probability plots for the specific gravities of particles from 3 to 250 µm measured during the 30 storms for the influent and effluent samples. These specific gravities were calculated based on the solids concentrations from filtering of samples that were sieved between 2 and 250 µm, and the measured accumulative particle volume using the Coulter Counter for the same particle size range. These calculated specific gravities had a mean of about 3.2 g/cc in the influent and about 1.5 g/cc in the effluent. The ranges were quite large, as expected, but do indicate the preferential removal of “heavier” particulates in the Up-Flo® Filter. Typically, stormwater specific gravities range from about 1.5 to 2.5 and contain a wide range of materials. These analyses show that the influent material was substantially different in characteristics compared to the effluent material.

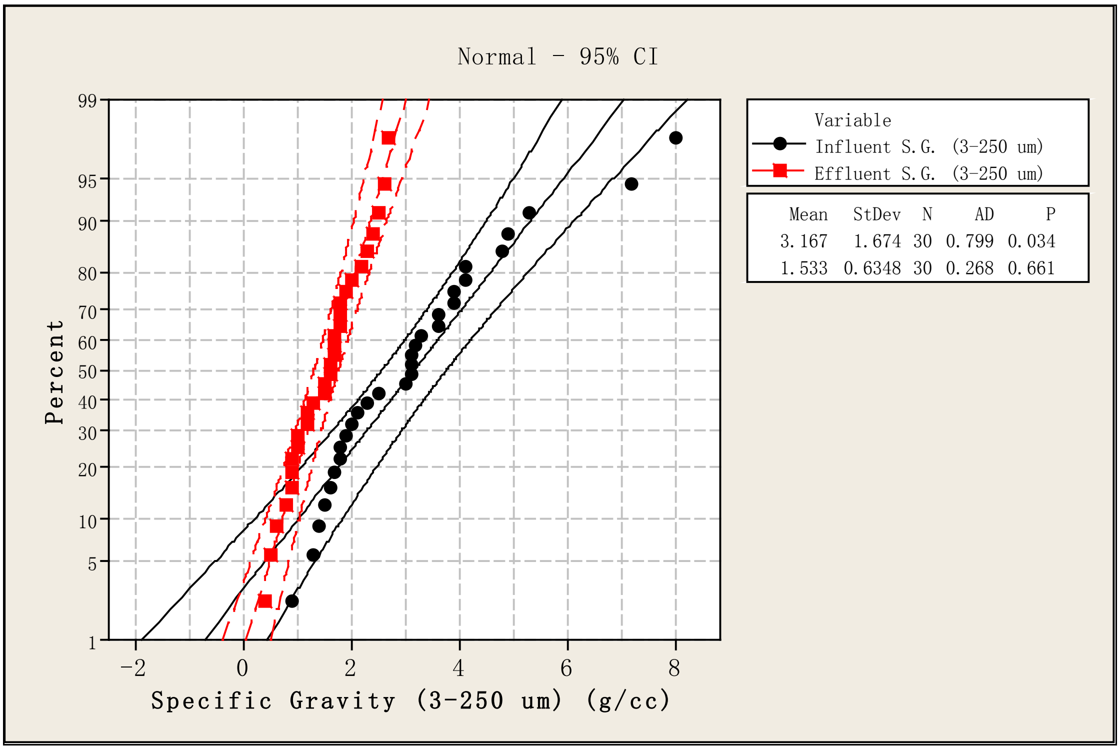
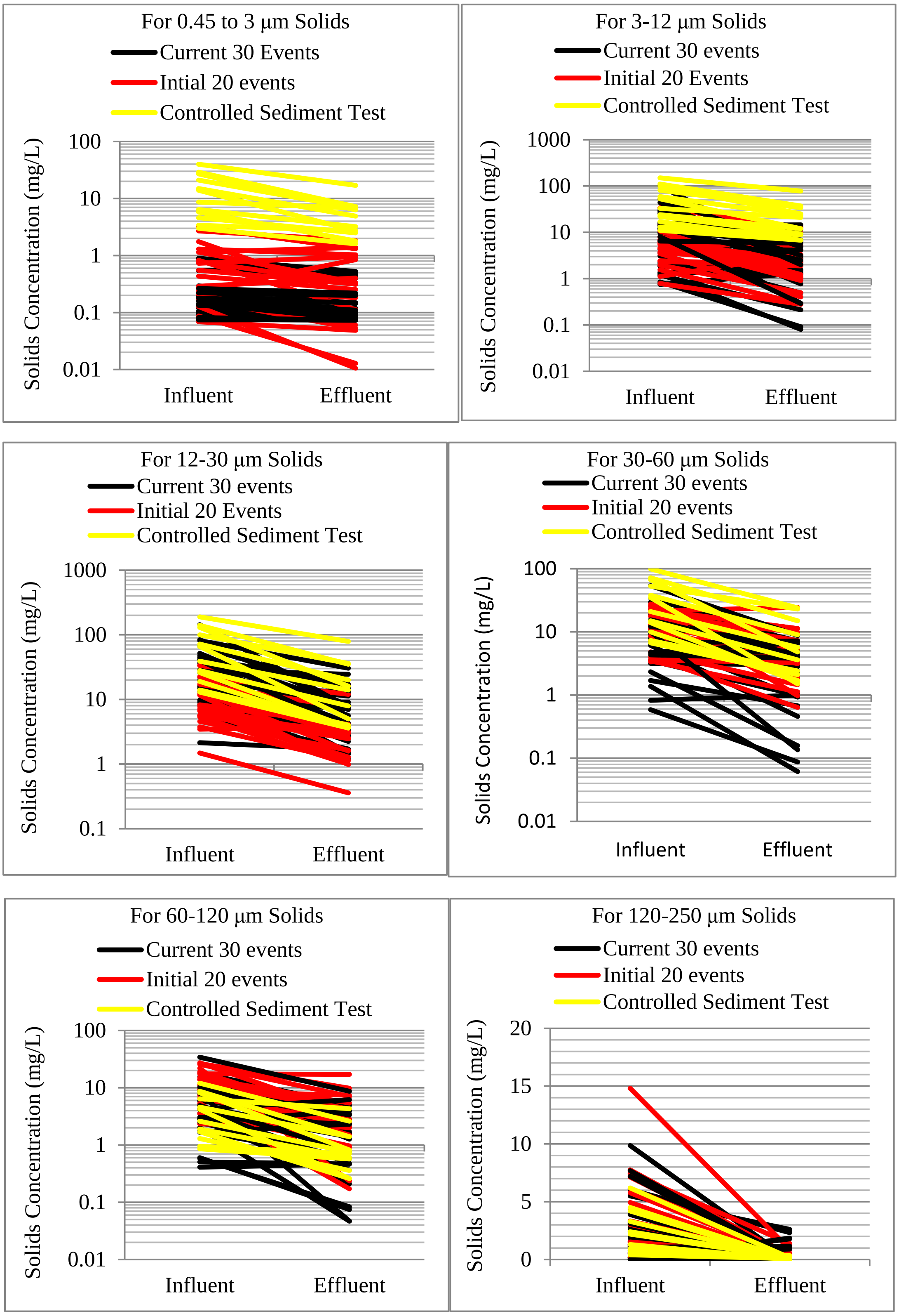


Figure 58: Probability Plot of Influent and Effluent Specific Gravity for 30 Sampled Storms

Figure 59 shows the line plots of solids performance for each particle range between the controlled tests and actual storms monitoring. The overall solids removal for either actual storms or controlled test increased as the particle sizes increased, as expected by the larger gravitational settling, but the concentrations of smaller particles for the controlled tests were apparently higher than those for the actual storms due to the river water. The river water used as the simulated runoff in the controlled test contributed an average of 22 mg/L (in the total size range from 0.45 to 106 µm, but with most expected to be in the very small, non-settleable particle sizes).


For 0.45 to 3 µm Solids
Current 30 Events
Intial 20 events
Controlled Sediment Test
Solids Concentration (mg/L)
100
10
1
0.1
0.01
Influent
Effluent
For 3-12 µm Solids
Current 30 events
Initial 20 Events
Controlled Sediment Test
Solids Concentration (mg/L)
1000
100
10
1
0.1
0.01
Influent
Effluent
For 12-30 µm Solids
Current 30 events
Initial 20 Events
Controlled Sediment Test
Solids Concentration (mg/L)
1000
100
10
1
0.1
Influent
Effluent
For 30-60 µm Solids
Current 30 events
Initial 20 events
Controlled Sediment Test
Solids Concentration (mg/L)
100
10
1
0.1
0.01
Influent
Effluent
For 60-120 µm Solids
Current 30 events
Initial 20 events
Controlled Sediment Test
Solids Concentration (mg/L)
100
10
1
0.1
0.01
Influent
Effluent
For 120-250 µm Solids
Current 30 events
Initial 20 events
Controlled Sediment Test
Solids Concentration (mg/L)
20
15
10
5
0
Influent
Effluent

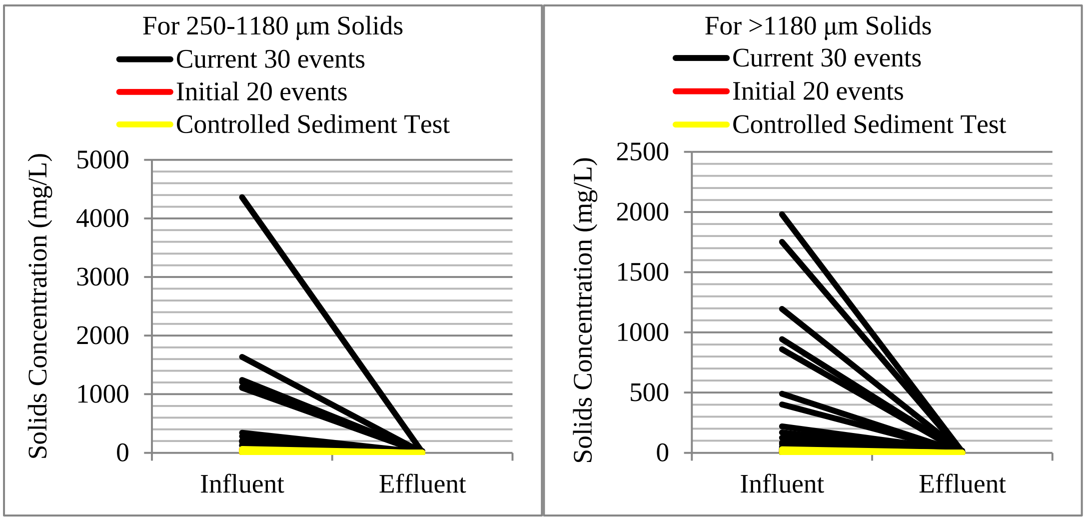


Figure 59: Line Plots of Particle Ranges between Actual Storms and Controlled Test

One-way ANOVA and Kruskal-Wallis tests (nonparametric) were applied to calculate the statistical significance and compare the percentile distributions between effluent solids concentrations for the different test phases. Figures 60 and 61 show that the differences of effluent SSC values between the controlled and actual storm monitoring are statistically significant, while there are similar concentration ranges for both actual storms monitoring phases.

```
Source   DF      SS     MS      F       P
Factor    2    9509   4754   5.64   0.006
Error    56   47203    843
Total    58   56711

S = 29.03    R-Sq = 16.77%    R-Sq(adj) = 13.79%

Level                         N    Mean   StDev
Effluent SSC(Controlled)     12   56.25   54.98
Effluent SSC(Initial 20)     17   23.44   16.82
Effluent SSC(Current 30)     30   25.56   18.02

                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level                         ----+---------+---------+---------+-----
Effluent SSC(Controlled)                         (---------*----------)
Effluent SSC(Initial 20)      (--------*-------)
Effluent SSC(Current 30)         (------*------)
                              ----+---------+---------+---------+-----
                                 16        32        48        64

Pooled StDev = 29.03
```

Figure 60: One-Way ANOVA of Effluent SSC between Actual Storms Monitoring and Controlled Test

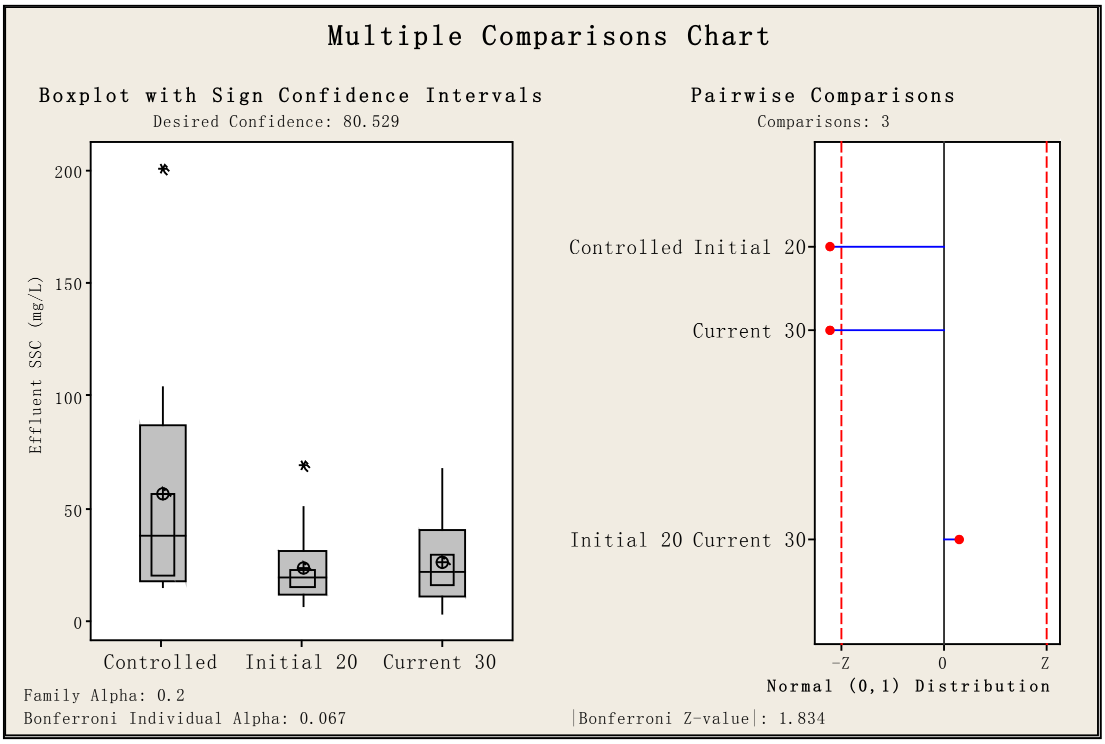


Figure 61: Multiple Comparison of Effluent SSC between Actual Storms Monitoring and Controlled Test

Figures 62 and 63 show that the differences of the 0.45-3 µm solids effluent concentrations between the controlled test and actual storms monitoring are statistically significant at the 95% confidence level. Nearly the same scales and medians were found for both actual storms monitoring phases without significant differences.

```
Source  DF      SS      MS      F      P
Factor   2  241.59  120.79  34.87  0.000
Error   59  204.40    3.46
Total   61  445.99

S = 1.861   R-Sq = 54.17%   R-Sq(adj) = 52.62%

Level                          N    Mean  StDev
Effluent (0.45-3um)(Cont      12   5.292  4.241
Effluent (0.45-3um)(Init      20   0.548  0.564
Effluent (0.45-3um)(Curr      30   0.158  0.129

                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level                          ---+---------+---------+---------+------
Effluent (0.45-3um)(Cont                                (----*-----)
Effluent (0.45-3um)(Init         (---*---)
Effluent (0.45-3um)(Curr       (---*--)
                               ---+---------+---------+---------+------
                                 0.00      2.00      4.00      6.00

Pooled StDev = 1.861
```

Figure 62: One-Way ANOVA of 0.45-3 µm Solids between Actual Storms Monitoring and Controlled Test

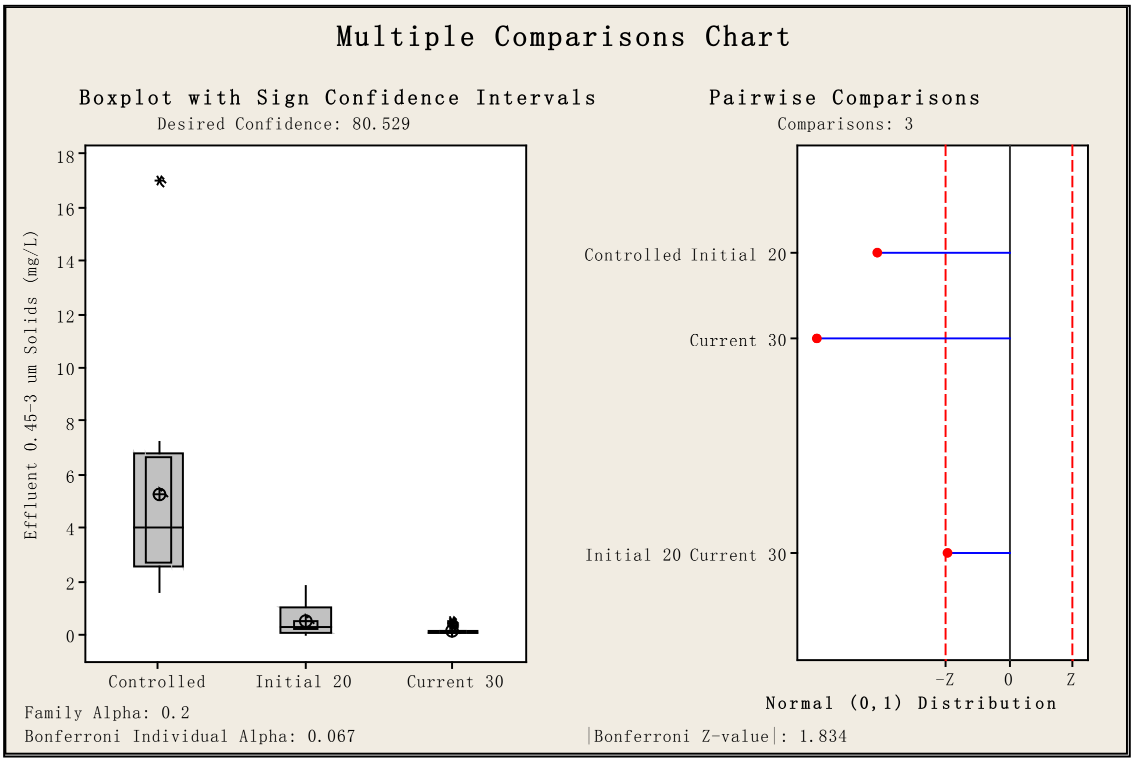


Figure 63: Multiple Comparison of 0.45-3 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 64 and 65 show that the differences for the 3-12 µm solids effluent concentrations between the controlled and actual storms monitoring are statistically significant, again at the 95% confidence level. The concentrations are notably higher for the controlled tests while they had similar ranges and medians during both actual storm monitoring phases.

```
Source  DF      SS      MS      F      P
Factor   2  3700.2  1850.1  21.30  0.000
Error   59  5123.7    86.8
Total   61  8823.9

S = 9.319   R-Sq = 41.93%   R-Sq(adj) = 39.97%

Level                          N    Mean   StDev
Effluent (3-12um)(Contro      12  22.817  20.233
Effluent (3-12um)(Initia      20   3.382   3.982
Effluent (3-12um)(Curren      30   3.185   3.320

                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level                          -+---------+---------+---------+--------
Effluent (3-12um)(Contro                             (------*-----)
Effluent (3-12um)(Initia        (----*----)
Effluent (3-12um)(Curren         (---*---)
                               -+---------+---------+---------+--------
                              0.0       8.0      16.0      24.0

Pooled StDev = 9.319
```

Figure 64: One-Way ANOVA of 3-12 µm Solids between Actual Storms Monitoring and Controlled Test

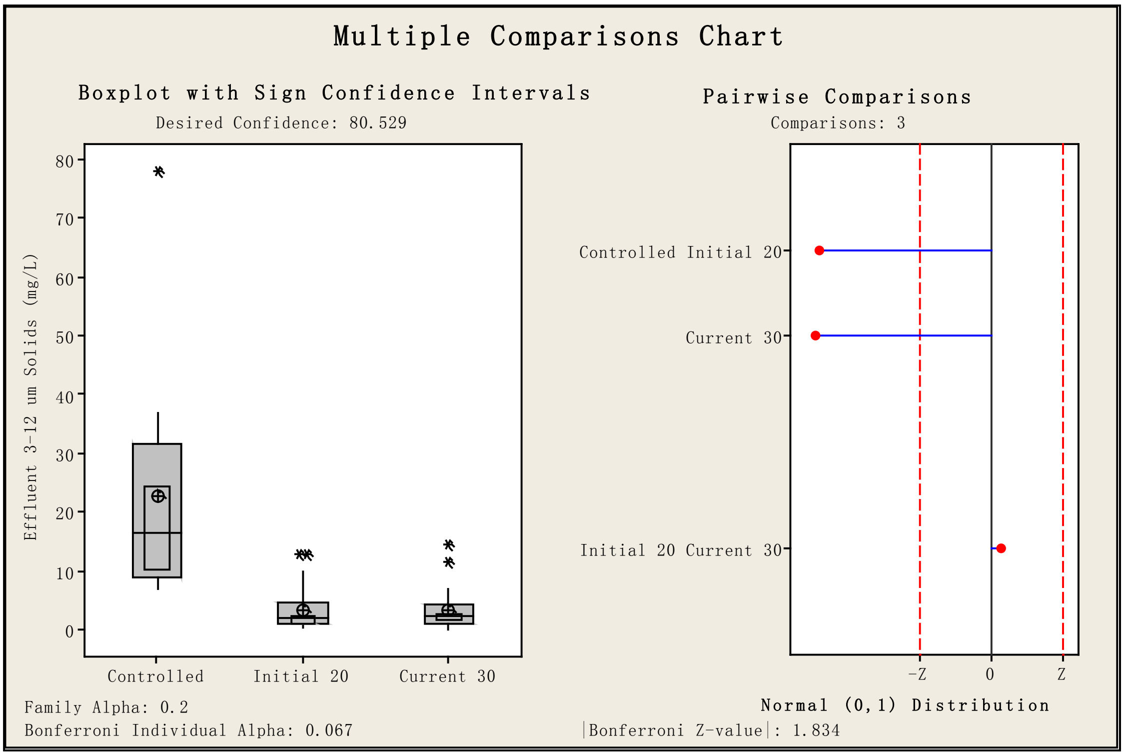


Figure 65: Multiple Comparison of 3-12 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 66 and 67 show that the differences for the 12-30 µm effluent solids concentrations between the controlled test and initial 20 storms monitoring were significantly different. However, the last 30 storm tests and the controlled tests were not significantly different. The initial 20 sampled storms had lower effluent concentrations compared to the recent 30 sampled storms, with a significant difference.

```
Source  DF    SS   MS     F      P
Factor   2  1654  827  6.68  0.002
Error   59  7307  124
Total   61  8961

S = 11.13   R-Sq = 18.46%   R-Sq(adj) = 15.69%

Level                       N   Mean  StDev
Effluent (12-30um)(Contr   12  18.98  22.22
Effluent (12-30um)(Initi   20   4.33   5.08
Effluent (12-30um)(Curre   30   8.14   6.91

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level                       -+---------+---------+---------+--------
Effluent (12-30um)(Contr                      (--------*--------)
Effluent (12-30um)(Initi    (------*------)
Effluent (12-30um)(Curre           (-----*----)
                            -+---------+---------+---------+--------
                             0.0       7.0      14.0      21.0

Pooled StDev = 11.13
```

Figure 66: One-Way ANOVA of 12-30 µm Solids between Actual Storms Monitoring and Controlled Test

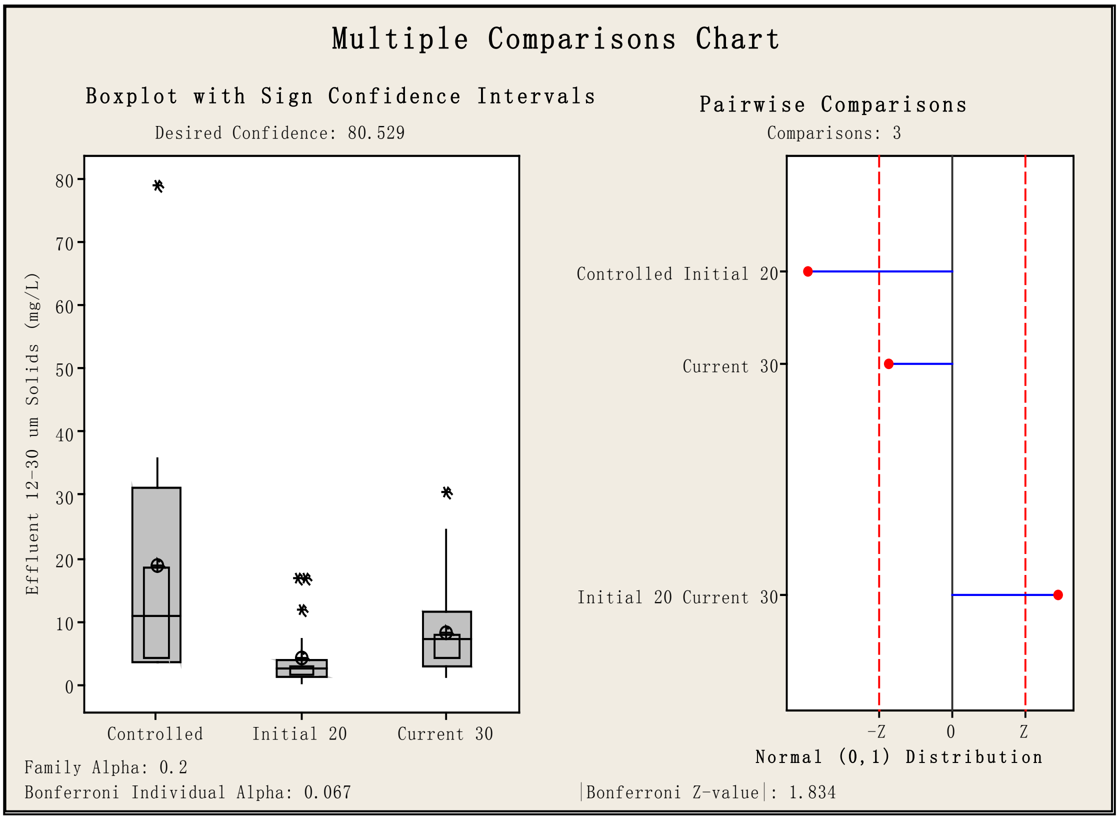


Figure 67: Multiple Comparison of 12-30 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 68 and 69 indicate that there are statistically significant differences for the 30-60 µm solids concentrations between the initial 20 storms and the current 30 storms effluent concentrations.

```
Source  DF      SS     MS     F      P
Factor   2   204.1  102.1  4.01  0.023
Error   59  1502.7   25.5
Total   61  1706.9

S = 5.047   R-Sq = 11.96%   R-Sq(adj) = 8.98%

Level                          N    Mean   StDev
Effluent (30-60um)(Contr      12   7.867   8.283
Effluent (30-60um)(Initi      20   5.758   5.433
Effluent (30-60um)(Curre      30   3.228   2.540

                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level                          ----+---------+---------+---------+-----
Effluent (30-60um)(Contr                     (----------*-----------)
Effluent (30-60um)(Initi              (--------*--------)
Effluent (30-60um)(Curre       (------*------)
                               ----+---------+---------+---------+-----
                                  2.5       5.0       7.5      10.0

Pooled StDev = 5.047
```

Figure 68: One-Way ANOVA of 30-60 µm Solids between Actual Storms Monitoring and Controlled Test

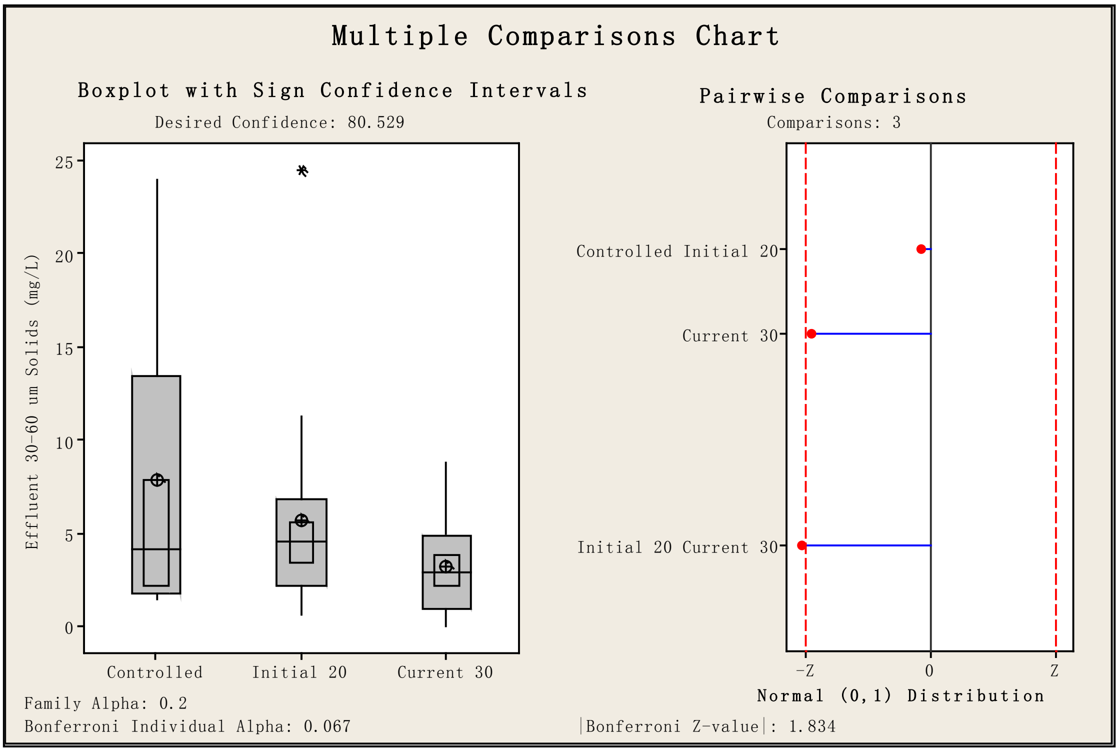


Figure 69: Multiple Comparison of 30-60 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 70 and 71 show that the differences for the 60-120 µm effluent solids concentrations for the initial 20 storms were significantly different from both the controlled test data and current 30 storms monitoring data. The effluent quality during the controlled tests was much lower in this particle range compared to the monitored events.

```
Source  DF      SS     MS     F      P
Factor   2   70.53  35.26  4.78  0.012
Error   59  434.83   7.37
Total   61  505.36

S = 2.715   R-Sq = 13.96%   R-Sq(adj) = 11.04%

Level                          N   Mean  StDev
Effluent (60-120um)(Cont  12  1.168  1.186
Effluent (60-120um)(Init  20  3.943  3.989
Effluent (60-120um)(Curr  30  1.993  2.008

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level                      ---+---------+---------+---------+------
Effluent (60-120um)(Cont  (---------*---------)
Effluent (60-120um)(Init                      (-------*-------)
Effluent (60-120um)(Curr            (-----*------)
                           ---+---------+---------+---------+------
                             0.0       1.5       3.0       4.5

Pooled StDev = 2.715
```

Figure 70: One-Way ANOVA of 60-120 µm Solids between Actual Storms Monitoring and Controlled Test

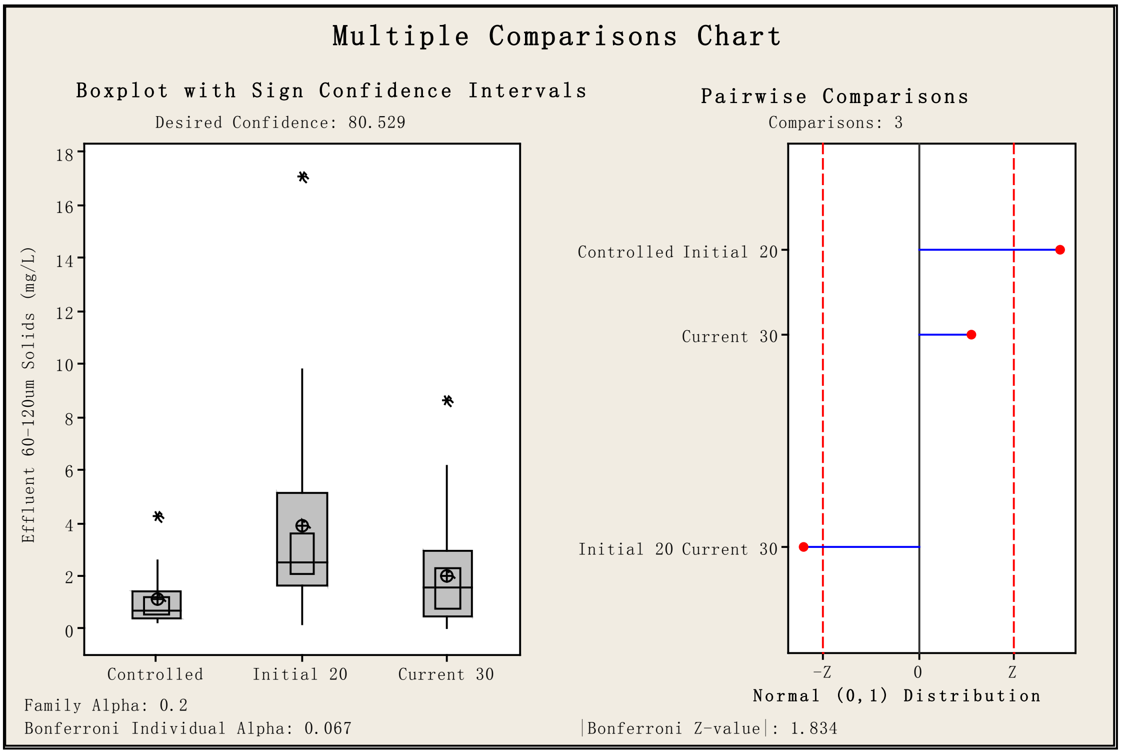


Figure 71: Multiple Comparison of 60-120 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 72 and 73 indicate that there were no statistically significant differences for the 120-250 µm solids effluent concentrations between the controlled tests and either actual storm monitoring results. The effluent solids concentrations in this range for all phases were low.

```
Source  DF      SS     MS     F      P
Factor   2   1.013  0.506  1.57  0.216
Error   59  19.002  0.322
Total   61  20.015

S = 0.5675   R-Sq = 5.06%   R-Sq(adj) = 1.84%

Level                          N    Mean   StDev
Effluent (120-250um)(Con      12  0.1098  0.0892
Effluent (120-250um)(Ini      20  0.3054  0.3156
Effluent (120-250um)(Cur      30  0.4486  0.7662

                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level                         ---------+---------+---------+---------+
Effluent (120-250um)(Con      (------------*-------------)
Effluent (120-250um)(Ini                 (---------*---------)
Effluent (120-250um)(Cur                         (-------*-------)
                              ---+---------+---------+---------+------
                               0.00      0.25      0.50      0.75

Pooled StDev = 0.5675
```

Figure 72: One-Way ANOVA of 120-250 µm Solids between Actual Storms Monitoring and Controlled Test

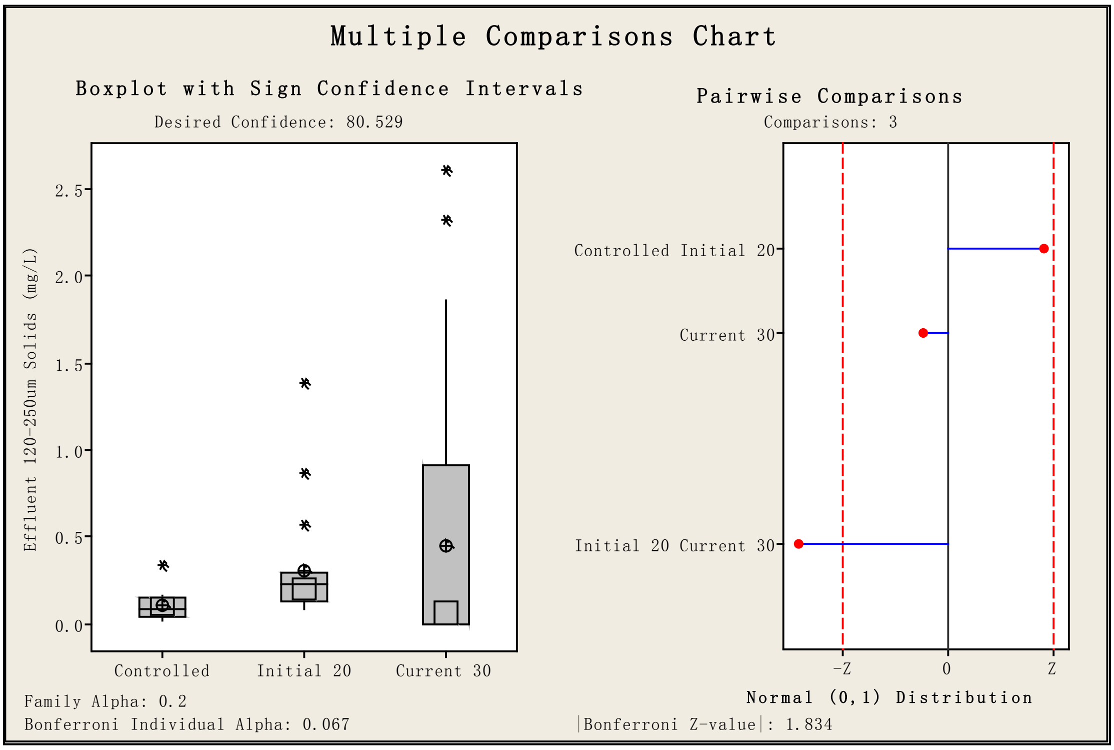


Figure 73: Multiple Comparison of 120-250 µm Solids between Actual Storms Monitoring and Controlled Test

Figures 74 and 75 indicate that the differences of the 250-1180 μm effluent solids concentrations between the controlled tests and both actual storms monitoring data are statistically significant. No significant difference was found between the initial 20 storms and the current 30 storms monitoring. The effluent quality during the controlled test was all zero. In contrast, the particles in this range were captured inconsistently during actual storm monitoring.

```
Source  DF      SS     MS     F      P
Factor   2   234.7  117.3  6.74  0.002
Error   59  1026.6   17.4
Total   61  1261.2

S = 4.171   R-Sq = 18.61%   R-Sq(adj) = 15.85%

Level                      N   Mean  StDev
Effluent (250-1180um)(Co  12  0.000  0.000
Effluent (250-1180um)(In  20  3.950  2.626
Effluent (250-1180um)(Cu  30  5.225  5.557

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level                        +---------+---------+---------+---------
Effluent (250-1180um)(Co     (---------*---------)
Effluent (250-1180um)(In                      (-------*------)
Effluent (250-1180um)(Cu                             (-----*-----)
                          ---+---------+---------+---------+------
                           -2.5       0.0       2.5       5.0

Pooled StDev = 4.171
```

Figure 74: One-Way ANOVA of 250-1180 μm Solids between Actual Storms Monitoring and Controlled Test

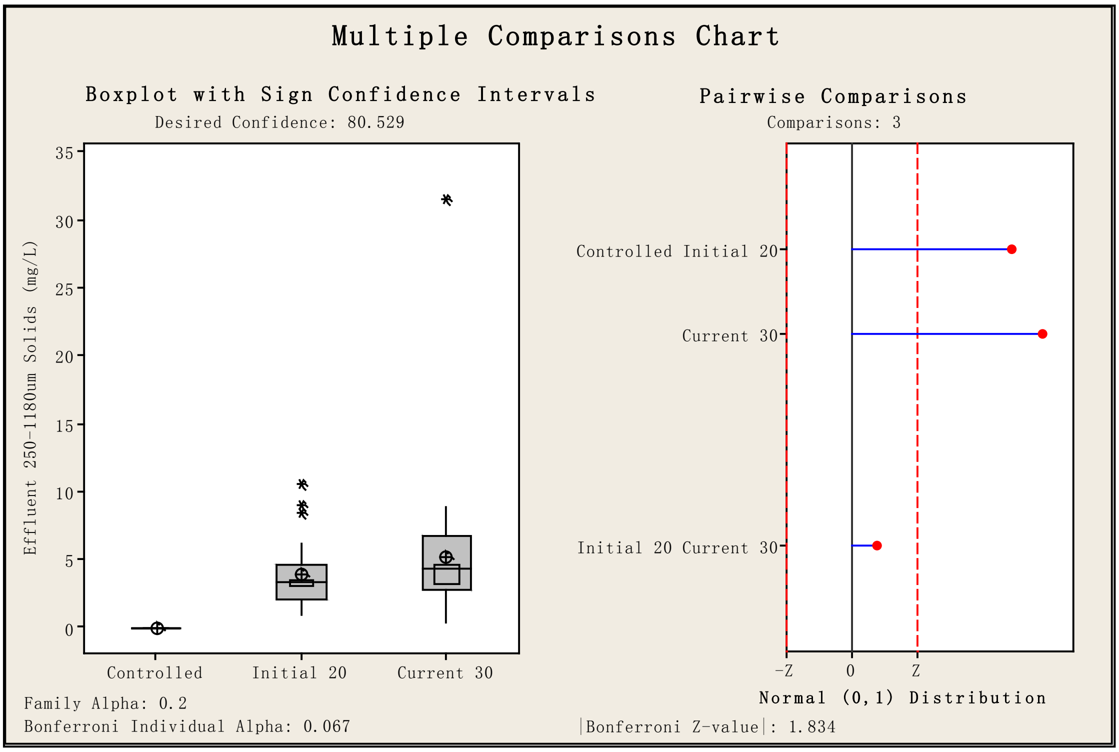


Figure 75: Multiple Comparison of 250-1180 μm Solids between Actual Storms Monitoring and Controlled Test

Figures 76 and 77 indicate that there were statistically significant differences of the >1180 μm effluent solids concentrations between the controlled tests and the actual storms monitoring. The effluent qualities for the controlled tests were also all zero and these large particles in this particle range were barely found in the effluent during actual storm monitoring.

```
Source  DF      SS     MS     F      P
Factor   2  115.94  57.97  9.52  0.000
Error   59  359.08   6.09
Total   61  475.02

S = 2.467   R-Sq = 24.41%   R-Sq(adj) = 21.84%

Level                          N    Mean   StDev
Effluent (>1180um)(Contr      12   0.000   0.000
Effluent (>1180um)(Initi      20   0.000   0.000
Effluent (>1180um)(Curre      30   2.736   3.519

                          Individual 95% CIs For Mean Based on Pooled StDev
Level                        +---------+---------+---------+---------
Effluent (>1180um)(Contr     (---------*---------)
Effluent (>1180um)(Initi        (------*------)
Effluent (>1180um)(Curre                          (-----*-----)
                             +---------+---------+---------+---------
                          -1.5       0.0       1.5       3.0

Pooled StDev = 2.467
```

Figure 76: One-Way ANOVA of >1180 µm Solids between Actual Storms Monitoring and Controlled Test

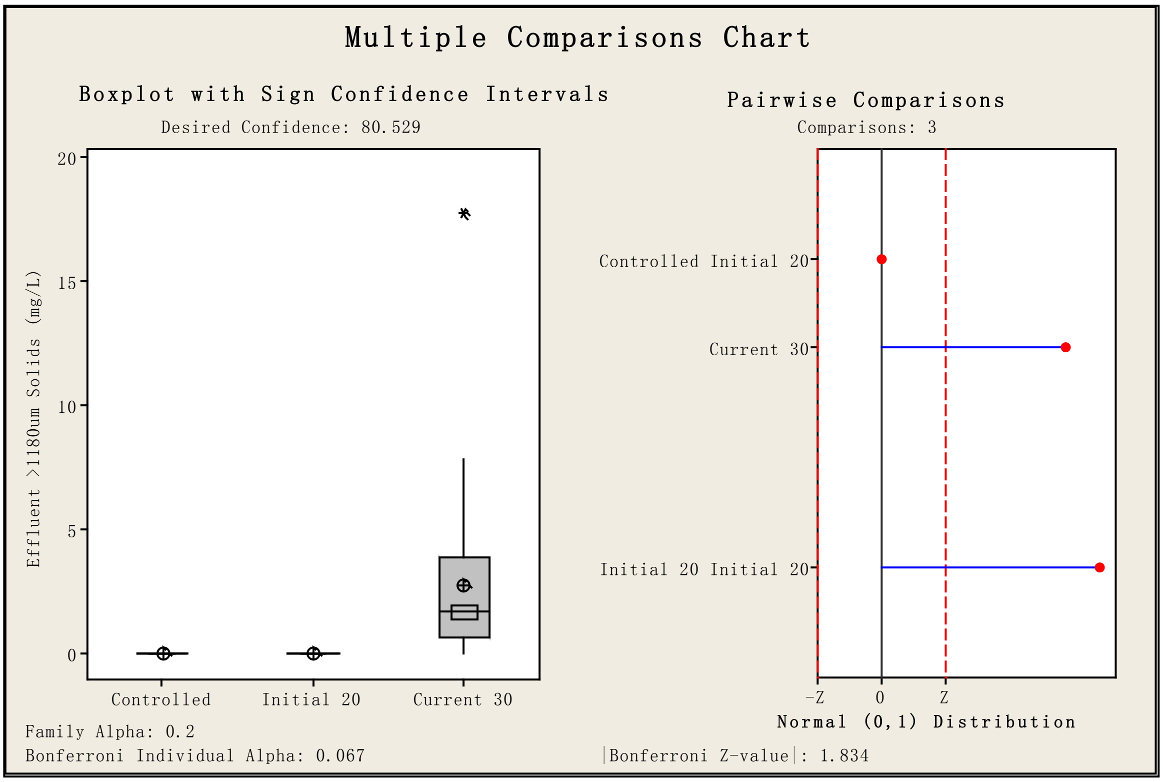


Figure 77: Multiple Comparison of >1180 µm Solids between Actual Storms Monitoring and Controlled Test

In summary, the effluent solids concentrations during the controlled tests were higher than those observed during the actual storm monitoring for the smaller particles (likely due to lower specific gravity of the fine sediment from the river water), but were much lower for the larger particles (likely due to the higher specific gravity of the medium and large particles from the ground silica). The SSC differences in performance were likely due to the different PSDs of the test and storm waters which biased the controlled tests that used river water. The PSDs for the controlled tests were not intended to be similar to stormwater, but were designed to provide sufficient particulate mass in each of the size ranges for analyses. Even though the SSC differences are not very useful, the differences for each size range are what was desired to be identified and are very useful when comparing testing procedures. Another reason for differences in the test methods may be due to the steady flows during the controlled tests vs. the highly irregular flows during the actual storm events.

5.5 Performance Evaluations of the Removal of Other Constituents

Several categories of other pollutants common in stormwater were also evaluated for their treatability in the Up-Flo® Filter. These other pollutants analyzed during this thesis research included inorganic nutrients, heavy metals, and bacteria. The analytical methods used for measuring these pollutants were listed previously in Table 3.

Figure 78 shows concentration line plots, while Table 20 includes the descriptive statistics for the nutrients monitored during the recent 30 sampled storms. The Up-Flo® Filter showed low removals for the analyzed nutrients, averagely about 17% for total nitrogen, close to zero for nitrates, about 8% for total phosphorus, and about 19% for dissolved phosphorus. The performance line plots show that most of the plots are relatively flat. These low removals are likely due to the very short contact time in the treatment media and the low influent concentrations at the test site. The total nitrogen effluent concentrations averaged <1 mg/L, the effluent nitrates averaged <0.2 mg/L, and the effluent total phosphorus concentrations averaged about 0.7 mg/L.

Table 21 summarizes the regression and ANOVA analyses for these nutrients for the 30 sampled storms, using $\log_{10}$ transformed data. The hypothesis tests using Wilcoxon Signed Rank test showed that statistically significant reductions (P-values < 0.05) occurred for total/dissolved nitrogen and phosphorus, even though the treatment levels were relatively low.

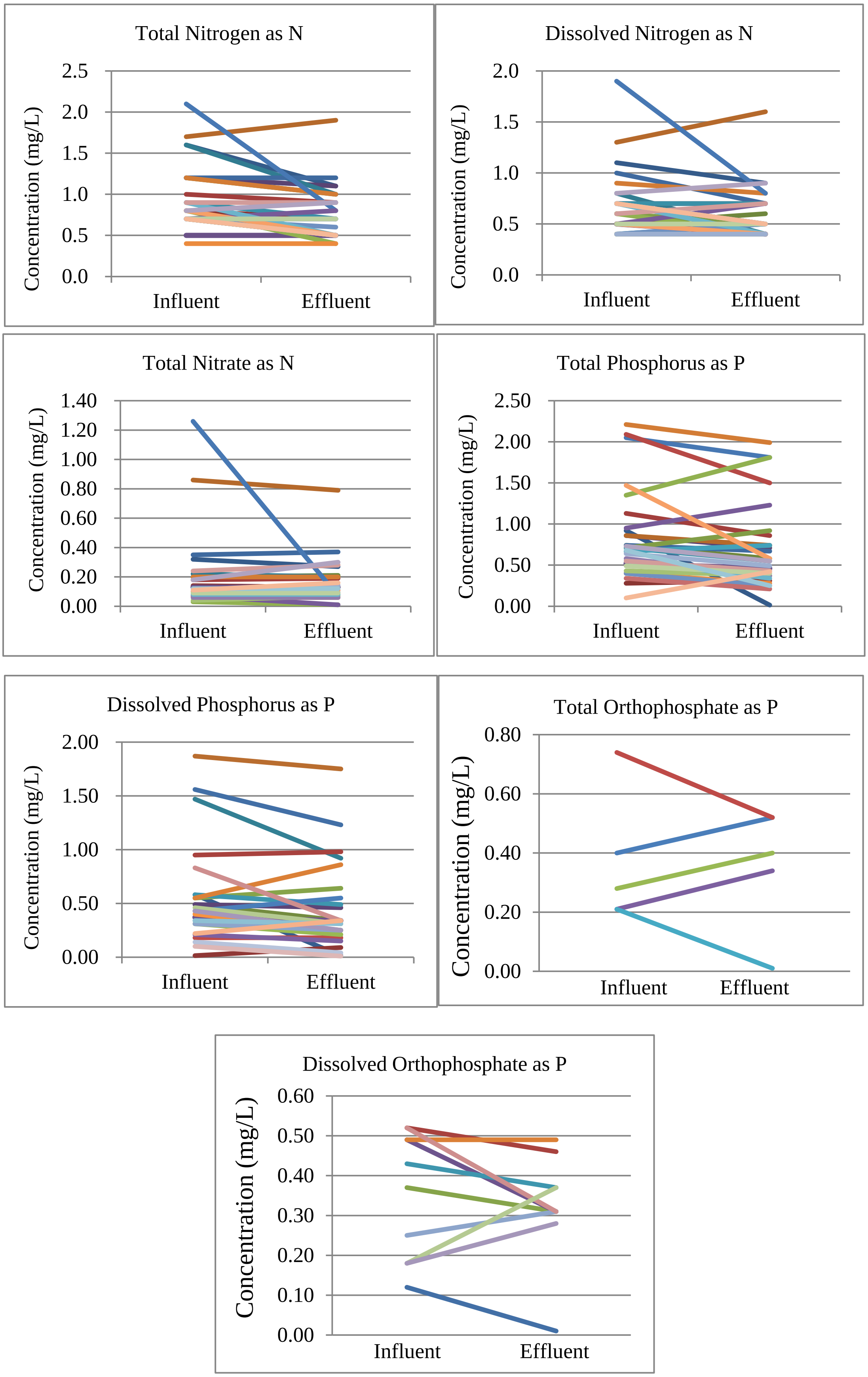


Figure 78: Performance Line Plots of Nutrient Constituents for 30 Sampled Storms

Table 20: Descriptive Statistics of Nutrients Removal for 30 Sampled Storms

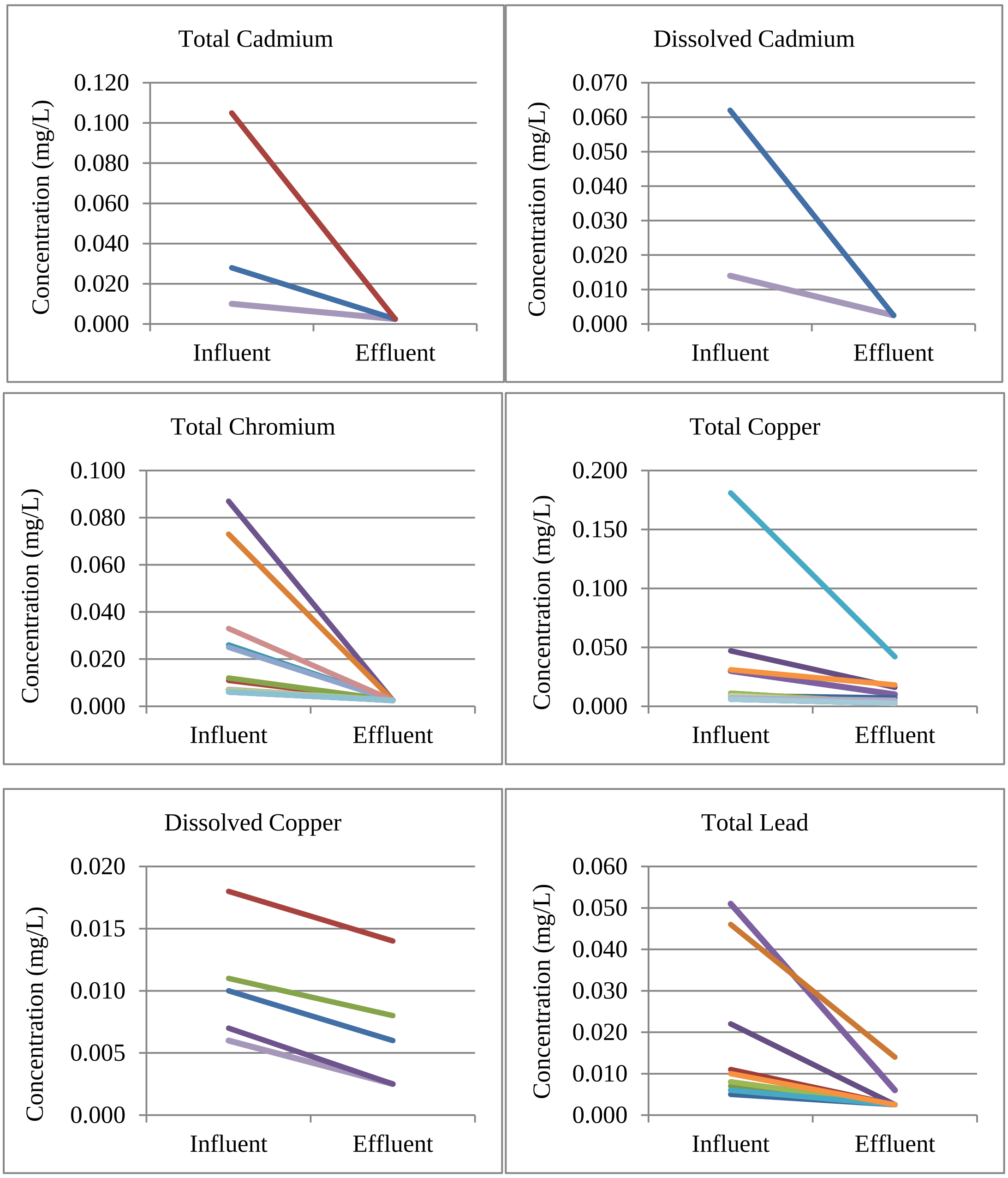
		Average	Median	Maximum	Minimum	Std. Dev.	COV
Total Nitrogen as N (mg/L)	Influent	0.9	0.8	2.1	0.4	0.4	0.41
	Effluent	0.8	0.7	1.9	0.4	0.3	0.42
	Removal Efficiency	16.5%	15.5%	61.9%	-14.3%	19.4%	1.17
Dissolved Nitrogen as N (mg/L)	Influent	0.7	0.6	1.9	0.4	0.3	0.48
	Effluent	0.6	0.5	1.6	0.4	0.3	0.43
	Removal Efficiency	8.8%	5.6%	57.9%	-40.0%	23.8%	2.71
Nitrate as N (mg/L)	Influent	0.19	0.11	1.26	0.03	0.25	1.34
	Effluent	0.16	0.12	0.79	0 to 0.02	0.15	0.92 to 0.94
	Removal Efficiency	(-6.7)% to (-3.5)%	-2.5%	94.4% to 100%	-100%	37.0% to 43.4%	(-12.31) to (-5.53)
Ammonia as N (mg/L)	Influent	BDL	BDL	BDL	BDL	NA	NA
	Effluent	BDL	BDL	BDL	BDL	NA	NA
	Removal Efficiency	NA	NA	NA	NA	NA	NA
Total Phosphorus as P (mg/L)	Influent	0.83	0.70	2.21	0.10	0.52	0.63
	Effluent	0.69	0.55	1.99	0.02	0.50	0.73
	Removal Efficiency	7.7%	20.0%	97.8% to 100%	-320%	67.8% to 67.9%	8.78 to 8.85
Dissolved Phosphorus as P (mg/L)	Influent	0.58	0.49	1.87	0.10	0.42	0.73
	Effluent	0.47	0.34	1.75	0.02	0.38 to 0.39	0.82
	Removal Efficiency	18.6% to 19.4%	18.9%	96.6% to 100%	-56.4%	34% to 35.8%	1.83 to 1.84
Total Orthophosphate as P (mg/L)	Influent	0.37	0.28	0.74	0.21	0.22	0.60
	Effluent	0.36	0.40	0.52	0 to 0.02	0.21	0.57 to 0.60
	Removal Efficiency	(-2.9)% to (-1.0)%	-30.0%	90.5% to 100%	-61.9%	62.4% to 66.0%	(-65.62) to (-21.45)
Dissolved Orthophosphate as P (mg/L)	Influent	0.36	0.40	0.52	0.12	0.16	0.44
	Effluent	0.32	0.31	0.49	0 to 0.02	0.13	0.39 to 0.41
	Removal Efficiency	1.7% to 3.4%	12.7%	83.3% to 100%	-105.6%	53.0% to 56.0%	16.62 to 31.09

Table 21: Summary of Regression and ANOVA of Nutrient Constituents for 30 Sampled Storms

Constituents	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
Total N as N	Log(y) = 0.7616 Log(x) - 0.1057	0.56	0.00	0.00	0.00	<0.001
Dissolved N as N	Log(y) = 0.6292 Log(x) - 0.1321	0.48	0.00	0.00	0.00	0.039
Nitrate as N	Log(y) = 1.0026 Log(x)*	0.88	0.00	NA	0.00	0.180
Total P as P	Log(y) = 0.6357 Log(x) - 0.1914	0.15	0.02	0.03	0.02	0.017
Dissolved P as P	Log(y) = 0.756 Log(x) - 0.2335	0.35	0.00	0.03	0.00	0.005
Total Orthophosphate as P	Log(y) = 0.7312 Log(x)*	0.60	0.01	NA	0.02	0.875
Dissolved Orthophosphate as P	Log(y) = 1.2536 Log(x)*	0.68	0.00	NA	0.00	0.641

* These constituents did not show significant removals (the p values were not <0.05), therefore these removal equations should be used with caution. A conservative approach would be to assume log (y) = 1.000 log (x) for these three nutrients (close to the stated equations, as the calculated equation slope coefficient CIs included 1.

Figure 79 and Table 22 are similar summaries of the data for the heavy metal constituents for the 30 sampled storms. The heavy metals had moderate to very high removals and low effluent concentrations. Total lead and total copper had average removal rates between about 40 and 95% (uncertainty due to some non-detected effluent concentrations) and effluent concentrations <10 µg/L; dissolved copper had average removals of 27 to 58%, while dissolved had a low 17% removal (but few observations as most were below the detection limit); total zinc had an average removal rate of about 45% and an average effluent concentration of <22 µg/L. Table 23 summarizes the regression and ANOVA results for copper and zinc removals. The other metal constituents (including Cr and Pb) did not have sufficient observations above the detection limits to allow regression and ANOVA analyses.



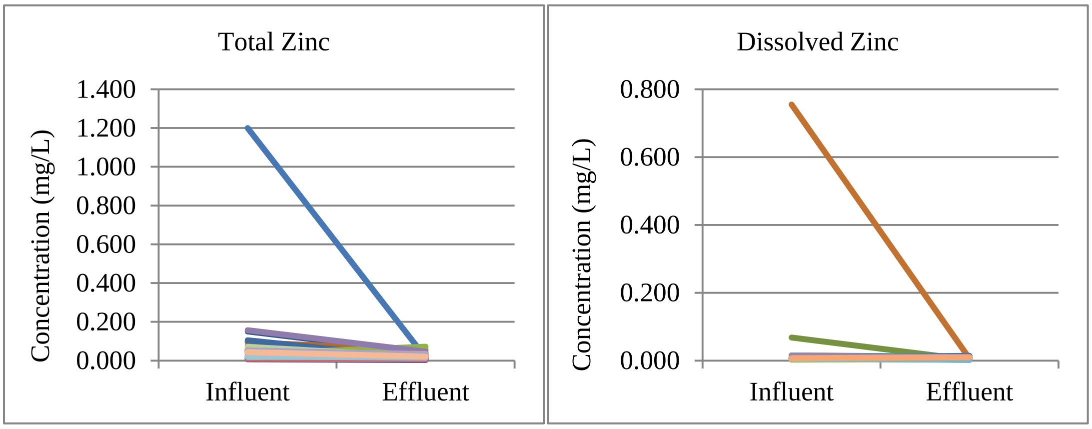


Figure 79: Performance Line Plots of Metal Constituents for 30 Sampled Storms

Table 22: Descriptive Statistics of Metal Removal for 30 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
Total Cadmium (mg/L)	Influent	0.048	0.028	0.105	0.010	0.050	1.06
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>75.8%	>82.1%	>95.2%	>50%	0% to 23.3%	0 to 0.31
Dissolved Cadmium (mg/L)	Influent	0.038	0.038	0.062	0.014	0.034	0.89
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>78.1%	>78.1%	>91.9%	>64.3%	0% to 19.6%	0 to 0.25
Total Chromium (mg/L)	Influent	0.027	0.012	0.087	0.006	0.028	1.06
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>57.9%	>58.3%	>94.3%	>16.7%	0% to 30.7%	0 to 0.53
Dissolved Chromium (mg/L)	Influent	BDL	BDL	BDL	BDL	NA	NA
	Effluent	BDL	BDL	BDL	BDL	NA	NA
	Removal Efficiency	NA	NA	NA	NA	NA	NA
Total Copper (mg/L)	Influent	0.023	0.009	0.181	0.006	0.042	1.82
	Effluent	0.005 to 0.010	0 to 0.005	0.042	0 to 0.005	0.010 to 0.011	1.02 to 2.14
	Removal Efficiency	39.1% to 84.4%	>37.5%	>76.8%	16.7% to 22.2%	17.3% to 27.5%	0.33 to 0.44
Dissolved Copper (mg/L)	Influent	0.010	0.010	0.018	0.006	0.005	0.45
	Effluent	0.006 to 0.008	0.006	0.014	0 to 0.005	0.004 to 0.006	0.50 to 1.05

	Removal Efficiency	26.9% to 57.9%	27.3% to 40.0%	>40.0%	16.7% to 22.2%	8.7% to 39.0%	0.32 to 0.67
Total Lead (mg/L)	Influent	0.016	0.008	0.051	0.005	0.016	1.02
	Effluent	0.002 to 0.006	0 to 0.005	0.014	0 to 0.005	0.003 to 0.004	0.44 to 2.55
	Removal Efficiency	42.8% to 96.5%	>37.5%	>88.2%	0% to 69.6%	9.1% to 26.4%	0.09 to 0.62
Dissolved Lead (mg/L)	Influent	0.006	0.006	0.006	0.006	NA	NA
	Effluent	0.005	0.005	0.005	0.005	NA	NA
	Removal Efficiency	16.7%	16.7%	16.7%	16.7%	NA	NA
Total Zinc* (mg/L)	Influent	0.050	0.042	0.157	0.007	0.040	0.79
	Effluent	0.021 to 0.022	0.018 to 0.020	0.072	0 to 0.005	0.015 to 0.016	0.69 to 0.75
	Removal Efficiency	42.1% to 45.9%	50%	>90.5%	-111.8%	39.6%	0.86 to 0.88
Dissolved Zinc* (mg/L)	Influent	0.012	0.007	0.068	0.005	0.015	1.23
	Effluent	0.007 to 0.008	0.007	0.014	0 to 0.005	0.003 to 0.004	0.35 to 0.65
	Removal Efficiency	6.1% to 22.5%	14.3% to 17.1%	>92.7%	-55.6%	38.5% to 54.8%	2.44 to 6.35

* The single very high Zn concentration values were not included in this summary table

Table 23: Summary of Regression and ANOVA of Metal Constituents for 30 Sampled Storms

Constituents	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
Total Cu	Log(y) = 0.625 Log(x) - 0.9021	0.96	0.00	0.00	0.00	0.063
Dissolved Cu	Log(y) = 1.0832 Log(x)*	0.50	0.00	NA	0.01	0.250
Total Zn	Log(y) = 0.3919 Log(x) - 1.2187	0.31	0.00	0.00	0.00	<0.001
Dissolved Zn	Log(y) = 1.0054 Log(x)*	0.83	0.00	NA	0.00	0.569

* Not significant, use with caution [Log(y) = 1.00 Log(x)]

Figure 80 and Table 24 summarize the concentration line plots and descriptive statistics for bacteria constituents for the 30 sampled storms. Bacteria had low to moderate levels of treatment performance, with average removals of 28%, 17%, and 56% of removal for Total Coliforms, *E. Coli*, and Enterococci, respectively. Table 25 has shown the regression model information. The regressions were all excellent ($p = 0.01$ and R^2>0.8) for regression model and the influent and effluent paired concentrations for *E. Coli* and Enterococci were significant based on the Wilcoxon Signed Rank test (the total coliform paired test did not indicate a significant difference, however).

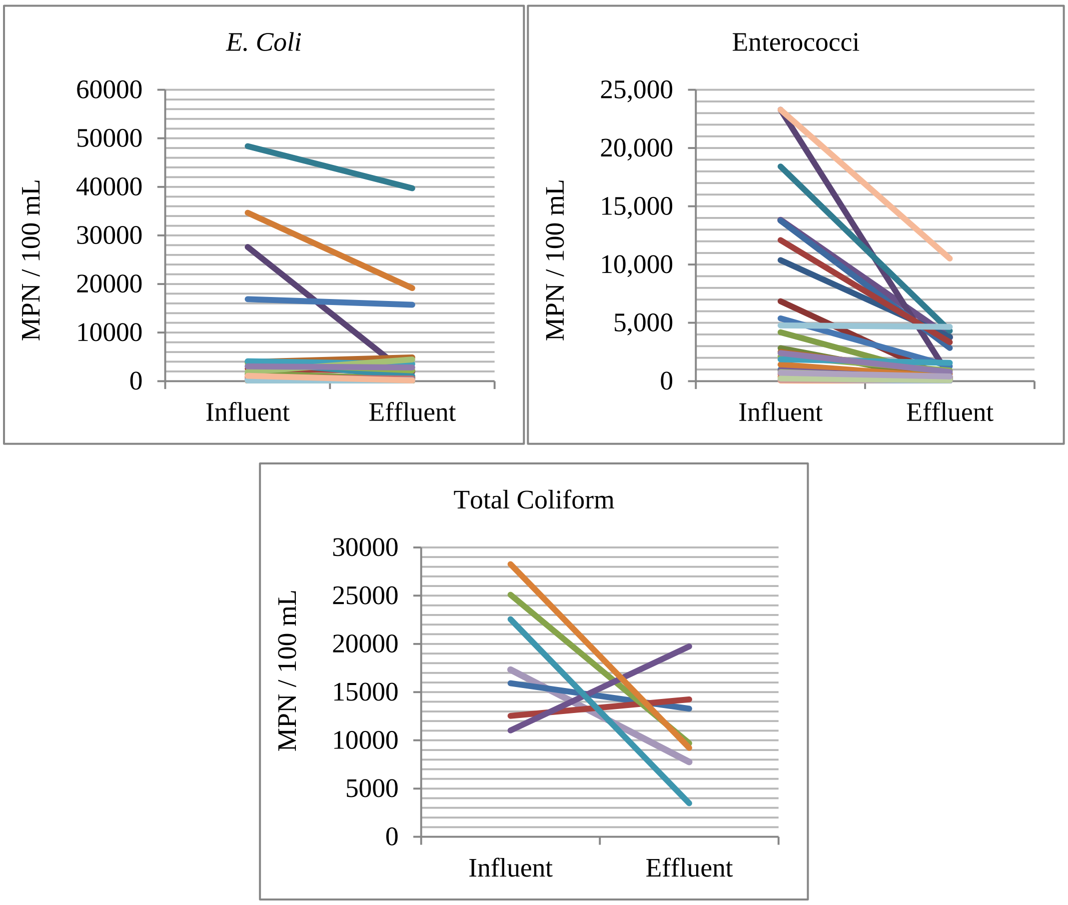


Figure 80: Performance Line Plots of Bacteria Constituents for 30 Sampled Storms

Table 24: Descriptive Statistics of Bacteria Removal for 30 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
Total Coliform (MPN/100 mL)	Influent	18,966	17,329	28,272	11033	6,496	0.34
	Effluent	19,316	15,532	48,392	3476	13,057	0.68
	Removal Efficiency	27.5%	55.2%	84.6%	-78.9%	57.6%	2.09
E. Coli (MPN/100 mL)	Influent	5,770	1,233	48,392	26	11,797	2.04
	Effluent	3,636	511	39,726	20	8,392	2.31
	Removal Efficiency	17.4%	24.6%	97.6%	-270.5%	71.00%	4.09
Enterococci (MPN/100 mL)	Influent	5,178	1,992	23,297	55	6,962	1.34
	Effluent	1,411	359	10,521	10	2,245	1.59
	Removal Efficiency	56.0%	69.9%	98.4%	-54.5%	39.3%	0.70

Table 25: Summary of Regression and ANOVA of Bacteria Constituents for 30 Sampled Storms

Constituents	Regression Equation	Adjusted R Square	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
Total Coliform	Log(y) = 0.9363 Log(x)*	0.83	0.00	NA	0.00	0.109
E. Coli	Log(y) = 0.9225 Log(x)	0.95	0.00	NA	0.00	0.001
Enterococci	Log(y) = 0.8206 Log(x)	0.94	0.00	NA	0.00	<0.001

* Not significant, use with caution [Log(y) = 1.00 Log(x)]

5.5.1 Performance Evaluations of Other Constituents during Different Monitoring Phases

This section summarizes the removal performance for the other constituents after combining the data of previous from the initial 20 storm events sampling effort with the recent 30 event data, resulting in a total of 50 sampled storms at the same test site that cover a broad range of rainfall and runoff characteristics to increase the confidence of the performance verifications.

Figure 81 and Table 26 are performance line plots and descriptive statistics for nutrient constituents for all 50 sampled storms. The combined performance indicates somewhat better low to moderate removals, with average removals for total nitrogen at 28% (average effluent quality of 1.2 mg/L) and 9% for nitrates (average effluent quality of 0.3 mg/L). Total phosphorus removals are about 14% (average effluent quality about 0.8 mg/L) and dissolved phosphorus at about 20% (average effluent quality of about 0.5 mg/L. The influent concentrations are relatively low, resulting in low percentage removals for many of the nutrients. Table 27 shows that all of the influent and effluent concentrations are significantly different and the regression equations are all significant..

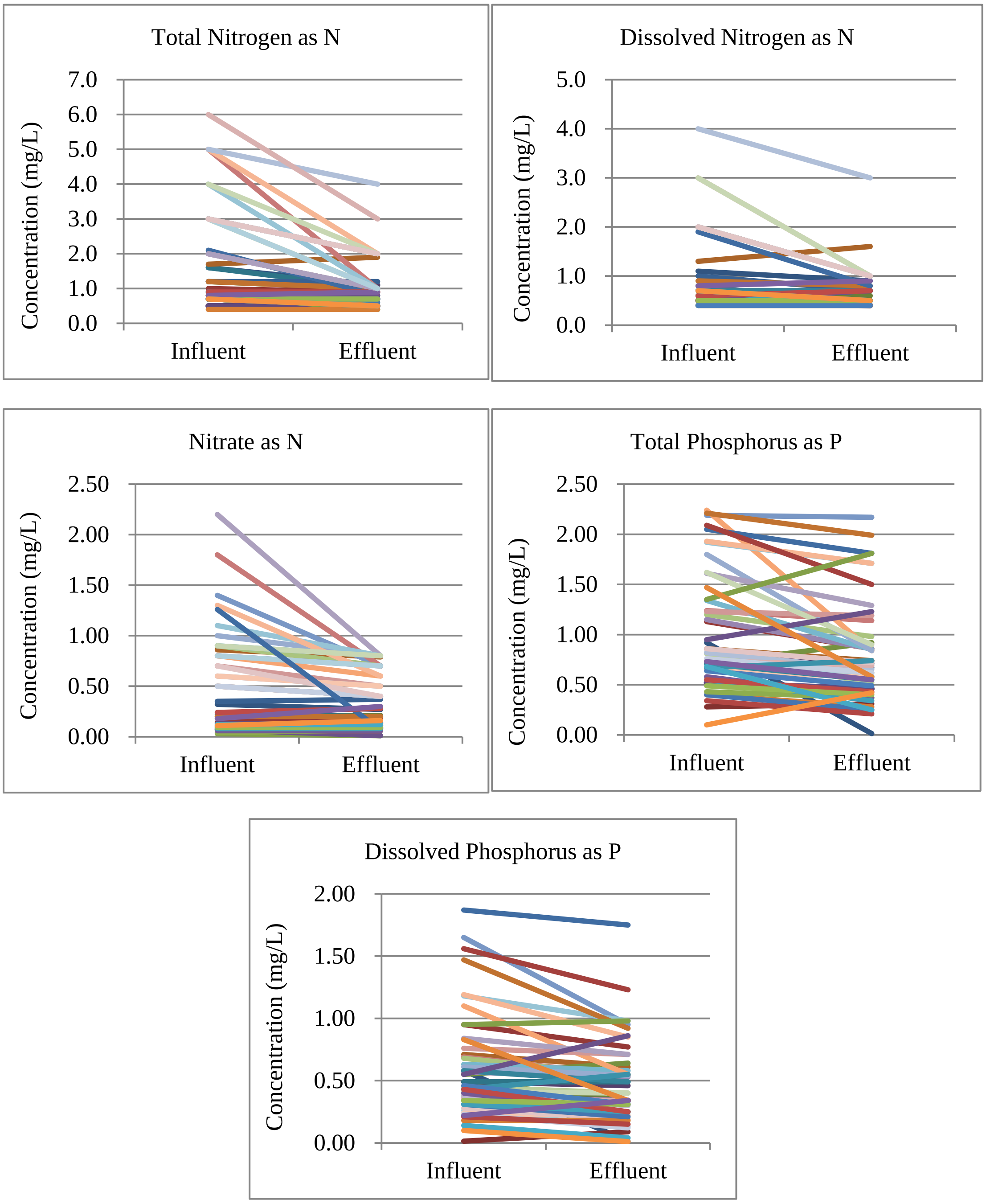


Figure 81: Performance Line Plots of Nutrient Constituents for 50 Sampled Storms

Table 26: Descriptive Statistics of Nutrients Removal for 50 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
Total Nitrogen as N (mg/L)	Influent	1.9	1.2	6.0	0.4	1.4	0.74
	Effluent	1.2	1.0	4.0	0.4	0.7	0.63
	Removal Efficiency	28.3%	29.9%	80.0%	-14.3%	23.2%	0.82
Dissolved Nitrogen as N (mg/L)	Influent	1.2	0.9	4.0	0.4	0.8	0.69
	Effluent	0.7	0.7	3.0	0.0	0.5	0.63
	Removal Efficiency	28.4%	28.6%	100.0%	-40.0%	32.8%	1.15
Nitrate as N (mg/L)	Influent	0.48	0.23	2.20	0.03	0.50	1.03
	Effluent	0.34	0.24	0.80	0 to 0.02	0.27	0.80
	Removal Efficiency	7.1% to 9.0%	10.1%	94.4% to 100%	-100%	34.8% to 38.3	4.3 to 4.9
Total Phosphorus as P (mg/L)	Influent	1.01	0.79	2.24	0.10	0.57	0.56
	Effluent	0.80	0.68	2.17	0 to 0.02	0.50	0.62
	Removal Efficiency	13.3%	18.4%	>98.8%	-320.0%	53.7%	4.05
Dissolved Phosphorus as P (mg/L)	Influent	0.61	0.49	1.87	0.10	0.41	0.67
	Effluent	0.48	0.40	1.75	0 to 0.02	0.34	0.71
	Removal Efficiency	19.6% to 20.1%	16.9%	>96.6%	-56.4%	27.8% to 29.1%	1.42 to 1.45

Table 27: Summary of Regression and ANOVA of Nutrient Constituents for 50 Sampled Storms

Constituents	Regression Equation	Adjusted R^2	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
Total N as N	Log(y) = 0.6678 Log(x) - 0.1157	0.73	0.00	0.00	0.00	<0.001
Dissolved N as N	Log(y) = 0.5641Log(x)-0.1521	0.74	0.00	0.00	0.00	<0.001
Nitrate as N	Log(y) = 0.7999 Log(x) - 0.2012	0.92	0.00	0.00	0.00	<0.001
Total P as P	Log(y) = 0.7407 Log(x) - 0.1445	0.28	0.00	0.00	0.00	<0.001
Dissolved P as P	Log(y) = 0.8114 Log(x) - 0.1917	0.44	0.00	0.00	0.00	<0.001

Figure 82 and Table 28 show the performance concentration line plots and summary of descriptive statistics for heavy metal removals for the 50 sampled storms. As similar to the removal performance found for the more recent 30 sampled storms, the overall performance also indicate moderate to high levels of heavy metal. The average removal rates for total Cu, Pb, and Zn were 38 to 84%, 45 to 98%, and 47 to 54%, respectively. Ranges are shown to consider the uncertainly due to the presence of some non-detectable effluent concentrations. The results of the Wilcoxon Signed Rank tests shown in Table 29 indicate significant removals for total copper and total zinc.

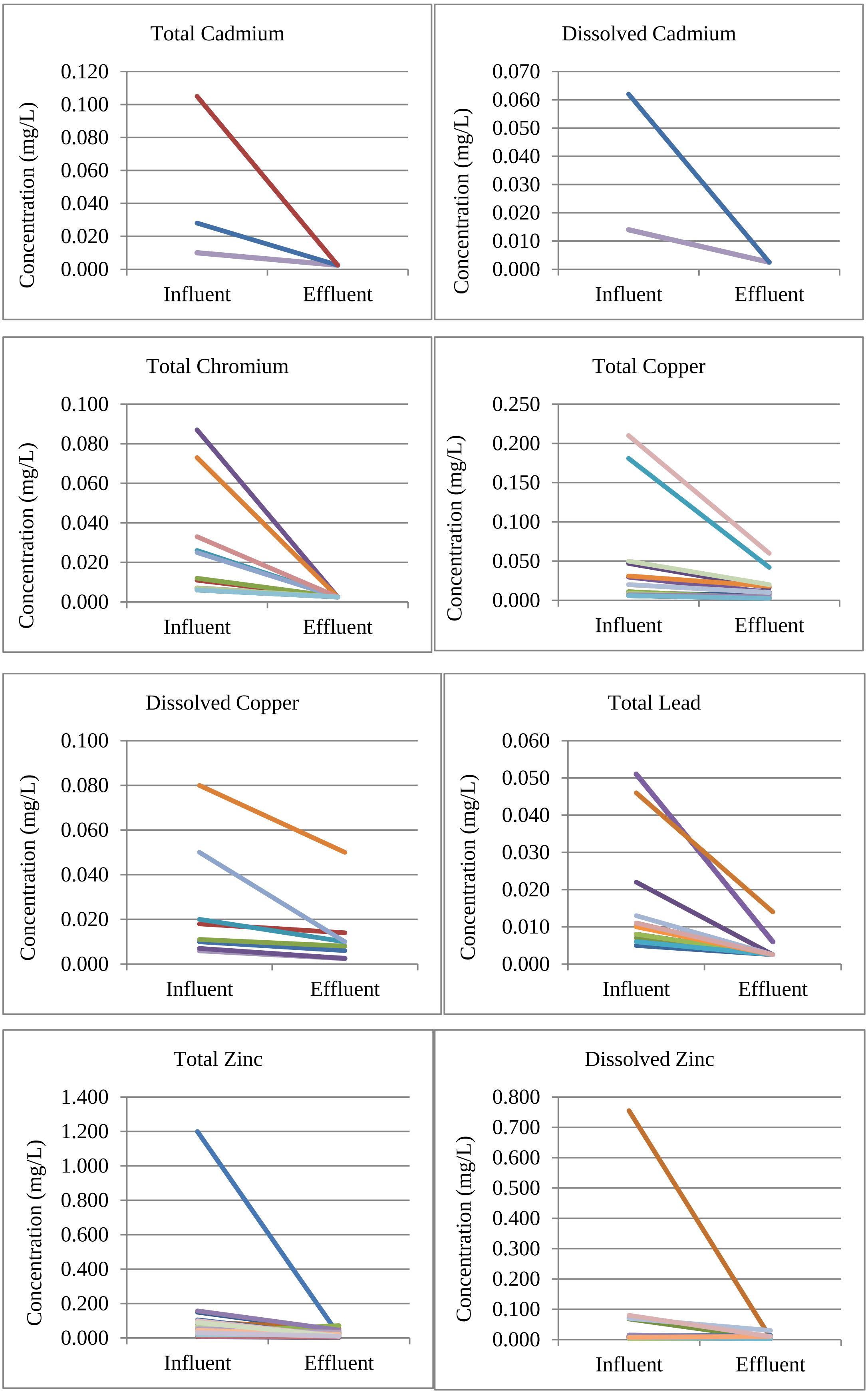


Figure 82: Performance Line Plots of Metal Constituents for 50 Sampled Storms

Table 28: Descriptive Statistics of Metals Removal for 50 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
Total Cadmium (mg/L)	Influent	0.048	0.028	0.105	0.010	0.050	1.06
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>75.8%	>82.1%	>95.2%	>50%	0% to 23.3%	0 to 0.31
Dissolved Cadmium (mg/L)	Influent	0.038	0.038	0.062	0.014	0.034	0.89
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>78.1%	>78.1%	>91.9%	>64.3%	0% to 19.6%	0 to 0.25
Total Chromium (mg/L)	Influent	0.027	0.012	0.087	0.006	0.028	1.06
	Effluent	0 to 0.005	0 to 0.005	0 to 0.005	0 to 0.005	0.000	0.00
	Removal Efficiency	>57.9%	>58.3%	>94.3%	>16.7%	0% to 30.7%	0 to 0.53
Dissolved Chromium (mg/L)	Influent	BDL	BDL	BDL	BDL	NA	NA
	Effluent	BDL	BDL	BDL	BDL	NA	NA
	Removal Efficiency	NA	NA	NA	NA	NA	NA
Total Copper (mg/L)	Influent	0.033	0.009	0.210	0.006	0.056	1.68
	Effluent	0.008 to 0.013	0 to 0.005	0.060	0 to 0.005	0.014 to 0.016	1.06 to 1.99
	Removal Efficiency	37.9% to 84.1%	>37.5%	>76.8%	0% to 22.2%	21.5% to 25.8%	0.31 to 0.57
Dissolved Copper (mg/L)	Influent	0.025	0.015	0.080	0.006	0.026	1.04
	Effluent	0.010 to 0.016	0.003 to 0.011	0.050	0 to 0.005	0.015 to 0.017	0.94 to 1.75
	Removal Efficiency	29.0% to 65.9%	27.9% to 70.0%	>60.0%	0% to 22.2%	17.7% to 36.9%	0.56 to 0.61
Total Lead (mg/L)	Influent	0.015	0.009	0.051	0.005	0.015	0.98
	Effluent	0.001 to 0.006	0 to 0.005	0.014	0 to 0.005	0.002 to 0.004	0.42 to 2.77
	Removal Efficiency	45.0% to 97.0%	>43.8%	>88.2%	0% to 69.6%	8.5% to 24.9%	0.09 to 0.55
Total Zinc* (mg/L)	Influent	0.053	0.044	0.157	0.007	0.039	0.74
	Effluent	0.019 to 0.022	0.017 to 0.020	0.072	0 to 0.005	0.014 to 0.017	0.66 to 0.88
	Removal Efficiency	45.% to 52.5%	50.0% to 52.3%	>90.5%	-111.8%	36.2% to 41.2%	0.78 to 0.80

Dissolved Zinc* (mg/L)	Influent	0.019	0.008	0.080	0.005	0.025	1.28
	Effluent	0.007 to 0.009	0.007 to 0.008	0.030	0 to 0.005	0.006 to 0.007	0.65 to 0.92
	Removal Efficiency	12.7% to 28.7%	15.5% to 23.6%	>92.7%	-55.6%	41.2% to 55.1%	1.92 to 3.23

*the single large Zn concentration value is not included in this table summary

Table 29: Summary of Regression and ANOVA of Metal Constituents for 50 Sampled Storms

Constituents	Regression Equation	Adjusted R^2	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
Total Cu	Log(y) = 0.6637 Log(x) - 0.8311	0.97	0.00	0.00	0.00	0.016
Dissolved Cu	Log(y) = 1.0934 Log(x)*	0.67	0.00	NA	0.00	0.125*
Total Zn	Log(y) = 0.3919 Log(x) - 1.2187	0.31	0.00	0.00	0.00	<0.001
Dissolved Zn	Log(y) = 1.0054 Log(x)*	0.84	0.00	NA	0.00	0.340*

* The reductions are not significant, use equations with caution [Log(y) = 1.00 Log(x)]

Figure 83 and Table 30 are the concentration performance line plots and descriptive statistics for bacteria constituents for the combined 50 sampled storms. Similarly to what had been found in the evaluation of recent 30 sampled storms, the performance of targeted bacteria constituents indicated moderate levels of treatability: the average removals were about 32% and 51% for *E. Coli* and Enterococci respectively. The very high adjusted R^2 values and highly significant equations and coefficients shown in Table 31 indicate excellent fitting of the data to the $\log_{10}$ transformed regression equations. The hypothesis tests using Wilcoxon Signed Rank test also indicate statistically significant reductions for both *E. Coli* and Enterococci.

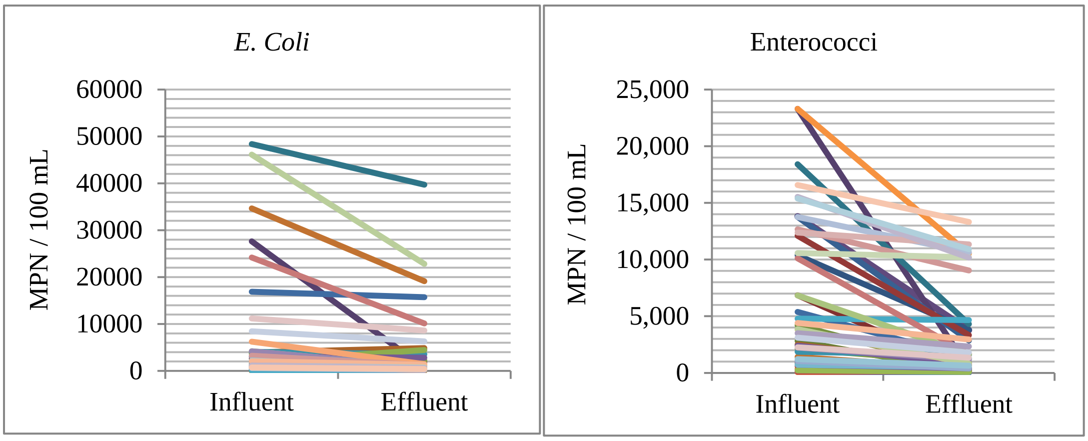


Figure 83: Performance Line Plots of Bacteria Constituents for 50 Sampled Storms

Table 30: Descriptive Statistics of Bacteria Removal for 50 Sampled Storms

		Average	Median	Maximum	Minimum	Std. Dev.	COV
E. Coli (MPN/100 mL)	Influent	6064	1870	48392	26	11404	1.88
	Effluent	3432	665	39726	20	7322	2.13
	Removal Efficiency	31.9%	43.1%	97.6%	-270.5%	58.49%	1.83
Enterococci (MPN/100 mL)	Influent	6027	3110	23297	55	6504	1.08
	Effluent	2734	820	13310	10	3804	1.39
	Removal Efficiency	50.6%	57.2%	98.4%	-54.5%	34.5%	0.68

Table 31: Summary of Regression and ANOVA of Bacteria Constituents for 50 Sampled Storms

Constituents	Regression Equation	Adjusted R^2	P-value of X Variable	P-value of Intercept	Significance Factor of Equation	P-value of Influent Equals to Effluent
E. Coli	Log(y) = 0.9095 Log(x)	0.97	0.00	NA	0.00	<0.001
Enterococci	Log(y) = 0.867 Log(x)	0.96	0.00	NA	0.00	<0.001

5.6 Summary of Overall Water Quality Performance of the Up-Flo® Filter

The field water quality performance evaluations of the full-scale Up-Flo® Filter relied on monitoring during actual storms. These water quality data provide overall valuable information of how the filter behaved over a one-year period (for the recent 30 events) under wide ranges of rainfall and runoff conditions. Sampling and analyses efforts of the previous monitoring phase (an initial 20 events) conducted by Togawa (2011) are also combined for these analyses to increase the power and confidence of the experimental results describing the performance of the Up-Flo® Filter.

Table 32 and Table 33 are summaries of the comprehensive water quality performance for the 30 sampled storms from the recent monitoring phase. All units described in the column of influent and effluent concentrations are in mg/L, except bacteria which are MPN/100 mL and turbidity which are NTU. The Wilcoxon Signed Rank Test was used for the hypothesis test, and "S" represents a significant reduction, while "N" represents a non-significant reduction (insufficient data counts to quantify a difference). All of the primary solids constituents, including TSS, SSC, VSS, TDS, and turbidity, plus the particles in each specific size ranges, have highly significant reductions with p-values of <0.01. The flow-weighted percent reductions were about 89% and 98% for TSS and SSC respectively, and increasing from fine particulates to larger particles with highest removal for the both large particle ranges (however these are heavily influenced by some of the unusually large loadings from periodic very large particles taken by auto-samplers; the next section shows an adjustment of this information based on captured sediment). There were also statistically significant reductions for total and dissolved nitrogen and total and dissolved phosphorus, but not for nitrates, nor for total and dissolved orthophosphates (due to low concentrations and/or many non-detected influent concentrations). For heavy metal performance, total chromium and total zinc had significant and large reductions, while total copper reductions were very close to being significant ($p = 0.06$). Other metal constituents had moderate levels of treatability, such as total/dissolved cadmium (>75%), total copper (>65%) and total lead (>58%), but had many non-detectable observations so few paired values were available for the hypothesis test. *E. coli* and enterococci had significant reductions (p-values of about 0.001), while total coliforms did not ($p = 0.11$).

Table 32: Summary of Overall Water Quality Performance for 30 Sampled Storms

Constituent	Influent Average Conc., mg/L (COV)	Effluent Average Conc., mg/L (COV)	Average % Reduction	Flow-weighted % Reduction	P-value (Significant or Not)	MDL
TSS	162 (0.91)	23 (0.75)	79.9%	89.1%	<0.001 (S)	1 mg/L
SSC	778 (1.76)	26 (0.71)	85.4%	98.2%	<0.001 (S)	1 mg/L
TDS	52 (0.45)	46 (0.50)	11.4%	19.5%	0.003 (S)	1 mg/L
VSS	35 (0.72)	9 (0.70)	69.2%	75.0%	<0.001 (S)	1 mg/L
Total N as N	0.9 (0.41)	0.8 (0.42)	16.5%	23.1%	<0.001 (S)	0.1 mg/L
Dissolved N as N	0.7 (0.48)	0.6 (0.43)	8.8%	16.7%	0.039 (S)	0.1 mg/L
Ammonia as N	BDL (NA)	BDL (NA)	NA	NA	NA	0.1 mg/L
Nitrate as N	0.19 (1.34)	0.16 (0.92 to 0.94)	(-6.7)% to (-3.5)%	11.4% to 11.7%	0.180 (N)	0.02 mg/L
Total P as P	0.83 (0.63)	0.69 (0.73)	7.7%	24.6%	0.017 (S)	0.02 mg/L
Dissolved P as P	0.58 (0.73)	0.47 (0.82)	18.6% to 19.4%	20.8% to 20.9%	0.005 (S)	0.02 mg/L
Total Ortho-P as P	0.37 (0.60)	0.36 (0.57 to 0.60)	(-2.9)% to (-1.0)%	1.6% to 3.6%	0.854 (N)	0.02 mg/L
Dissolved Ortho-P as P	0.36 (0.44)	0.32 (0.39 to 0.41)	1.7% to 3.4%	1.2% to 1.4%	0.641 (N)	0.02 mg/L
Total Cd	0.048 (1.06)	0 to 0.005 (0.00)	75.8% to 100%	91.9% to 100%	0.125 (N)	0.005 mg/L
Dissolved Cd	0.038 (0.89)	0 to 0.005 (0.00)	78.1% to 100%	87.6% to 100%	0.250 (N)	0.005 mg/L
Total Cr	0.027 (1.06)	0 to 0.005 (0.00)	57.9% to 100%	85.5% to 100%	<0.001 (S)	0.005 mg/L
Dissolved Cr	BDL (NA)	BDL (NA)	NA	NA	NA	0.005 mg/L
Total Cu	0.023 (1.82)	0.005 to 0.010 (1.02 to 2.14)	39.1% to 84.4%	64.3% to 72.8%	0.059 (N)	0.005 mg/L
Dissolved Cu	0.010 (0.45)	0.006 to 0.008 (0.50 to 1.05)	26.9% to 57.9%	26.1% to 34.0%	0.250 (N)	0.005 mg/L
Total Pb	0.016 (1.02)	0.002 to 0.006 (0.44 to 2.55)	42.8% to 96.5%	57.5% to 86.0%	0.007 (S)	0.005 mg/L
Dissolved Pb	0.006 (NA)	0.005 (NA)	16.7%	16.7%	0.750 (N)	0.005 mg/L
Total Zn	0.088 (2.42)	0.021 to 0.022 (0.69 to 0.75)	44.0% to 47.7%	71.7% to 72.8%	<0.001 (S)	0.005 mg/L
Dissolved Zn	0.056 (3.22)	0.007 to 0.008 (0.35 to 0.65)	11.5% to 27.0%	84.0% to 86.5%	0.569 (N)	0.005 mg/L
Total Coliform	18966 (0.34)	19316 (0.68)	27.5%	-78.8%	0.109 (N)	<1
E. Coli	5770 (2.04)	3636 (2.31)	17.4%	41.8%	0.001 (S)	<1
Enterococci	5178 (1.34)	1411 (1.59)	56.0%	70.3%	<0.001 (S)	<1
Turbidity	32.5 (0.88)	11.7 (0.83)	55.7%	58.5%	<0.001 (S)	0 NTU

Table 33: Summary of Overall Water Quality Performance for 30 Sampled Storms (2)

Particle Size Range	Influent Average Conc., mg/L (COV)	Effluent Average Conc., mg/L (COV)	Average Percentage Reduction	Flow-weighted Percent Reduction	P-value (Significant or Not)	MDL
0.45 to 3	0.22 (0.96)	0.16 (0.82)	20.0%	21.7%	<0.001 (S)	1 mg/L
3 to 12	15.28 (1.34)	3.19 (1.04)	56.8%	83.1%	<0.001 (S)	1 mg/L
12 to 30	33.84 (0.88)	8.14 (0.85)	66.5%	80.2%	<0.001 (S)	1 mg/L
30 to 60	10.61 (1.09)	3.23 (0.79)	57.0%	64.2%	<0.001 (S)	1 mg/L
60 to 120	6.22 (1.12)	1.99 (1.01)	54.0%	66.8%	<0.001 (S)	1 mg/L
120 to 250	2.29 (1.12)	0.45 (1.71)	76.4%	69.3%	<0.001 (S)	1 mg/L
250 to 1180	424.62 (2.06)	5.23 (1.06)	84.7%	99.5%	<0.001 (S)	1 mg/L
>1180	287.04 (1.84)	2.74 (1.29)	93.1%	99.5%	<0.001 (S)	1 mg/L

Similarly, Tables 34 and Table 35 show the overall water quality performance of the Up-Flo® Filter for all 50 sampled storm events monitored at the Bama Belle test site. Again, all solids constituents, including each particle size range, have significant reductions with p-values of <0.001 and high levels of flow-weighted reductions for TSS and SSC. The removals for all nutrients also have significant reductions due to the increase in numbers of paired observations having detectible concentrations. The flow-weighted calculated levels of treatment were low to moderate, ranging from about 20% for dissolved phosphorus to about 34% for total nitrogen. The overall treatability for heavy metals were not significant for total and dissolved Cd, dissolved Cu, dissolved Pb and dissolved Zn due to numerous non-detected influent concentration values. The flow-weighted levels of control were all high for those constituents having sufficient data, ranging from 62 to 72% for total copper, to greater than 85% for total chromium. The flow-weighted removals for *E. Coli* (46%) and Enterococci (56%) were also significant (p<0.001).

Table 34: Summary of Overall Water Quality Performance for 50 Sampled Storms

Constituent	Influent Average Conc., mg/L (COV)	Effluent Average Conc., mg/L (COV)	Average Percentage Reduction	Flow-weighted Percent Reduction	P-value (Significant or Not)	MDL
TSS	126 (0.98)	21 (0.75)	75.7%	87.8%	<0.001 (S)	1 mg/L
SSC	521 (2.19)	25 (0.70)	77.8%	97.8%	<0.001 (S)	1 mg/L
TDS	76 (0.68)	54 (0.52)	20.8%	31.8%	<0.001 (S)	1 mg/L
Total N as N	1.9 (0.74)	1.2 (0.63)	28.3%	34.4%	<0.001 (S)	0.1 mg/L
Dissolved N as N	1.2 (0.69)	0.7 (0.63)	28.4%	33.9%	<0.001 (S)	0.1 mg/L
Nitrate as N	0.48 (1.03)	0.34 (0.79 to 0.80)	7.1% to 9.0%	27.9% to 28.0%	<0.001 (S)	0.02 mg/L
Total P as P	1.01 (0.56)	0.80 (0.62)	13.2% to 13.3%	24.1%	<0.001 (S)	0.02 mg/L
Dissolved P as P	0.61 (0.67)	0.48 (0.70 to 0.71)	19.6% to 20.1%	21.5% to 21.6%	<0.001 (S)	0.02 mg/L
Total Cd	0.048 (1.06)	0.005 (0.00)	75.8% to 100%	91.9% to 100%	0.125 (N)	0.005 mg/L
Dissolved Cd	0.038 (0.89)	0.005 (0.00)	78.1% to 100%	87.6% to 100%	0.250 (N)	0.005 mg/L
Total Cr	0.027 (1.06)	0.005 (0.00)	57.9% to 100%	85.5% to 100%	<0.001 (S)	0.005 mg/L
Dissolved Cr	BDL (NA)	BDL (NA)	NA	NA	NA	0.005 mg/L
Total Cu	0.033 (1.68)	0.013 (1.06)	37.9% to 84.1%	62.6% to 72.9%	0.016 (S)	0.005 mg/L
Dissolved Cu	0.025 (1.04)	0.016 (0.94)	29.0% to 65.9%	33.6% to 53.7%	0.125 (N)	0.005 mg/L
Total Pb	0.015 (0.98)	0.006 (0.42)	45.0% to 97.0%	57.6% to 86.8%	0.002 (S)	0.005 mg/L
Dissolved Pb	0.006 (NA)	0.005 (NA)	16.7%	16.7%	0.750 (N)	0.005 mg/L
Total Zn	0.087 (2.30)	0.022 (0.66)	46.7% to 53.8%	71.7% to 74.5%	<0.001 (S)	0.005 mg/L
Dissolved Zn	0.058 (2.94)	0.009 (0.65)	17.3% to 32.4%	82.3% to 85.2%	0.340 (N)	0.005 mg/L
E. Coli	6064 (1.88)	3432 (2.13)	31.9%	46.1%	<0.001 (S)	<1
Enterococci	6027 (1.08)	2734 (1.79)	50.6%	55.8%	<0.001 (S)	<1
Turbidity	26.8 (0.91)	10.0 (0.81)	53.6%	58.4%	<0.001 (S)	0 NTU

Table 35: Summary of Overall Water Quality Performance for 50 Sampled Storms (2)

Particle Size Range	Influent Average Conc., mg/L (COV)	Effluent Average Conc., mg/L (COV)	Average Percentage Reduction	Flow-weighted Percent Reduction	P-value (Significant or Not)	MDL
0.45 to 3	0.51 (1.44)	0.31 (1.31)	23.9%	36.5%	<0.001 (S)	1 mg/L
3 to 12	12.33 (1.40)	3.26 (1.09)	51.4%	80.2%	<0.001 (S)	1 mg/L
12 to 30	24.95 (1.04)	6.62 (0.98)	65.4%	79.1%	<0.001 (S)	1 mg/L
30 to 60	12.32 (0.86)	4.24 (0.97)	56.5%	64.3%	<0.001 (S)	1 mg/L
60 to 120	8.95 (0.91)	2.77 (1.11)	58.6%	68.9%	<0.001 (S)	1 mg/L
120 to 250	3.12 (1.03)	0.39 (1.60)	81.0%	79.6%	<0.001 (S)	1 mg/L
250 to 1180	260.30 (2.70)	4.72 (0.98)	31.6%	99.4%	<0.001 (S)	1 mg/L
>1180	176.23 (2.43)	1.64 (1.84)	95.9%	99.5%	<0.001 (S)	1 mg/L

5.7 Sump Sediment Monitoring and Mass Balance Analyses

Grab samples of the filter sump material were collected at the end of the monitoring period for drying and further analyses. Analyses included particle size distribution (PSD), percent volatile solids, specific gravity, along with selected constituents for each defined particle size range. The sediment analyses effort also included continuous monitoring of sump sediment accumulations by periodically manually measuring the sediment depth, and automatically by using a liquid-filled (degassed water) USGS load-cell scour sensor (from Rickly Hydrological Company). The used filter media bags were also replaced with new bags, dried and weighed to estimate the accumulation of solids within the media, which along with the sump accumulated material, was used to examine an overall mass balance.

Figure 84 is a time series plot of both the manual sediment measurements compared to the automatic sediment measurements using the scour sensor. The accumulative runoff volume is also shown on the chart. The continuous monitoring from scour sensor tracks the manual measurements very well, but only after about 4 inches of sediment has accumulated.

Both of the measurement methods are also consistent with the increments of accumulative runoff volumes. At the end of the one year monitoring period, about 10 inches of sump sediment was found associated with about 980,000 gallons of runoff that passed through the filter system. In order to prevent sediment accumulations to remain well away from the bottom of the filter media bags and coarse screening, the sediment needs to be at least 1 ft below those critical elevations. This results in about 2 ft of allowable sediment accumulation in the sump. At 10 inches per year, the sump sediment would have to be removed after about 2.5 years, or sooner. The transient drop in the middle of the plot at the beginning of October 2012 was due to interim sump sediment collection.

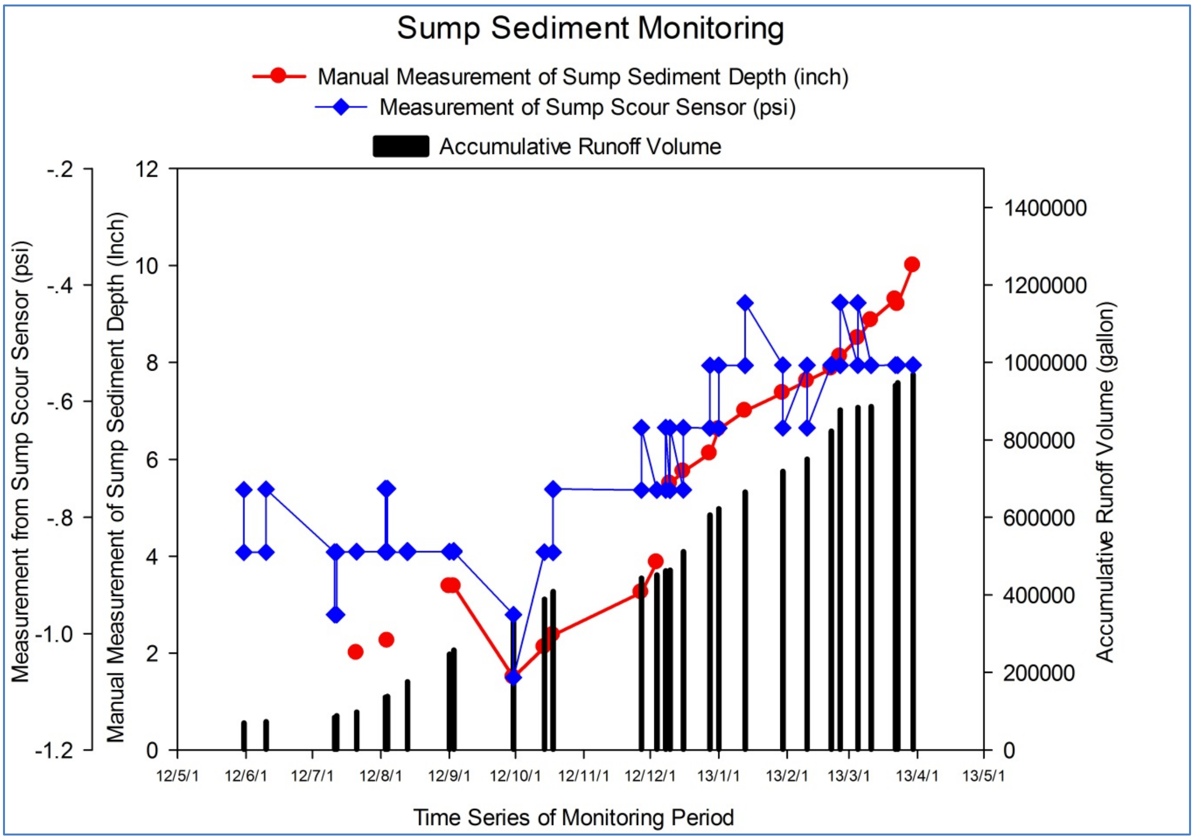


Figure 84: Sump Sediment Monitoring of One-Year Period

At the end of the monitoring period on April 2, 2013, grab samples of sump sediment were collected, dried, and analyzed (nutrients and heavy metals) and physical (solids characteristics and specific gravity). Table 36 and Figure 85 show the analysis results for nutrients, while Table 37 and Figure 86 show the analysis results for heavy metals. Total sulfite and total sulfide were analyzed to evaluate the potential for anaerobic conditions in the sediment and binding of heavy metals. These were both undetected for all samples. Total sulfate, total phosphorus, and all the heavy metal constituents tended to be higher on the organic leaves and on the very small particles. However, since these both represented very small portions of the sediment mass, the bulk of the contaminants were associated with intermediate-sized particulates.

Table 36: Nutrient Content of Sump Sediment Samples

	COD (mg/kg)	Total N (mg/kg)	Total P (mg/kg)	Total Sulfide (mg/kg)	Total Sulfate (mg/kg)	Total Sulfite (mg/kg)
Leaves	4200	1790	127	BDL	1260	BDL
Sticks	1610	2600	115	BDL	522	BDL
>2800	1300	2740	131	BDL	540	BDL
1400 - 2800	1570	2660	312	BDL	545	BDL
710-1400	1580	1930	161	BDL	691	BDL
355-710	830	812	303	BDL	574	BDL
180-355	1000	588	335	BDL	362	BDL
75-180	800	1900	350	BDL	949	BDL
45-75	1310	1710	815	BDL	1780	BDL
<45 (Pan)	1650	2740	670	BDL	2310	BDL

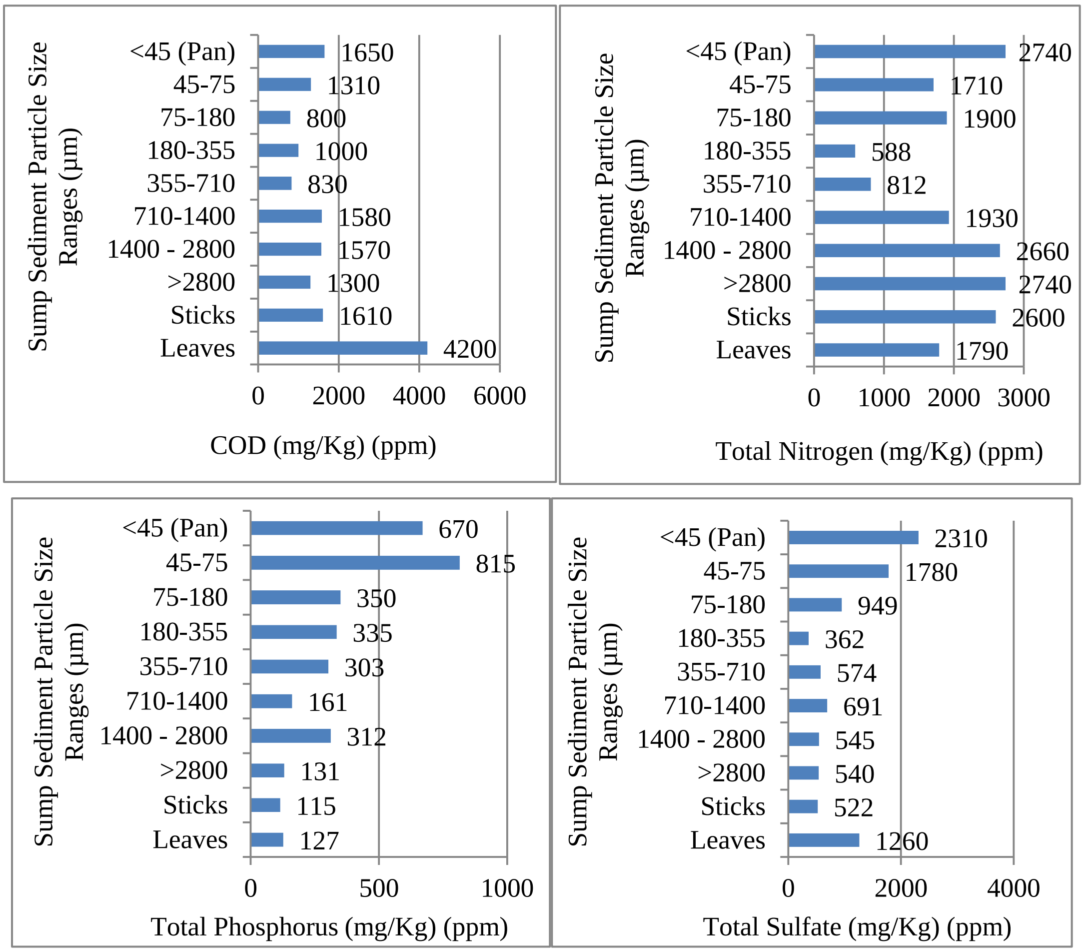


Figure 85: Histograms of Nutrient Content of Sump Sediment Samples

Table 37: Heavy Metal Content of Sump Sediment Samples

	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Copper (mg/kg)	Zinc (mg/kg)
Leaves	2.1	24	4.3	9	28
Sticks	BDL	14	2.1	5	46
>2800	BDL	6	1.9	3	BDL
1400 - 2800	0.8	60	6.1	10	31
710-1400	0.8	160	15.1	18	56
355-710	0.7	97	15.6	15	71
180-355	BDL	85	14.7	25	71
75-180	11.0	81	35.5	29	76
45-75	2.0	135	60.2	41	198
<45 (Pan)	2.4	157	51.6	48	245

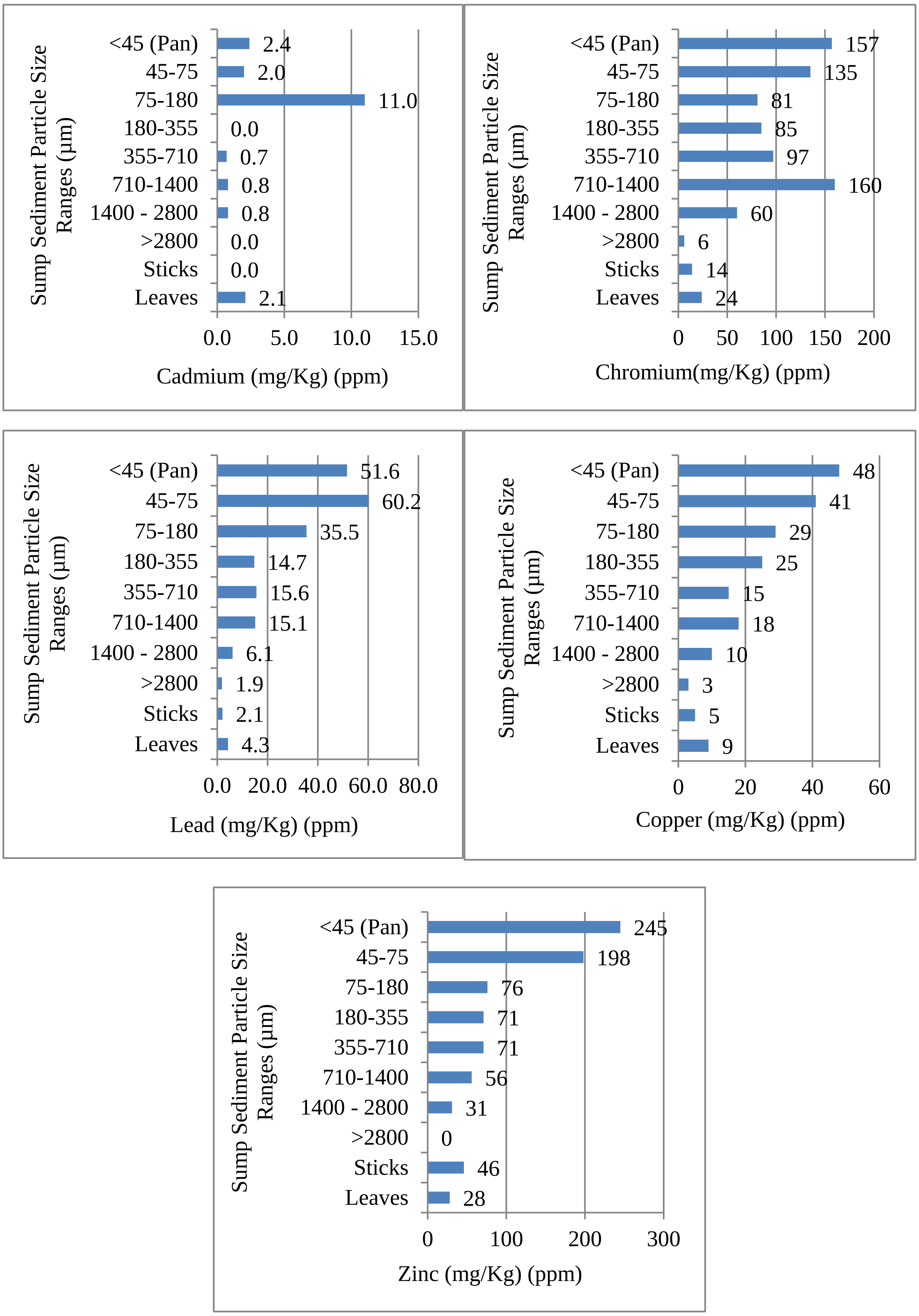


Figure 86: Histograms of Heavy Metal Content of Sump Sediment Samples

A series of sump sediment analyses were focused on the evaluation of solids characteristics. Table 38 shows that the average dry bulk density of the sediment was about

0.46 g/cc with a coefficient of uniformity of 7.22 (the ratio of the 60th percentile diameter to the 10th percentile diameter). This bulk density value is very low, but reflects the relatively large fraction of leaves in the sediment sump, being about 3.5% by mass, but because they are light, they represent a large fraction of the total sump material volume. Table 39 shows that the specific gravity of sediment increased as the solids decreased, indicating increasing amounts of mineral soil; this is opposite as shown by the percentage of volatile solids which decreased with decreasing particle size, indicating more organic material in the larger sized fractions..

Table 38: Solids Characteristics of Sump Sediment Samples

Overall Dry Bulk Density (g/cc)	d_{10} (um)	d_{30} (um)	d_{50} (um)	d_{60} (um)	Coefficient of Uniformity (C_u)	Coefficient of Gradation (C_k)
0.46	97	250	480	700	7.22	0.92

Table 39: Solids Characteristics of Sump Sediment Samples (2)

Sieve size range (um)	Specific Gravity (g/cc)	Percentage of Volatile Solids Trial #1 (%)	Percentage of Volatile Solids Trial #2 (%)	Average of Volatile Solids (%)
Leaves	2.28	93.2	93.1	93.2
Sticks	0.84	79.8	82.6	81.2
>2800	0.66	66.5	75.4	70.9
1400 - 2800	1.15	55.3	60.3	57.8
710-1400	1.43	42.2	43.2	42.7
355-710	2.56	26.3	26.0	26.1
180-355	2.76	19.0	19.8	19.4
75-180	2.97	20.7	20.5	20.6
45-75	3.30	25.5	25.8	25.7
<45 (Pan)	3.46	25.9	26.1	26.0

At the end of the monitoring period, about 10 inches of sump sediment was determined by manual measurements. Based on the geometry of the filter sump and measured dry bulk value (0.46 g/cc), this corresponds to about 10.5 ft^3 of material and about 300 lbs of sediment. About 115 lbs of this total were assumed to be associated with the 25 selected storms (that did not have unusual size distributions), based on the ratio of the monitored runoff depth during the monitored storms and all storms during the period. Five sampled events were not included in the sum of loads calculations because of unusual high loads of fine particulates for some size ranges which led to a large bias in the mass balance. In addition, about 20 lbs of additional material was captured in the filter media and flow distribution material during the one year (weight increase from initial weighing and then at the end of the study period after the media bags and flow distribution material were dried and weighed); therefore about 7.7 lbs of added material was associated with the 25 sampled storms. A, total of about 122 lbs of solids was estimated to be retained in the filter media and sump as the particulate removal amount associated with the 25 monitored storms during the one year period.

A particle size distribution plot of the analyzed sump sediment is shown in Figure 87, showing that the median particle size in the sump was about 450 µm, and only about 10% of the captured mass retained in the sump was less than 100 µm. This is typical for catchbasin sumps as the turbulent conditions hinder settling of fine material during storms. Also, any scour during large events would likely remove the very small particles as the bed load protection was damaged.

Table 40 shows the overall mass balance calculations and compares the amount of particulate solids retained in the treatment device with the amount calculated to be retained by the automatic samplers. As the particle size distribution (PSD) of captured solids in the media bags is unknown, only particles which are less than 250 µm were assumed to be retained in the media bags, and the same portion of the PSD of the sump sediment from 0.45 to 250 µm was used to establish the correlated PSD for solids captured in the media bags. For the 25 sampled storms, the overall mass balance shows a large difference (about 79 lbs) between auto-sampling and sump sediment calculations, mainly contributed associated with the 3 to 60 µm particle range. These fine particulates are typically not to be found in catchbasin sump sediment as they would unlikely settle during rain events and are also easily scoured. The mass portions of large particles greater than 250 µm from the sump were used instead of the sieved amounts from the automatic sampling due to unusual erosion issues near the treatment device that resulted in unrepresentative loads of these very large materials where the sample intake was located. The automatic samplers are also inefficient in collecting these large materials and bedload sampler data (such as from the sump) are more representative measures of these large materials in the runoff.

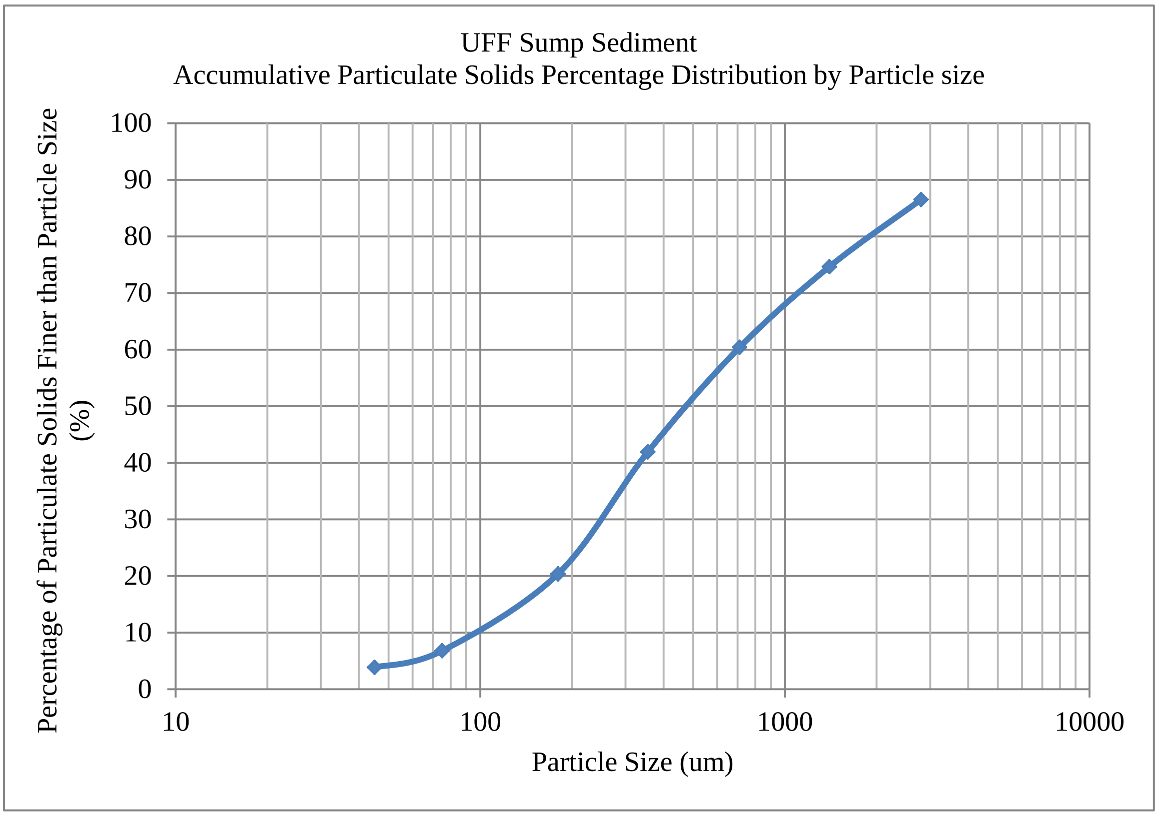


Figure 87: Particle Size Distribution of Sampled Sump Sediment

Table 40: Overall Mass Balance of Filter System of One-Year Monitoring Period

Particle Size Range (um)	Prorated Mass in the sump for Sampled Storms (lbs)	Prorated Mass in the filter media for Sampled Storms (lbs)	Total Prorated Mass Retained in the sump and media bags for Sampled Storms (lbs)	Influent Mass for Sampled Storms (lbs)	Effluent Mass for Sampled Storms (lbs)	Amount retained in UpFlow filter based on Automatic Samplers (plus fraction from sump for >250 um) (lbs)	Difference (sump and bag material minus mass measured by samplers) (lbs)
< 0.45	0.0	0.00	0.0	0.0	0.0	0.0	0.0
0.45 - 3	0.4	0.08	0.4	0.6	0.5	0.2	0.3
3 - 12	0.8	0.18	1.0	49.1	7.3	41.8	-40.8
12 - 30	1.6	0.36	2.0	69.2	20.6	48.6	-46.6
30 - 60	2.9	0.63	3.5	28.6	9.2	19.5	-15.9
60 - 120	8.6	1.88	10.4	21.2	5.8	15.4	-4.9
120 - 250	20.6	4.52	25.1	23.9	1.4	22.5	2.6
250 - 1180	46.9	-	46.9	44.1	14.1	30.1	16.9
> 1180	32.9	-	32.9	29.5	6.1	23.4	9.6
Total:	115	7.65	122	266	65	201	-79

Table 41 is a section of Table 40 showing the overall accumulative mass associated with the 25 sampled events for each particle range based on results from auto-samplers with the corrected prorated sump portion for the large particles (>250 µm), compared to the measured effluent loads. Large fractions of the influent mass were found in the range of 3 - 30 µm. The overall removal performance was about 76%.

Table 41: Accumulative Mass of Influent and Effluent for 25 Sampled Storms Based on Auto-Sampling Results

Particle Size Range (um)	Influent Total Mass (With Sump) (lbs)	Effluent Total Mass (lbs)	Percent Reduction
< 0.45	0.0	0.0	0.0
0.45 - 3	0.7	0.5	26.2
3 - 12	49.1	7.3	85.2
12 - 30	69.2	20.6	70.2
30 - 60	28.6	9.2	67.9
60 - 120	21.2	5.8	72.7
120 - 250	23.9	1.4	94.1
250 - 1180	44.1	14.1	68.1
> 1180	29.5	6.1	79.2
Total:	266.2	64.9	75.6

Figures 88 and 89 are the particle size distributions for the accumulative solids percentage and mass associated with the 25 sampled events, including the prorated sump sediment portions. The influent PSD plot is similar to the effluent plot. Figure 89 shows that the solids removal is consistent for each particle range, and very large for the largest sizes, as expected.

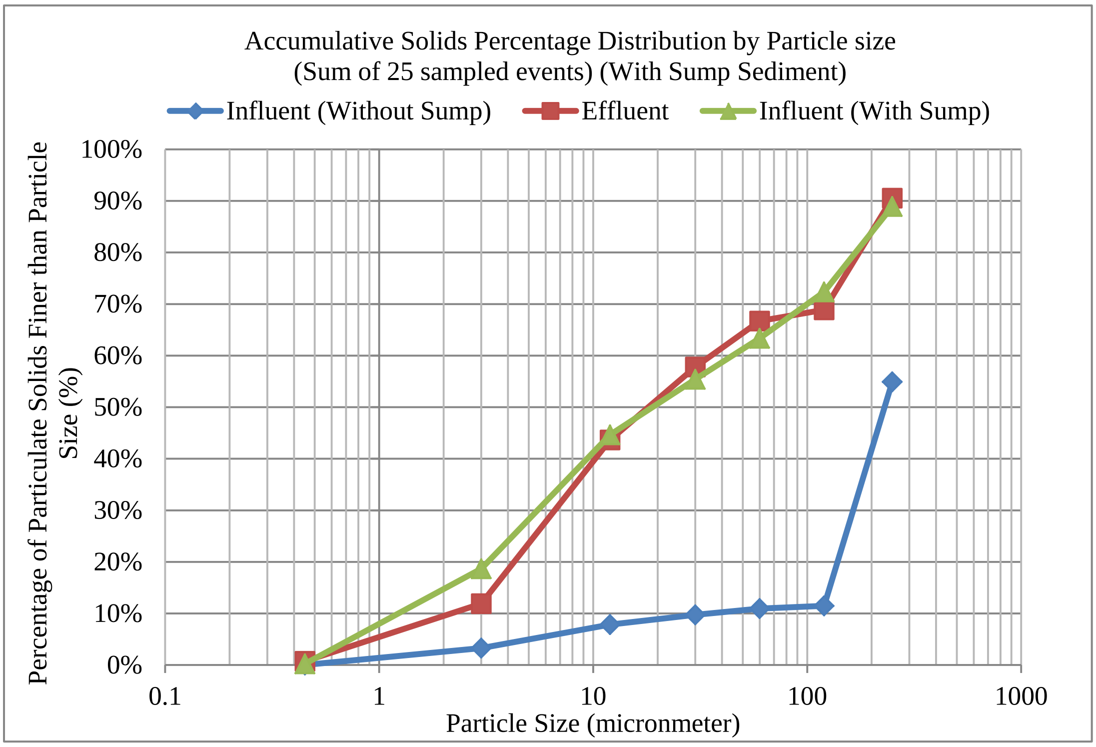


Figure 88: Accumulative Solids Percentage Distribution by Particle Size with Sump Sediment (25 Sampled Events)

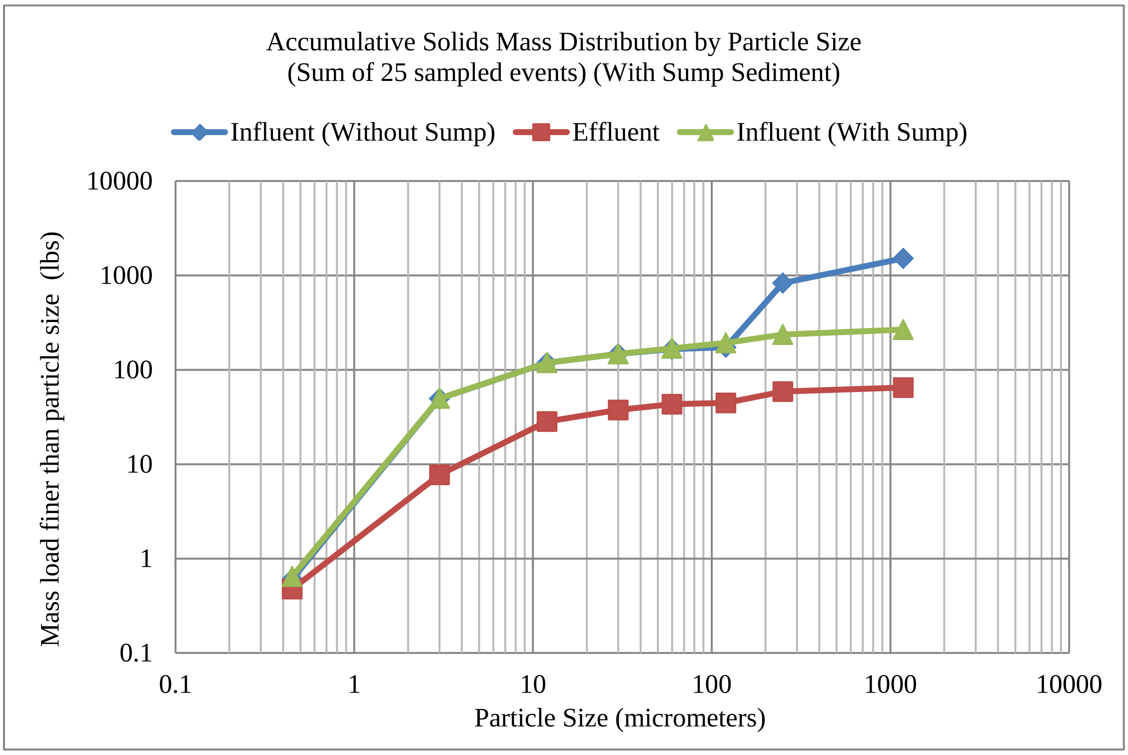


Figure 89: Accumulative Solids Mass Distribution by Particle Size with Sump Sediment (25 Sampled Events)

The results from the current monitoring phase (30 events) were combined with data from the previous initial monitoring (20 events) to obtain the largest amount of data for the most confident verification of the full-scale Up-Flo® Filter. When examining the data set for the sum-of-loads calculations, a total of 41 sampled storm events were used for the final evaluation. Nine of the storm event data had unusual particle size distributions resulting in large biases in the mass balance (4 events from the initial monitoring and 5 events from current monitoring). Table 42 shows the overall accumulative sum-of-loads associated with the 41 sampled events for each of the particle sizes <250 µm based on results from the auto-samplers, and from pro-rated sump data for the particles >250 µm (which the autosamplers cannot effectively collect).

The total sediment measured in the sump was associated with the total rains occurring in the monitoring period. This total amount was pro-rated corresponding to the total rain depth for the sampled rains. Similar pro-rated calculations were also conducted based on runoff amounts, with very similar results. The solids captured for each specific particle range increased as the particle sizes increased. The overall removal rate for the total particulates was about 80%.

Table 42: Accumulative Mass of Influent and Effluent Total Particulates by Particle Size Range for 41 Sampled Storms

Particle Size Range (um)	Influent Total Mass (With Sump) (lbs)	Effluent Total Mass (lbs)	Percent Reduction
0.45 - 3	1.75	1.13	35.55
3 - 12	58.79	11.41	80.59
12 - 30	85.24	26.03	69.47
30 - 60	52.35	16.29	68.88
60 - 120	43.04	11.01	74.42
120 - 250	52.94	1.97	96.27
250 - 1180	120.54	19.49	83.83
> 1180	63.28	6.14	90.30
Total:	477.94	93.47	80.44

Table 43 shows the overall mass balance for the 41 sampled storms, comparing the mass of solids retained in the filter system with the amount calculated to be captured according to the automatic samplers. All the particles retained in the media bags were assumed to be less than 250 µm, and the same portion of the PSD of the sump sediment from 0.45 to 250 µm was used to establish the correlated PSD for solids captured in the media bags. The combined overall mass balance indicated a difference of about 174 lbs between the auto-sampler and sump sediment calculations. This difference was likely due to several issues, including the calculations for the dry bulk density of the sump material that contained appreciable amounts of leaves (about 3.5% by mass, but much by volume). This organic material expanded upon drying and had a very large water sorptive capacity that affected the porosity measurements. The calculated bulk density from the laboratory measurements was only about 0.5 g/cc, which is about half of the value usually seen for catchbasin sump material. If this bulk density was increased to this typical value, the comparisons of removals would be closer. In addition, the differences were mainly associated with the larger removals measured by the autosamplers for particle in the size ranges from 3 to 60 μm. These particles are not adequately retained in catchbasin sumps which would tend to bias the particle size distributions by the different sampling methods and sampling locations.

Table 43: Overall Mass Balance of Filter System Combining Initial and Current Monitoring

Particle Size Range (um)	Prorated Mass in the sump for Sampled Storms (lbs)	Prorated Mass in the filter media for Sampled Storms (lbs) *	Total Prorated Mass Retained in the sump and media bags for Sampled Storms (lbs)	Influent Mass for Sampled Storms (lbs)	Effluent Mass for Sampled Storms (lbs)	Amount retained in UpFlow filter based on Automatic Samplers (plus fraction from sump for >250 um) (lbs)	Difference (sump and bag material minus mass measured by samplers) (lbs)
< 0.45	0.0	0.00	0.0	0.0	0.0	0.0	0.0
0.45 - 3	0.4	0.08	0.4	1.7	1.1	0.6	-0.2
3 - 12	0.8	0.18	1.0	58.8	11.4	47.4	-46.4
12 - 30	1.6	0.36	2.0	85.2	26.0	59.2	-57.2
30 - 60	2.9	0.63	3.5	52.4	16.3	36.1	-32.6
60 - 120	8.6	1.88	10.4	43.0	11.0	32.0	-21.6
120 - 250	20.6	4.52	25.1	52.9	2.0	51.0	-25.9
250 - 1180	117.3	-	117.3	120.5	19.5	101.1	16.2
> 1180	50.6	-	50.6	63.3	6.1	57.1	-6.5
Total:	203	7.65	210.4	478	93	384	-174

* The total mass retained in the media bags during the initial 16 sampled events is unknown

Figures 90 and 91 show the particle size distributions for the accumulative solids percentage and mass for these 41 sampled storm events, incorporating the prorated portion of the sump sediment. The accumulative percentage plot indicates that the overall median particle size of the influent was about 60 µm, while the median particle size for the effluent was about 20 µm, These distributions indicate a possible under-reporting of influent particulates in the 30 to 250 µm size range, which is consistent with the mass balance observations for these sizes.

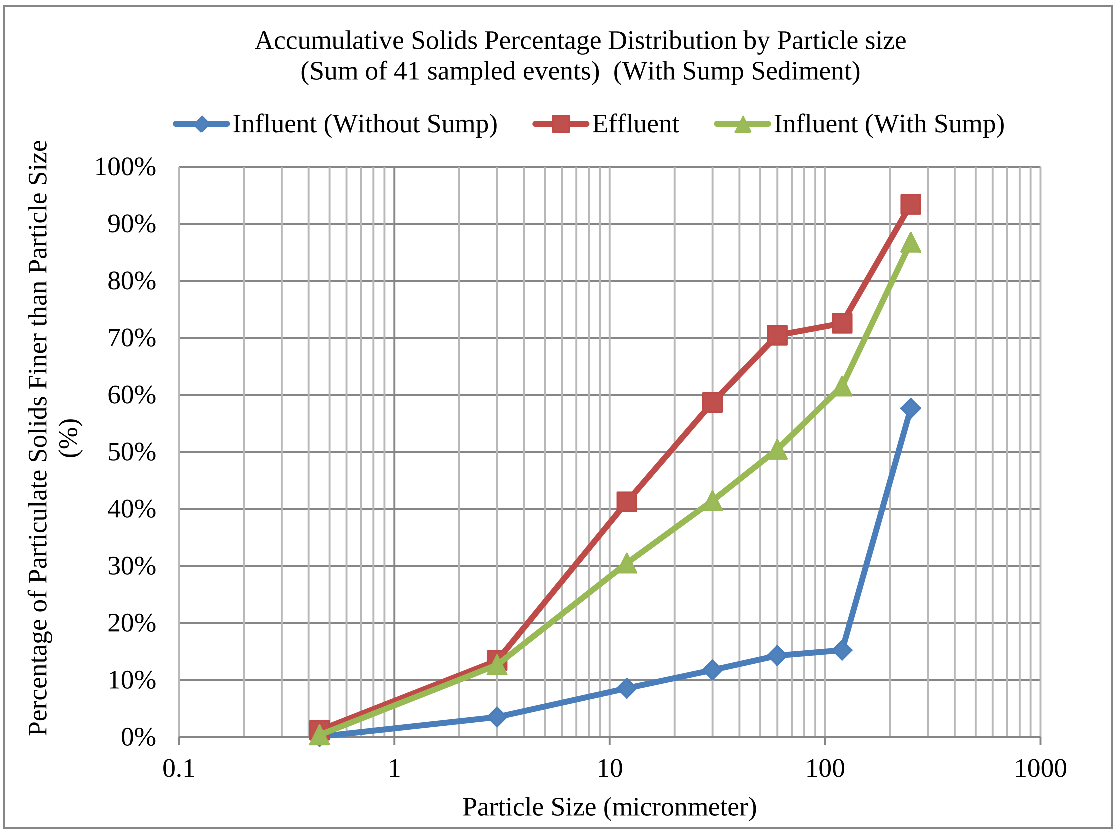


Figure 90: Accumulative Solids Percentage Distribution by Particle Size with Sump Sediment (41 Sampled Events)

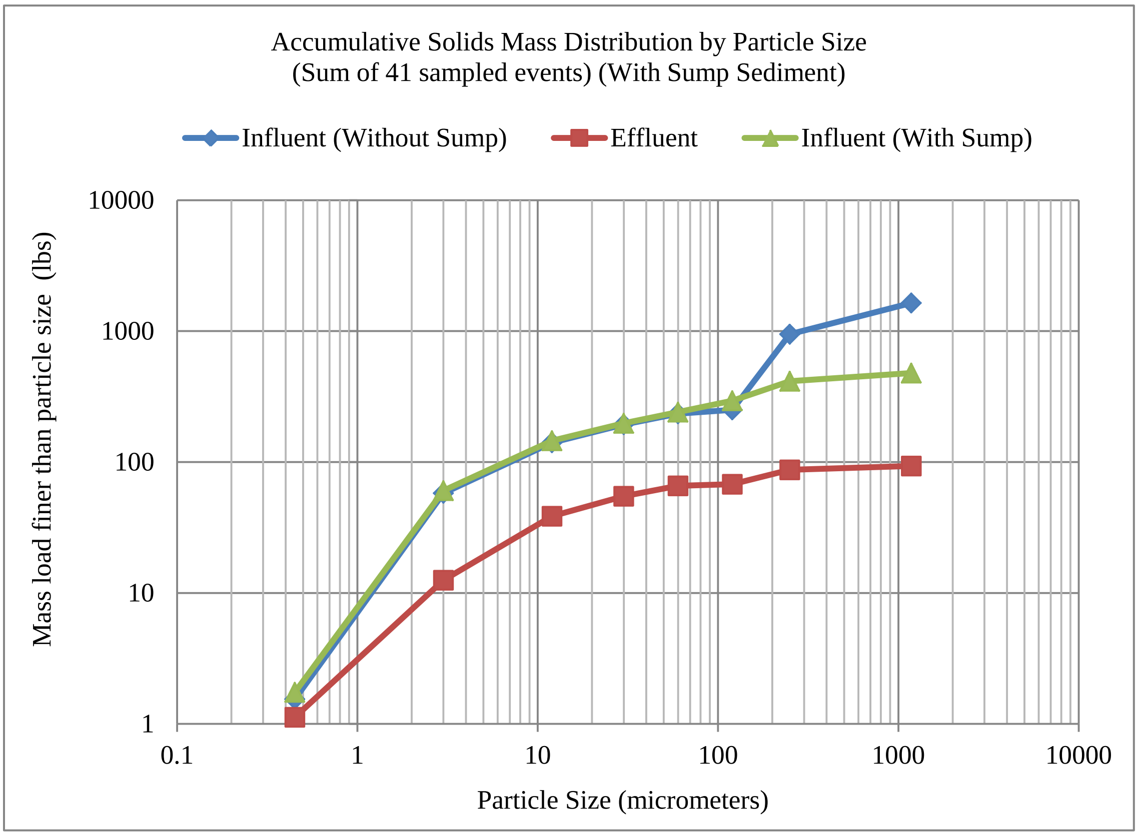


Figure 91: Accumulative Solids Mass Distribution by Particle Size with Sump Sediment (41 Sampled Events)

CHAPTER 6

CONCLUSIONS, FINDINGS AND RECOMMANDATIONS

6.1. Conclusions

The field performance verification of the full-scale Up-Flo® Filter at the Bama Belle parking area, Tuscaloosa, AL, was completed at the end of March, 2013. The overall performance through this final one-year monitoring period, including hydraulic capability, water quality treatability, and maintenance requirements, is summarized below:

1. During the varying rains of the monitoring period, the full scale Up-Flo® Filter consistently had very high treatment flow rates, until January of 2013 when there was a major decrease in the flow rate before bypassing started. During this one year period, a total of about 49 inches of rainfall and almost one million gallons of runoff were monitored for flows and rainfall (but not all was sampled for water quality analyses). About 74% of the total flow was completely treated with no bypass, while the remaining flow portion received partial treatment. About 50% of the total flow during intense rains having peak 5-min rainfall intensities of about 5 in/hr were fully treated. For the first seven months of the monitoring period, the design hydraulic capacity (treatment flow rate) was about 150 GPM, as expected. There were large variations and slight degradations of treatment flow rates over time. For the first seven months of operation before January 13, 2013 (after about 34.5 inches of total rain and 658,000 gallons of total runoff), significant

degradation in the treatment flow rate occurred (the maximum flow before the bypass was initiated), dropping from about 150 GPM to about 30 to 50 GPM which was consistently held through the end of the monitoring period at the end of March 2013, with no further degradation in flow capacity. The amount of bypass increased greatly during this time, with more partially treated water mixed with less fully treated water, degrading overall treatment performance. The monitoring continued after this treatment flow rate decrease to verify operation after needed maintenance. The performance was noted to decrease, but complete failure did not occur.

2. The water quality treatment performance of the full scale Up-Flo® Filter was verified by monitoring under a typical application during actual rains. These tests confirmed the measured removals during the earlier tests. The Up-Flo® Filter was found to have very good to excellent removals for particulate solids, good to very good removals for heavy metals, moderate removals for bacteria, and low to moderate removals for nutrients. TSS and SSC had about 89% and 98% mass reductions (by flow-weighted) during the 30 sampled storms. Statistically significant removals were found for TDS, VSS, and turbidity and many other constituents, while dissolved heavy metals and some of the nutrients had too few detectable concentrations to detect significant differences based on the number of storms monitored. Removals for each particle size range were statistically significant, with very high removals for the large particles (approaching 100%) and lower removals for the smallest particles.

    Significant removals were identified for both total and dissolved nitrogen and total and dissolved phosphorus, but not for nitrates or for orthophosphates. When considering the additional storm data analyses from previous monitoring phases, the overall removal performance for these pollutants was improved, with added confidence. The mass balance verification calculations containing the sump sediment portion also demonstrated the treatability for solids constituents.

6.2. Findings and Recommendations

Observations and findings during the field work and laboratory analyses resulted in several important findings and recommendations, as summarized below:

1. Glass-fiber filters, compared to membrane filters, for TSS and SSC analyses resulted in more consistent results with higher yields. Membrane filters, having nominal pore size sizes of about 0.45 µm, were also found to have unstable mass balance results during different drying periods at 103 to105 ˚C, resulting in some negative mass changes, which affected the method detection limit. The maximum operating temperature for membrane filters is reported as 75 ˚C (variable for different manufacturers), but that seems to be rarely considered. The use of glass fiber filers result in more consistent results and are therefore preferred.
    a. Parallel lab studies during this time also found that the stir plate and pipetting method for TSS subsampling resulted in higher recoveries of the particulates compared to "shake and pour" TSS subsampling methods.
    b. The use of the SSC cone splitter method was also preferred compared to a churn splitter.
2. The location of the sampler intake in the flow stream was also found to have a

significant effect on the measured influent solids measurements. This is especially true when nearby erosion sources unevenly affect the flow stream. Completely mixed flows are preferred to be sampled, but may not be possible in all cases. During the field observations, most of settleable (heavy) sediments accumulated preferentially at specific locations. If the sampler intake was near these areas, the amount of larger particles in the sample did not represent full flow conditions. For this reason, this research found that using the bedload measurements for the large sediment was more representative.

The stormwater samples taken using auto-samplers are expected to represent actual runoff conditions. If the sampler intake was placed where bedload accumulated, the influent sample may not be representative of the total flow. Therefore, the mass balance calculations, as discussed in Section 5.7, use the prorated large particle portions from the sump sediment analyses, instead of using the portions from automatic samplers for the largest particles to minimize the performance calculation errors.

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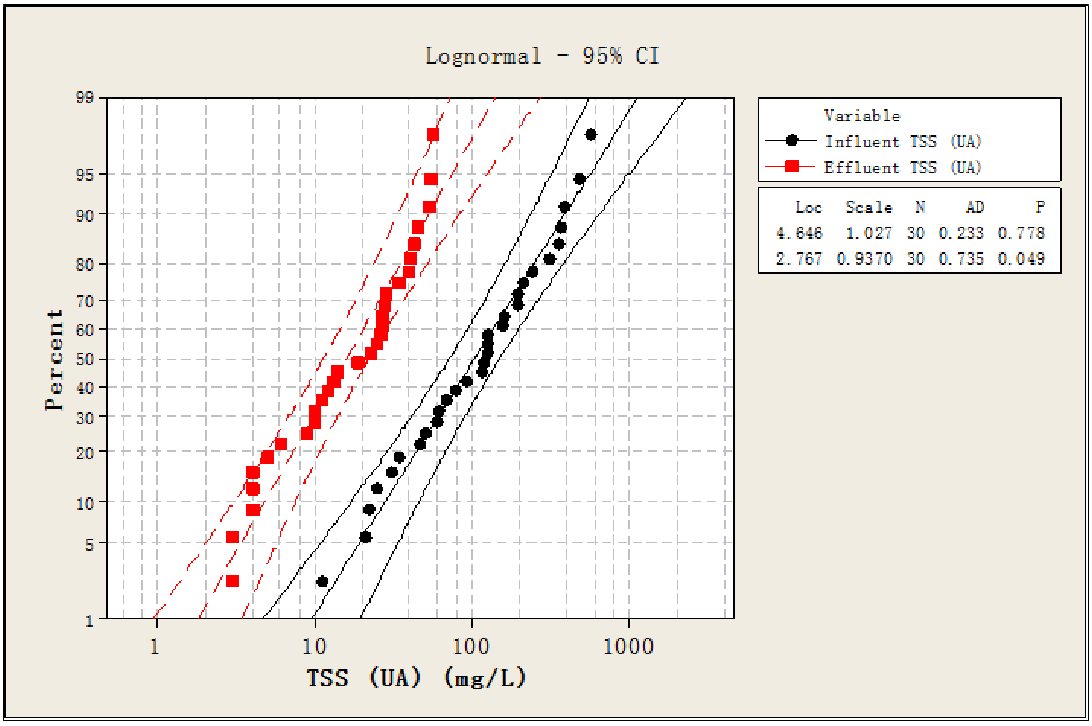
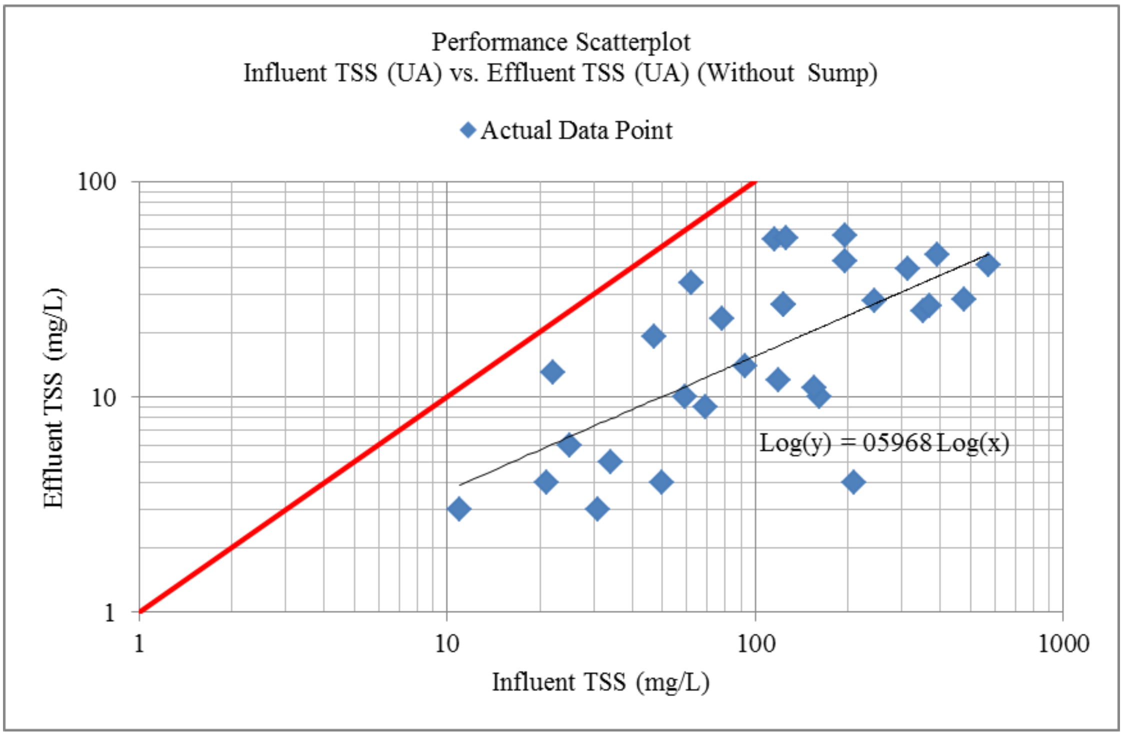
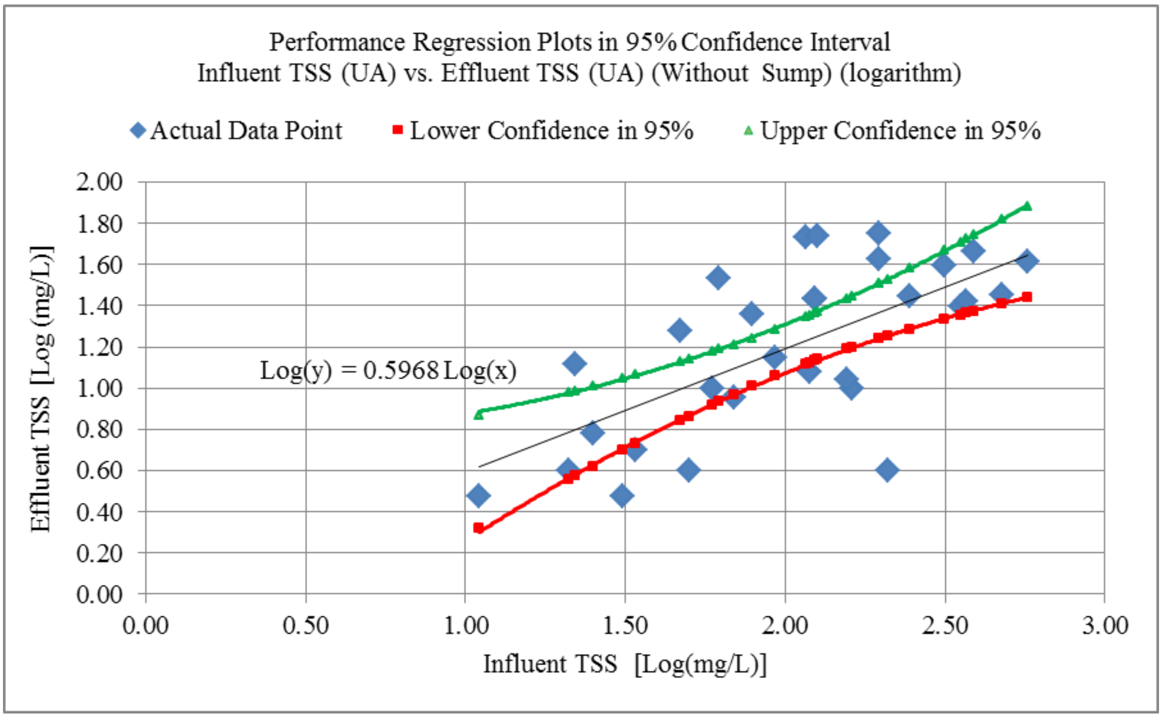
APPENDICES

Appendix A.1: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for TSS (30 Sampled Storms)







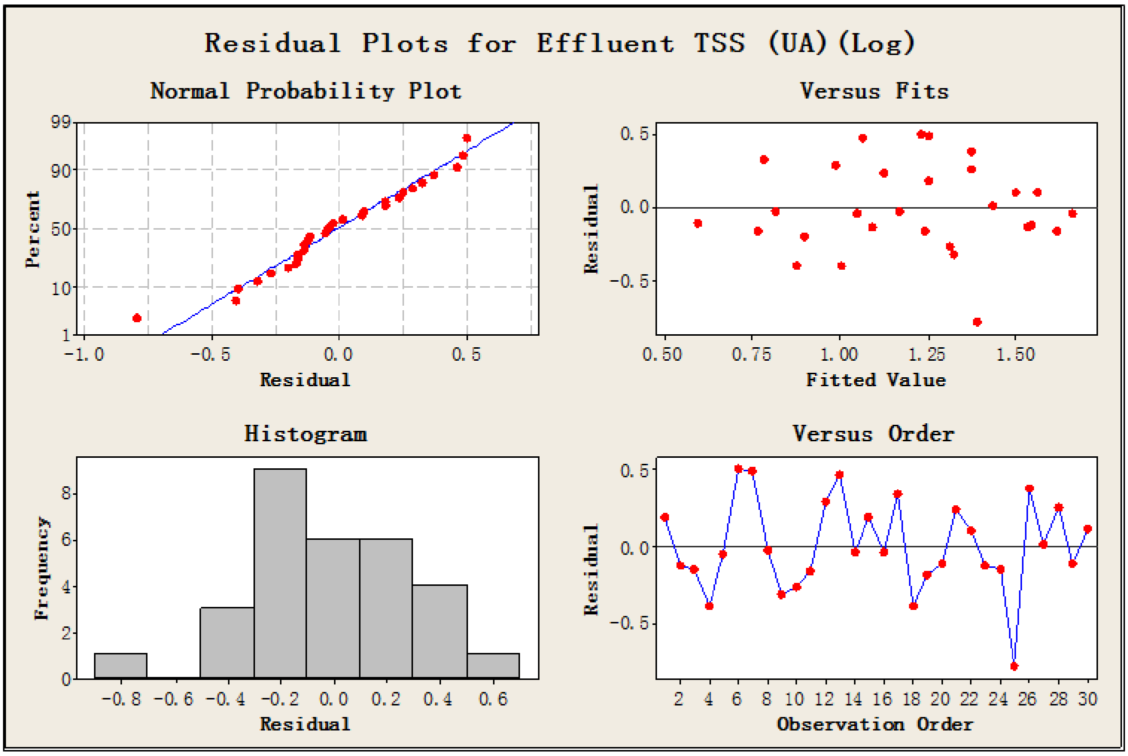
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97
R Square	0.95
Adjusted R Square	0.91
Standard Error	0.30
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	45.56	45.56	515.13	0.0000
Residual	29.00	2.56	0.09		
Total	30.00	48.13			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.5968	0.03	22.70	0.0000	0.54	0.65	0.54	0.65



Wilcoxon Signed Rank Test

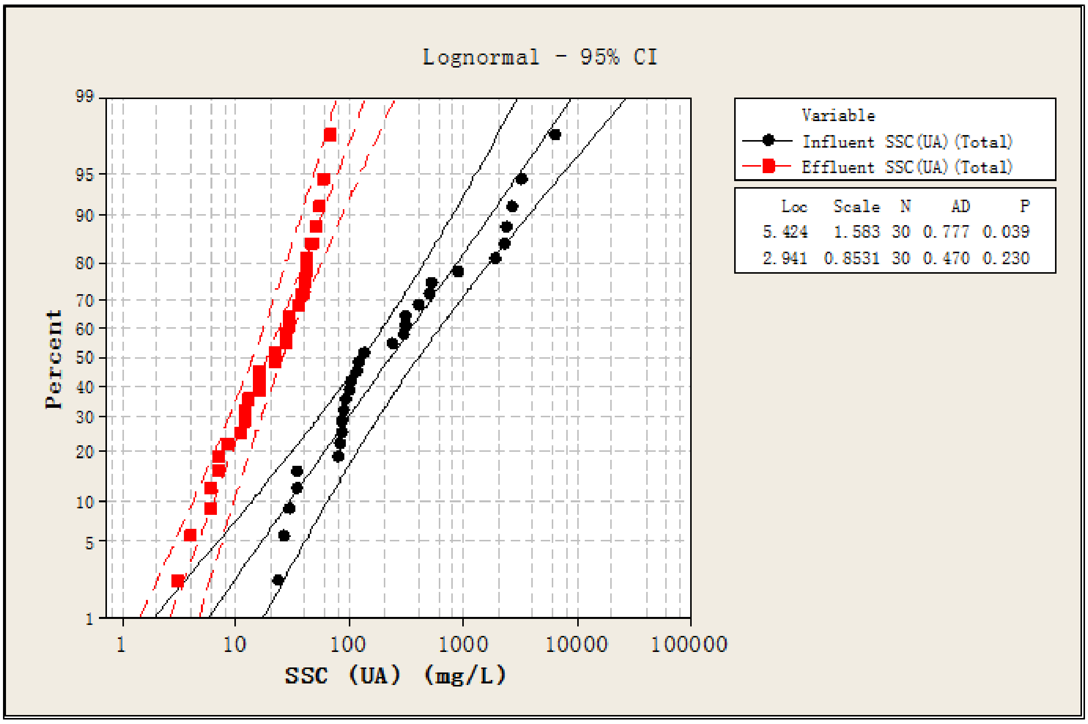
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

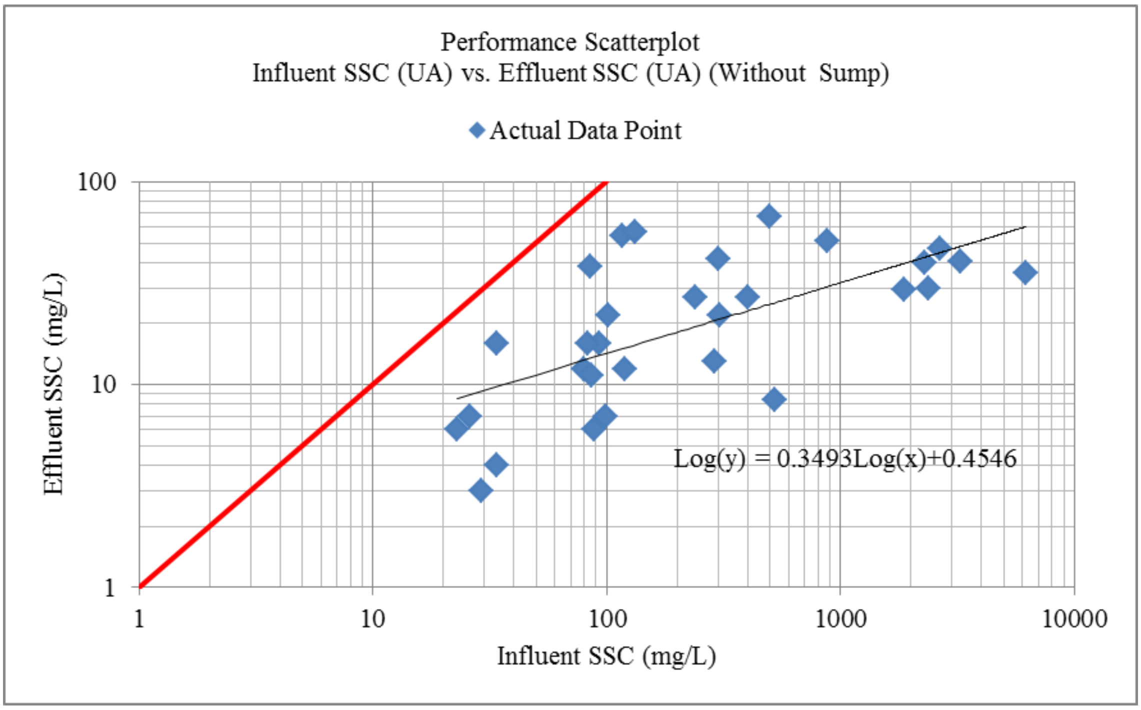
Group	N	Missing	Median	0.25	0.75
Influent TSS	30.00	0.00	121.50	49.25	218.75
Effluent TSS	30.00	0.00	21.00	8.25	35.38

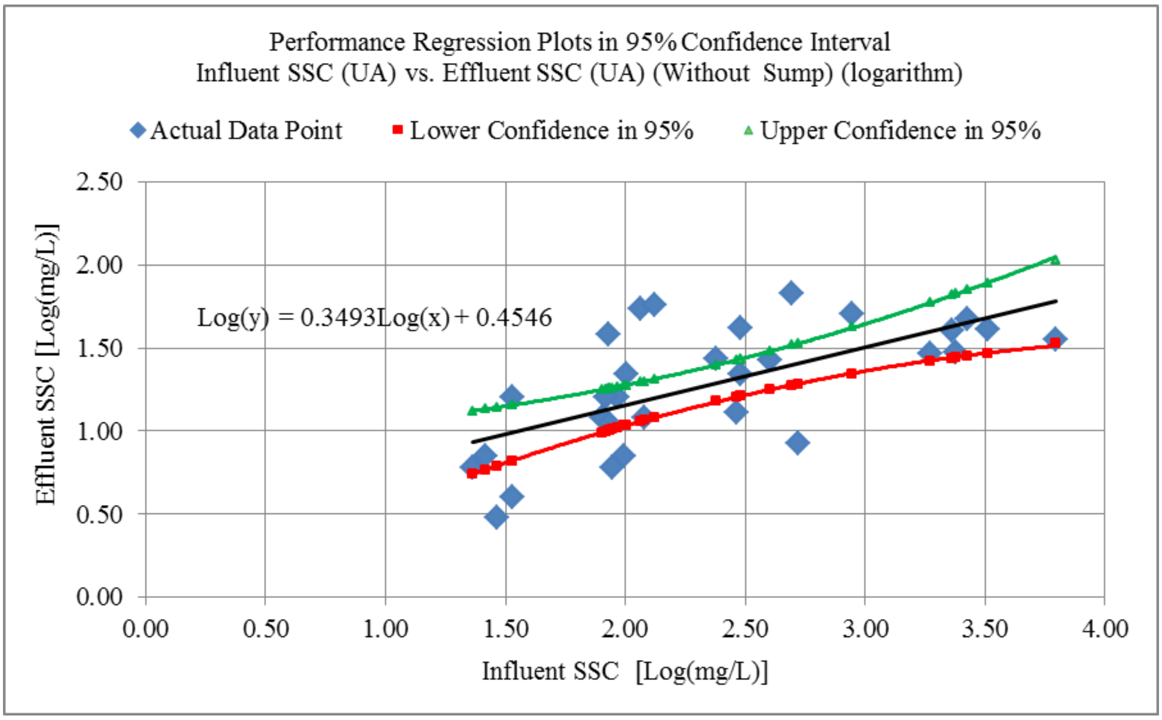
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.783
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.2: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for SSC (30 Sampled Storms)







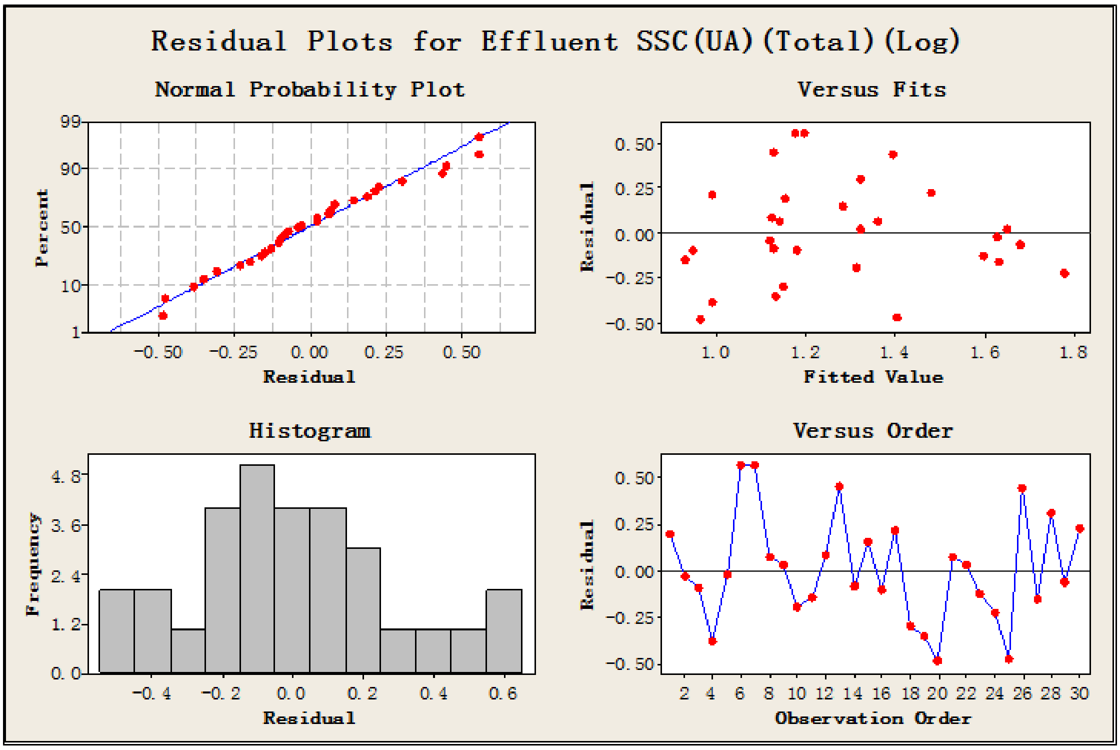
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.65
R Square	0.42
Adjusted R Square	0.40
Standard Error	0.29
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.67	1.67	20.28	0.00
Residual	28.00	2.31	0.08		
Total	29.00	3.98			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.45	0.19	2.39	0.02	0.07	0.84	0.07	0.84
X Variable 1	0.35	0.08	4.50	0.00	0.19	0.51	0.19	0.51



Wilcoxon Signed Rank Test

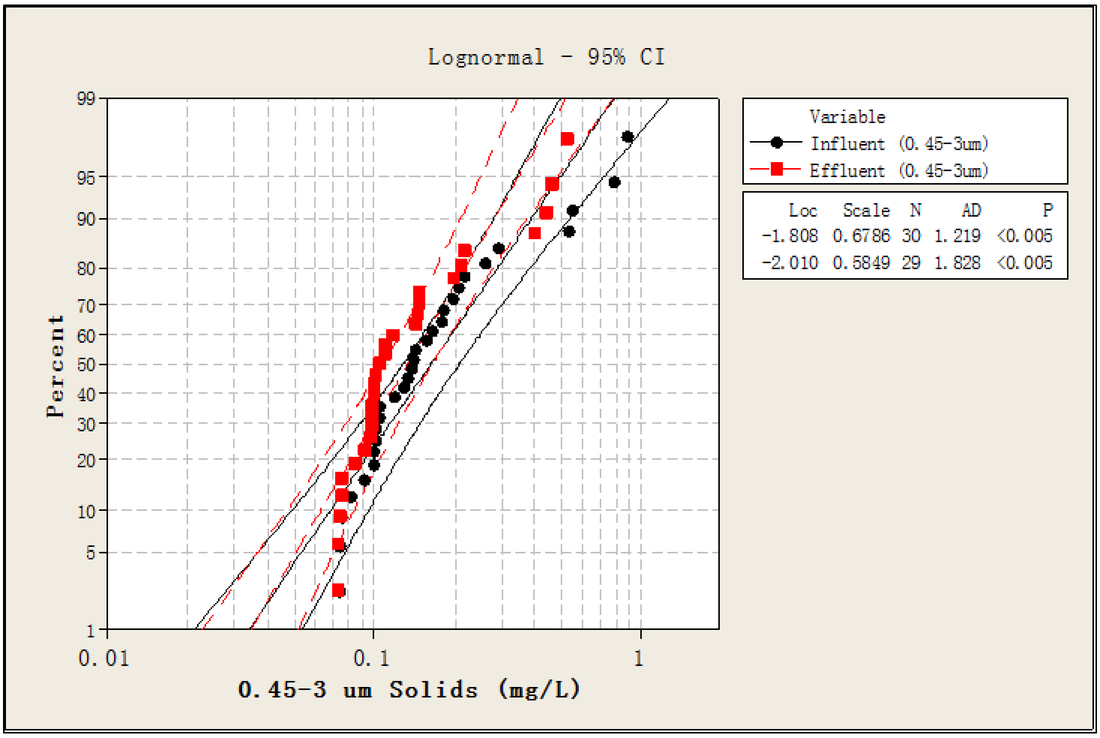
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

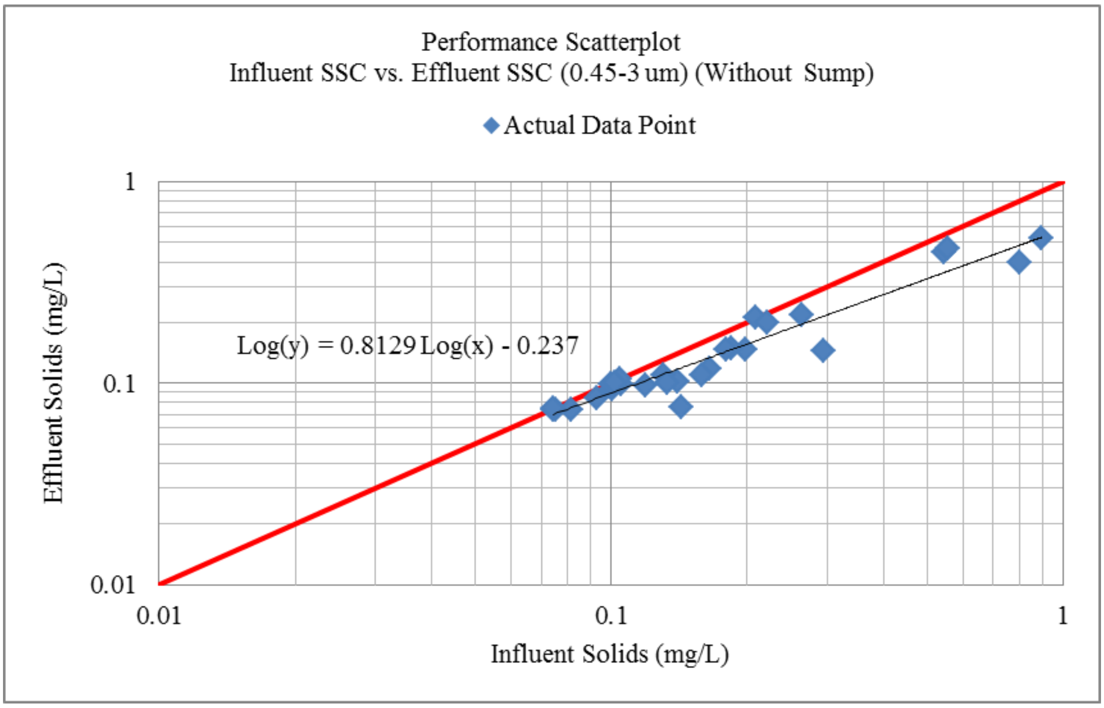
Group	N	Missing	Median	0.25	0.75
Influent SSC UA	30.00	0.00	126.50	84.50	612.33
Effluent SSC UA	30.00	0.00	22.00	10.35	40.19

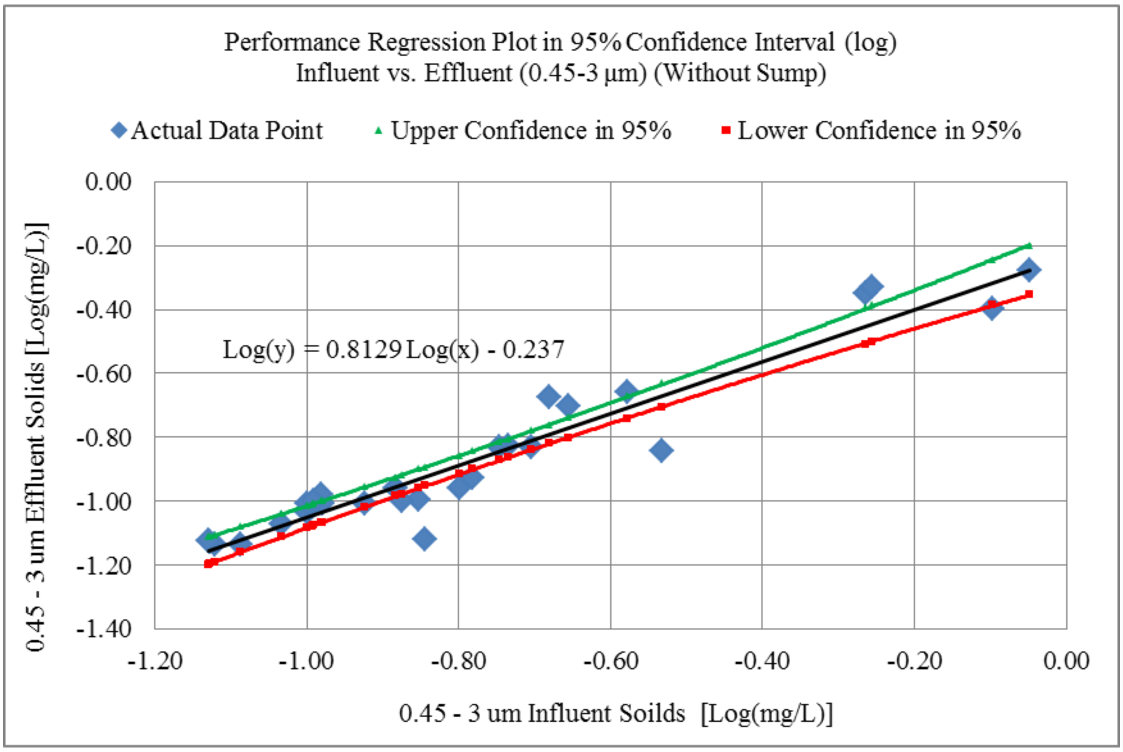
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.782
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.3: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 0.45-3 µm Solids (30 Sampled Storms)







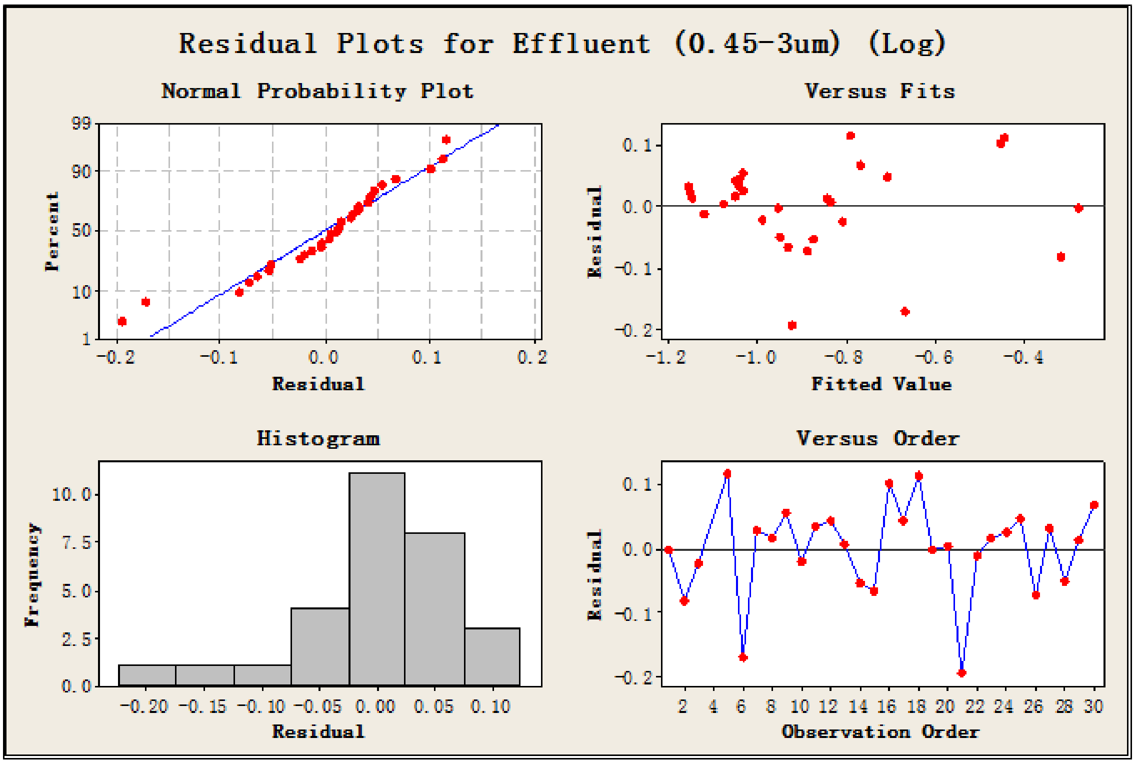
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.96
R Square	0.92
Adjusted R Square	0.92
Standard Error	0.07
Observations	29.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.66	1.66	306.58	0.00
Residual	27.00	0.15	0.01		
Total	28.00	1.81			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.24	0.04	-6.11	0.00	-0.32	-0.16	-0.32	-0.16
X Variable 1	0.81	0.05	17.51	0.00	0.72	0.91	0.72	0.91

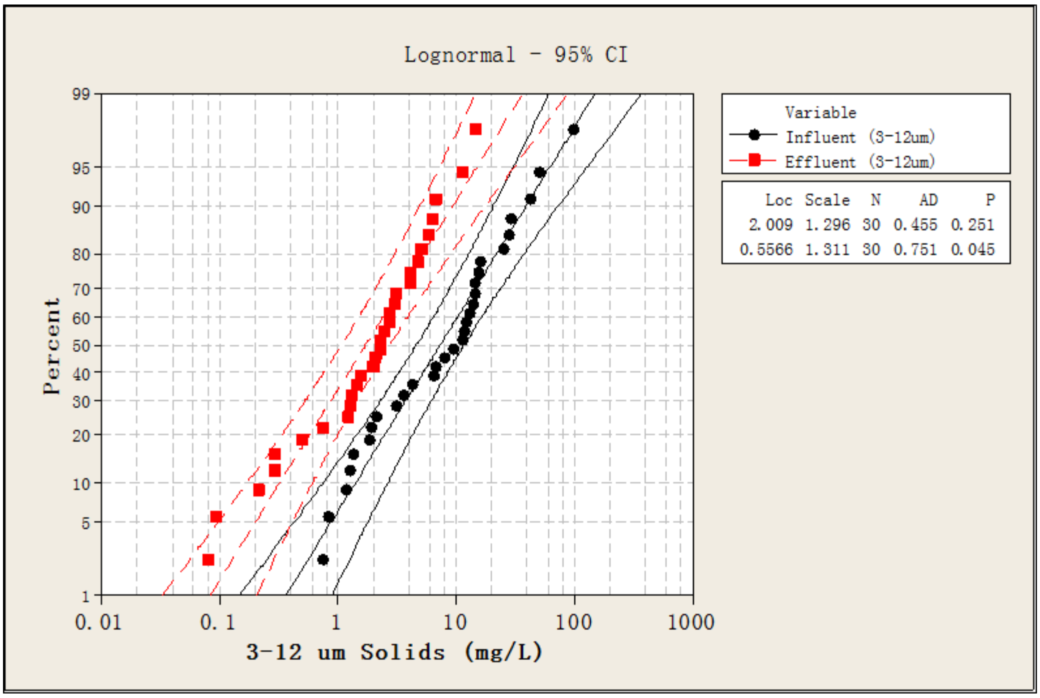


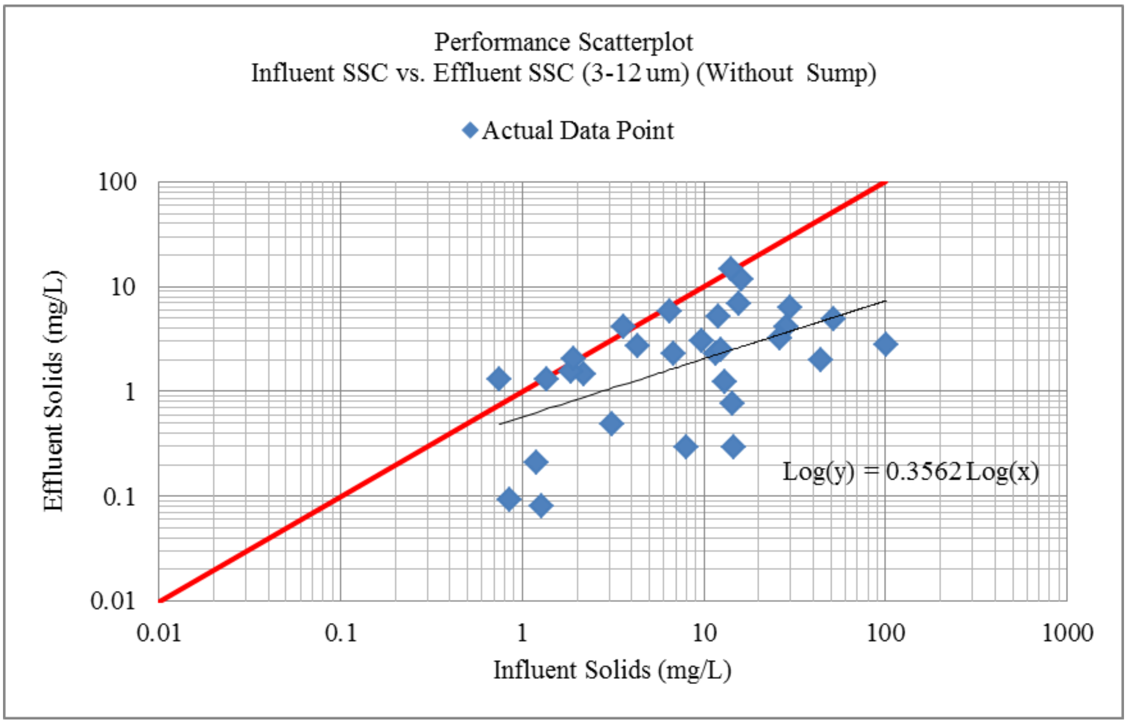
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent 0.45-3um	30.00	0.00	0.14	0.10	0.21
Effluent 0.45-3um	30.00	0.00	0.10	0.09	0.16

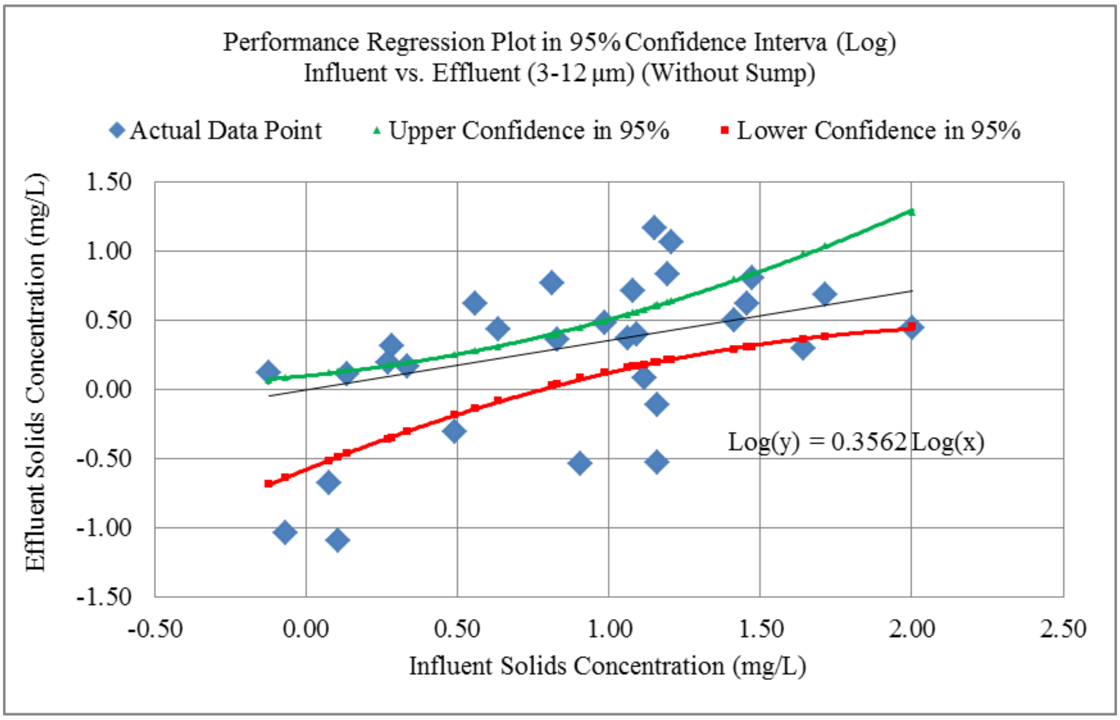
W= -441.000 T+ = 12.000 T-= -453.000
Z-Statistic (based on positive ranks) = -4.535
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.4: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 3-12 µm Solids (30 Sampled Storms)







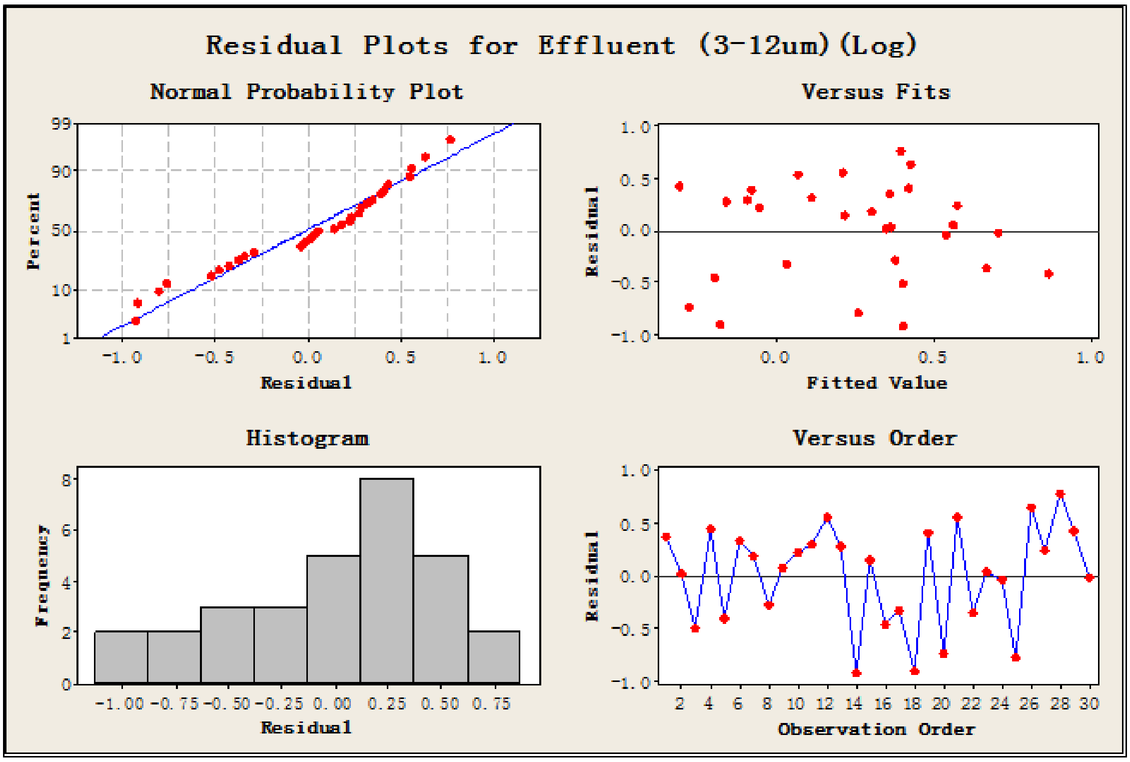
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.60
R Square	0.36
Adjusted R Square	0.33
Standard Error	0.49
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	4.06	4.06	16.62	0.00
Residual	29.00	7.09	0.24		
Total	30.00	11.15			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.36	0.09	4.08	0.00	0.18	0.53	0.18	0.53



Wilcoxon Signed Rank Test

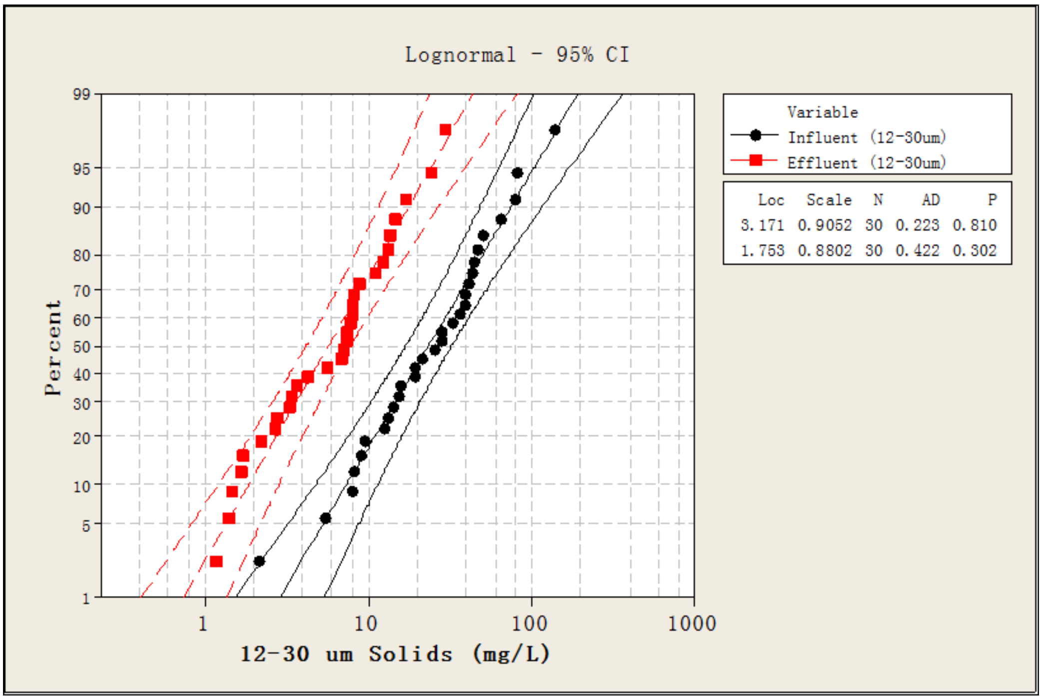
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

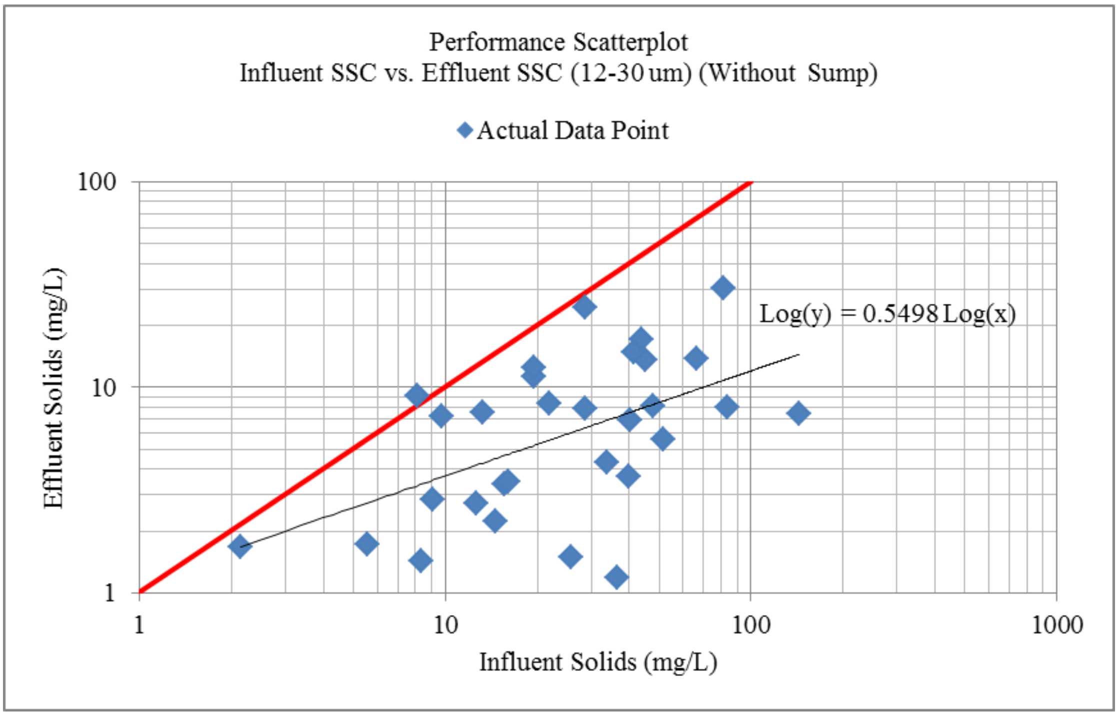
Group	N	Missing	Median	0.25	0.75
Influent 3-12um	30.00	0.00	10.65	2.11	15.78
Effluent 3-12um	30.00	0.00	2.30	1.11	4.34

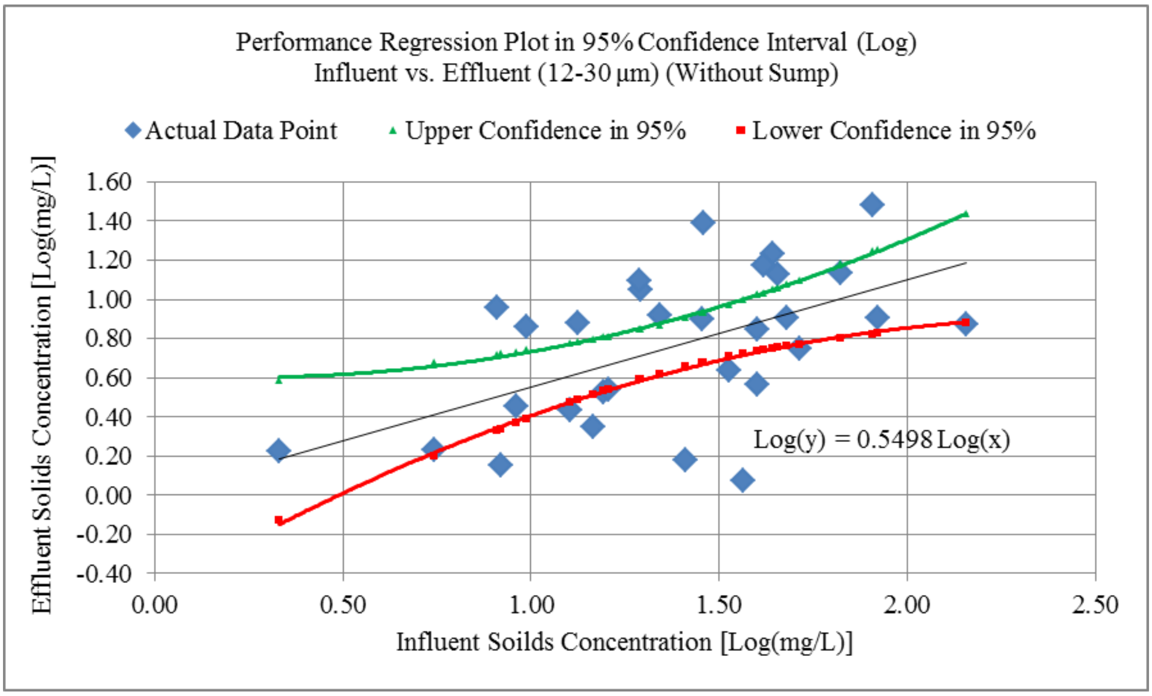
W= -431.000 T+ = 17.000 T-= -448.000
Z-Statistic (based on positive ranks) = -4.432
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.5: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 12-30 µm Solids (30 Sampled Storms)







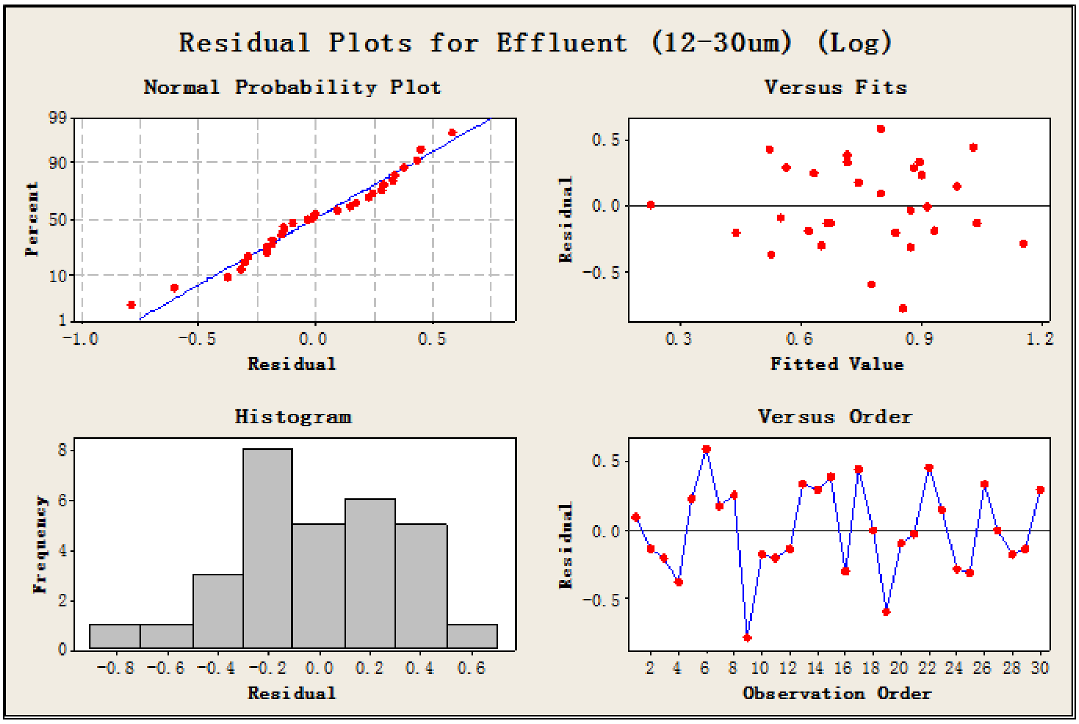
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.93
R Square	0.86
Adjusted R Square	0.82
Standard Error	0.33
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1.00	18.55	18.55	175.20	0.00
Residual	29.00	3.07	0.11		
Total	30.00	21.62			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.55	0.04	13.24	0.00	0.46	0.63	0.46	0.63



Wilcoxon Signed Rank Test

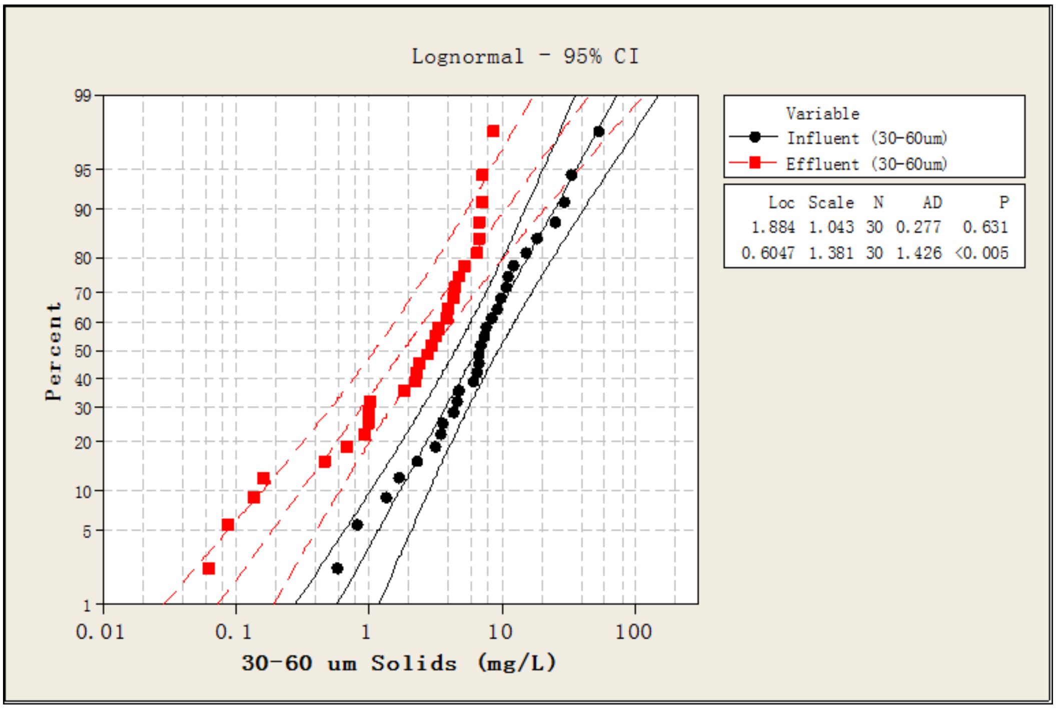
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

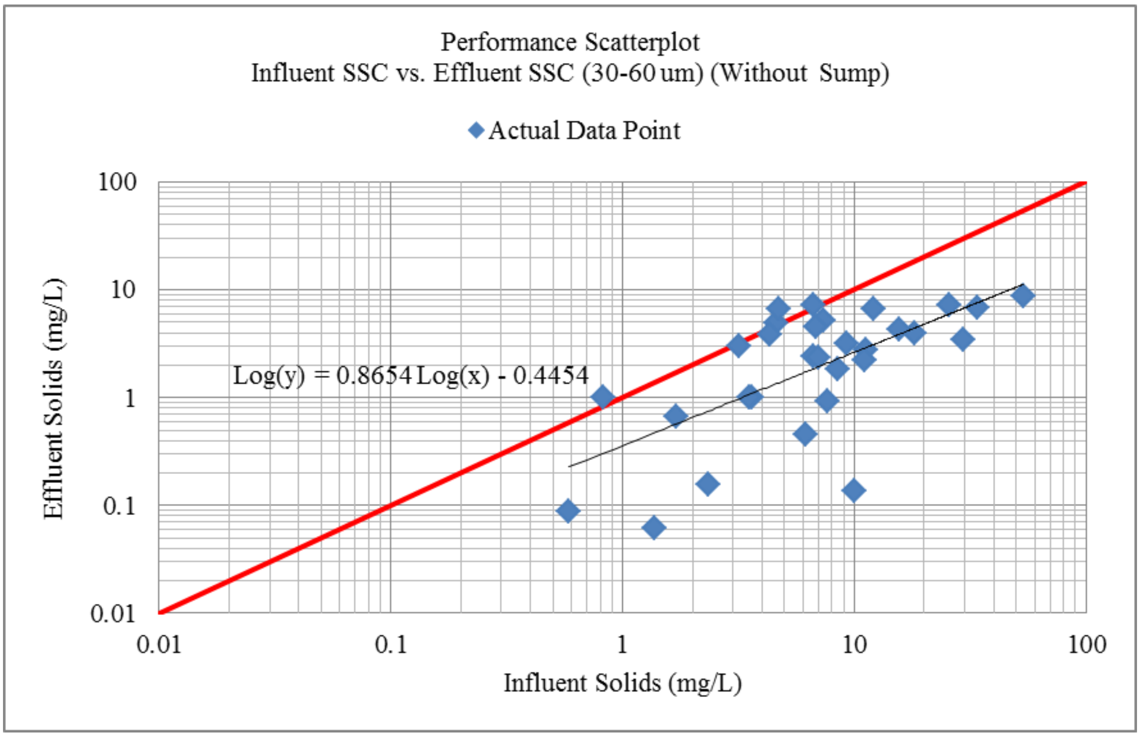
Group	N	Missing	Median	0.25	0.75
Influent 12-30um	30.00	0.00	27.16	13.14	44.17
Effluent 12-30um	30.00	0.00	7.34	2.80	11.57

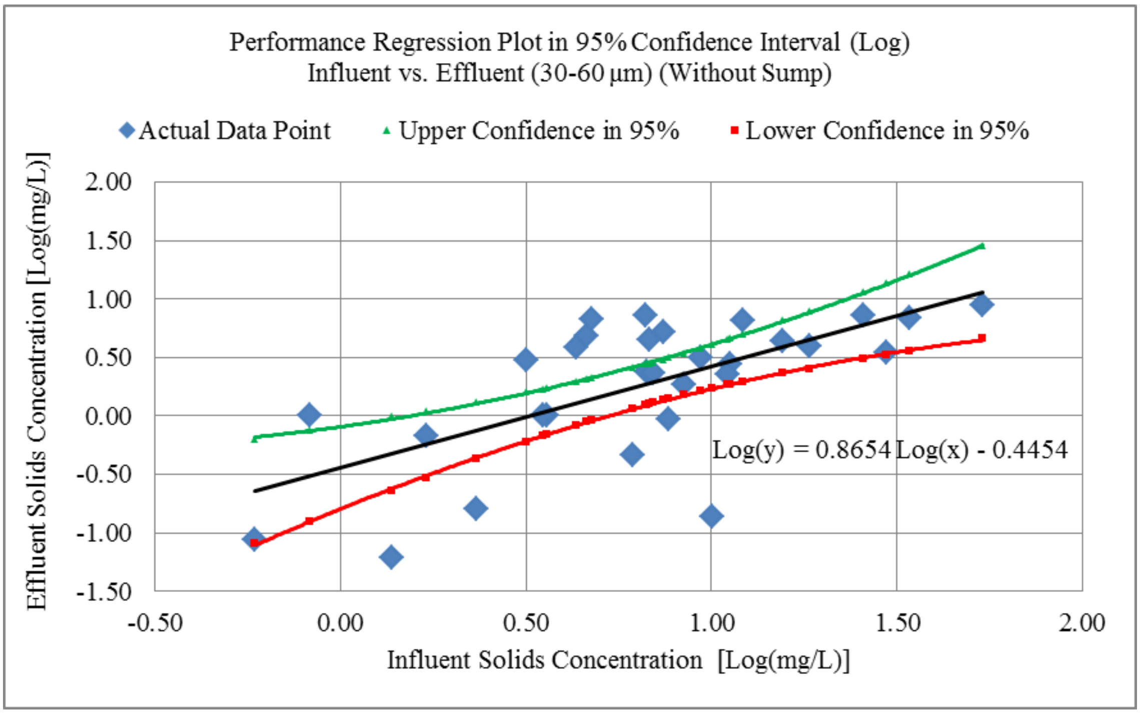
W= -461.000 T+ = 2.000 T-= -463.000
Z-Statistic (based on positive ranks) = -4.741
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.6: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 30-60 µm Solids (30 Sampled Storms)







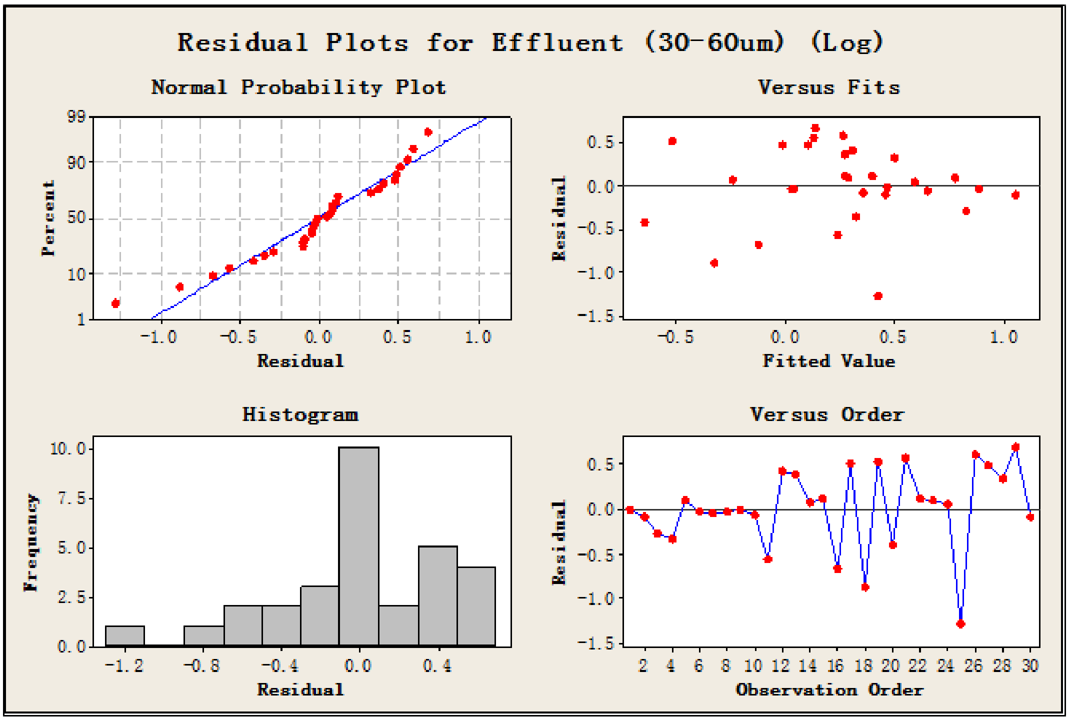
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.65
R Square	0.43
Adjusted R Square	0.41
Standard Error	0.46
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	4.46	4.46	20.90	0.00
Residual	28.00	5.97	0.21		
Total	29.00	10.43			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.45	0.18	-2.53	0.02	-0.81	-0.08	-0.81	-0.08
X Variable 1	0.87	0.19	4.57	0.00	0.48	1.25	0.48	1.25



Wilcoxon Signed Rank Test

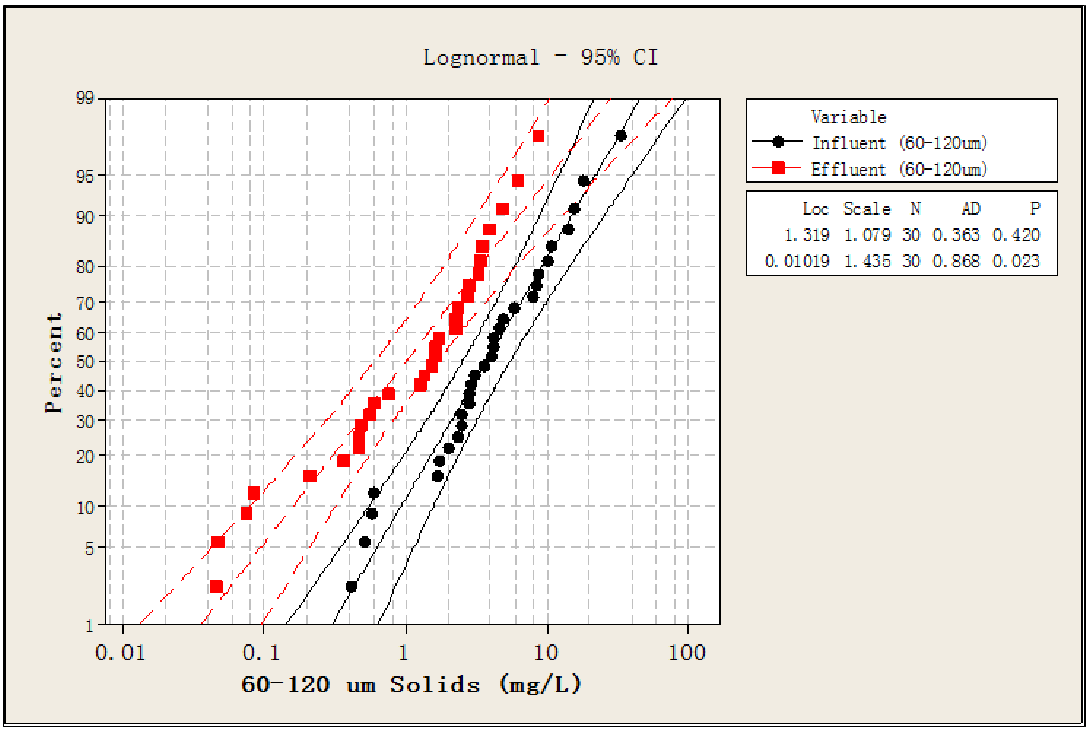
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

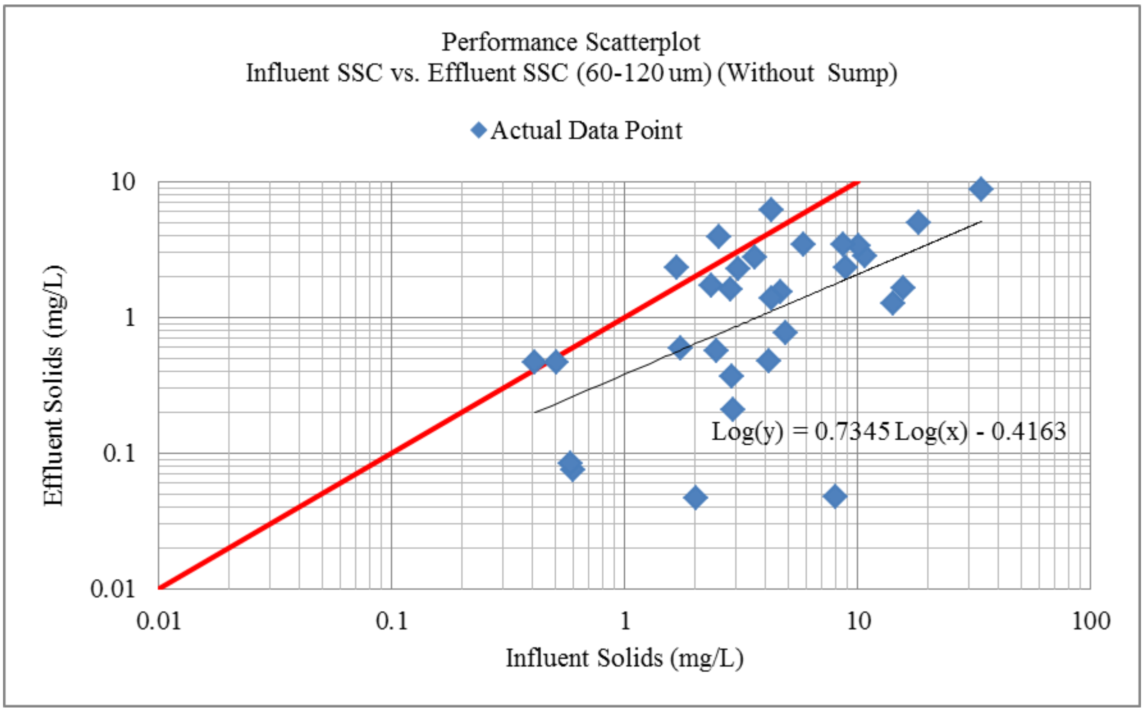
Group	N	Missing	Median	0.25	0.75
Influent 30-60um	30.00	0.00	6.88	3.58	11.49
Effluent 30-60um	30.00	0.00	2.91	0.98	4.95

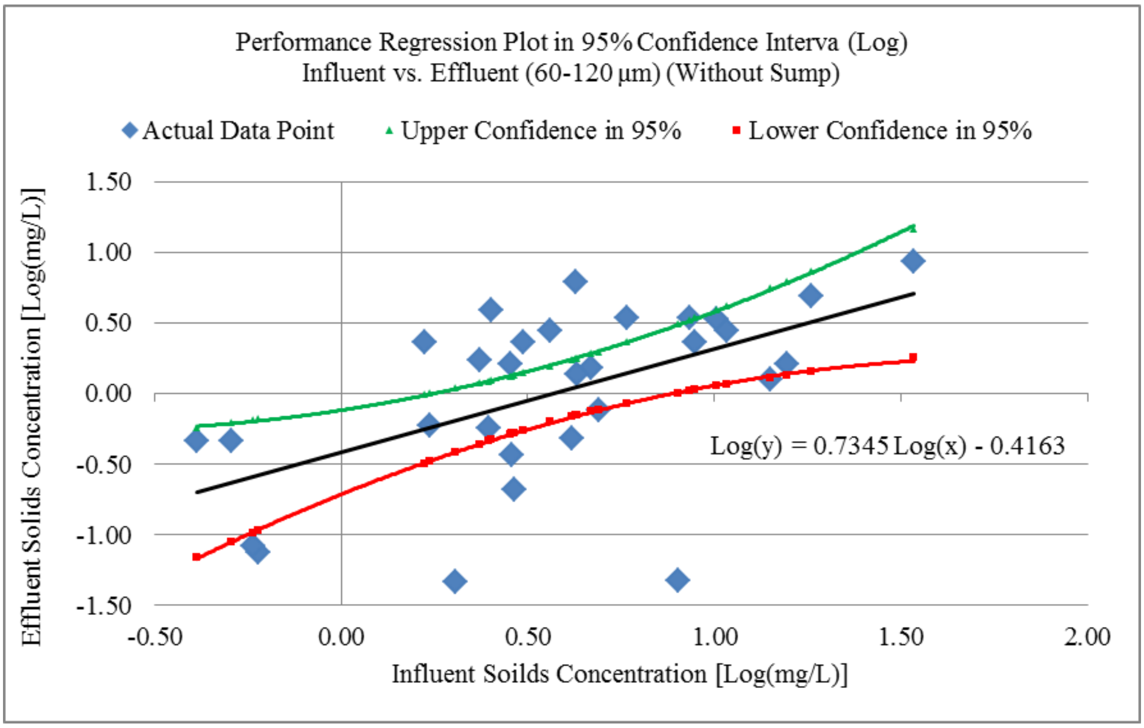
W= -425.000 T+ = 20.000 T-= -445.000
Z-Statistic (based on positive ranks) = -4.371
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.7: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 60-120 µm Solids (30 Sampled Storms)







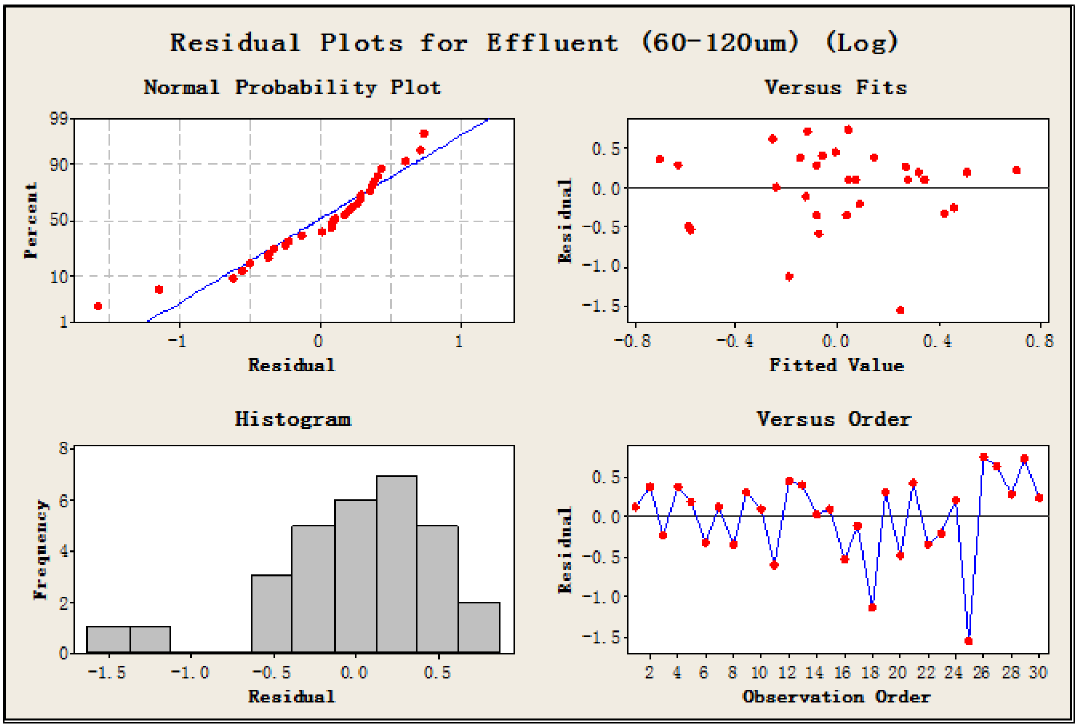
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.55
R Square	0.31
Adjusted R Square	0.28
Standard Error	0.53
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1.00	3.44	3.44	12.29	0.00
Residual	28.00	7.83	0.28		
Total	29.00	11.26			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.42	0.15	-2.70	0.01	-0.73	-0.10	-0.73	-0.10
X Variable 1	0.73	0.21	3.51	0.00	0.31	1.16	0.31	1.16



Wilcoxon Signed Rank Test

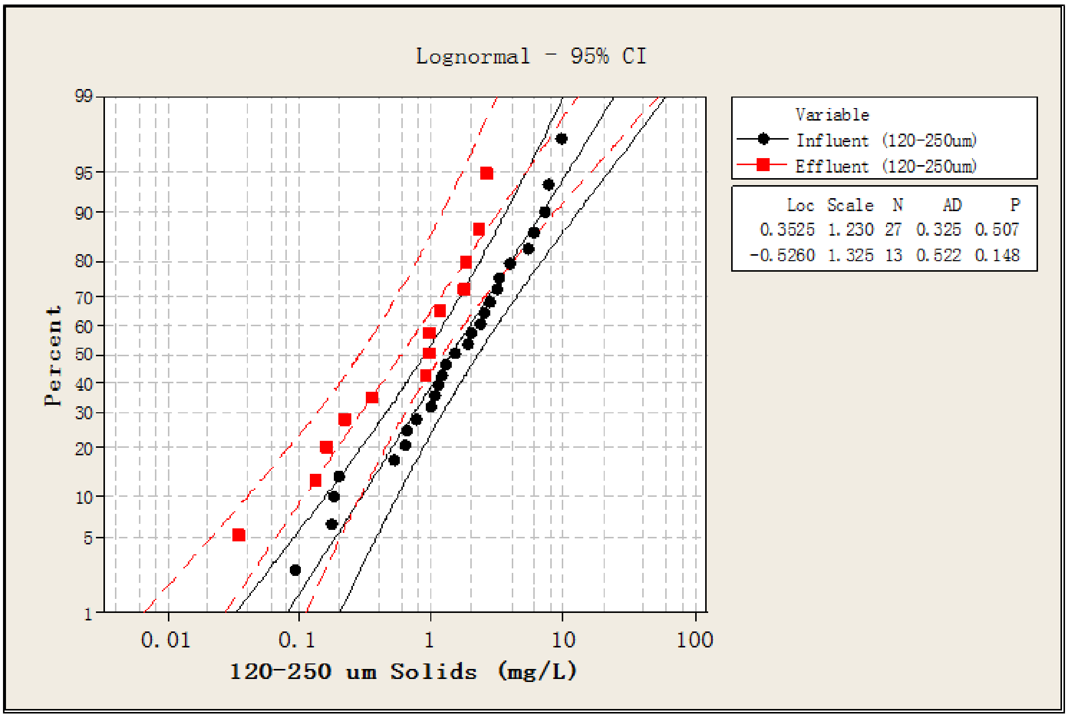
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

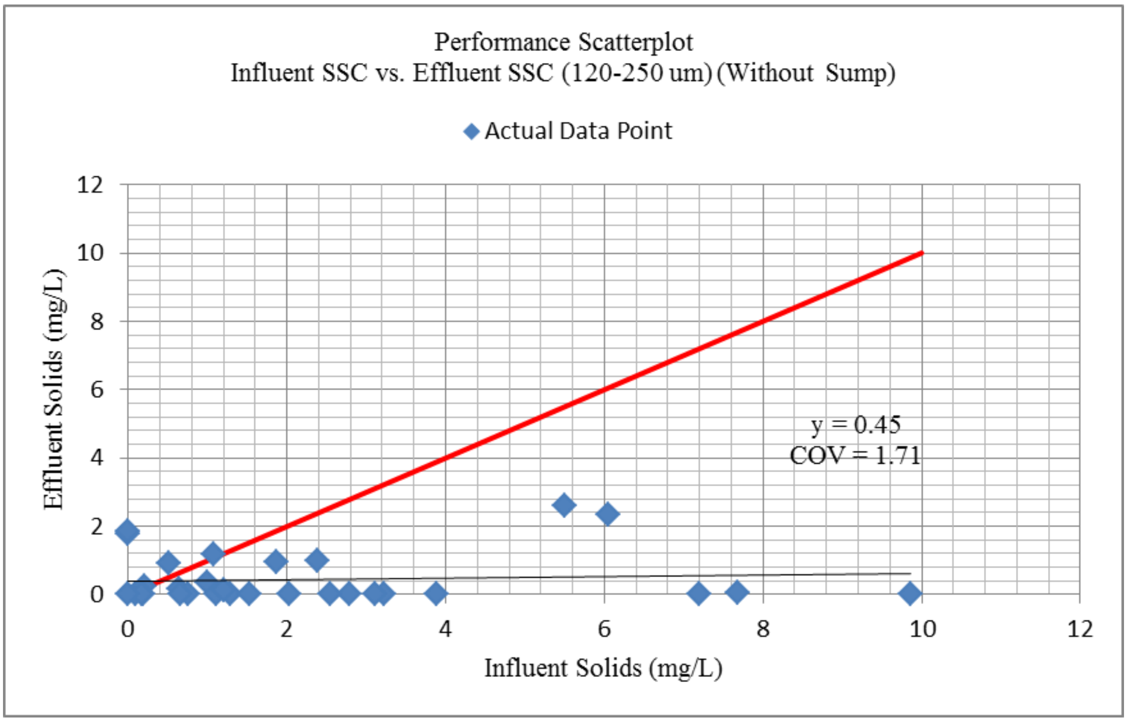
Group	N	Missing	Median	0.25	0.75
Influent 60-120um	30.00	0.00	3.89	2.27	8.68
Effluent 60-120um	30.00	0.00	1.58	0.47	2.95

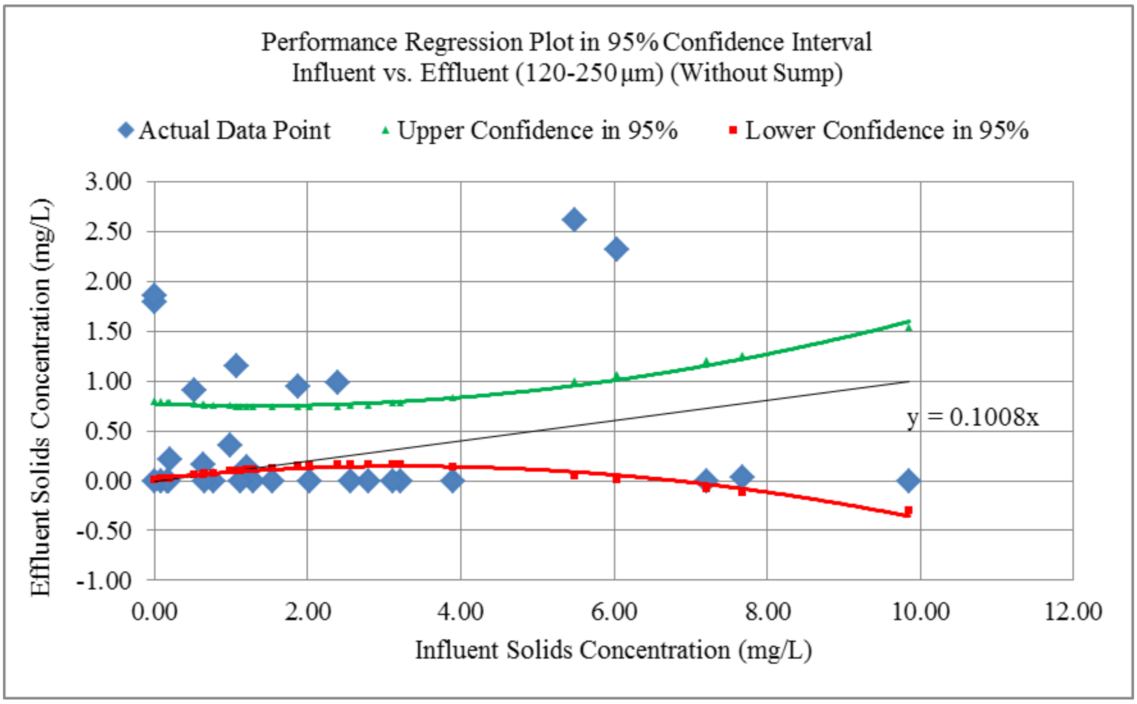
W= -401.000 T+ = 32.000 T-= -433.000
Z-Statistic (based on positive ranks) = -4.124
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.8: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 120-250 µm Solids (30 Sampled Storms)







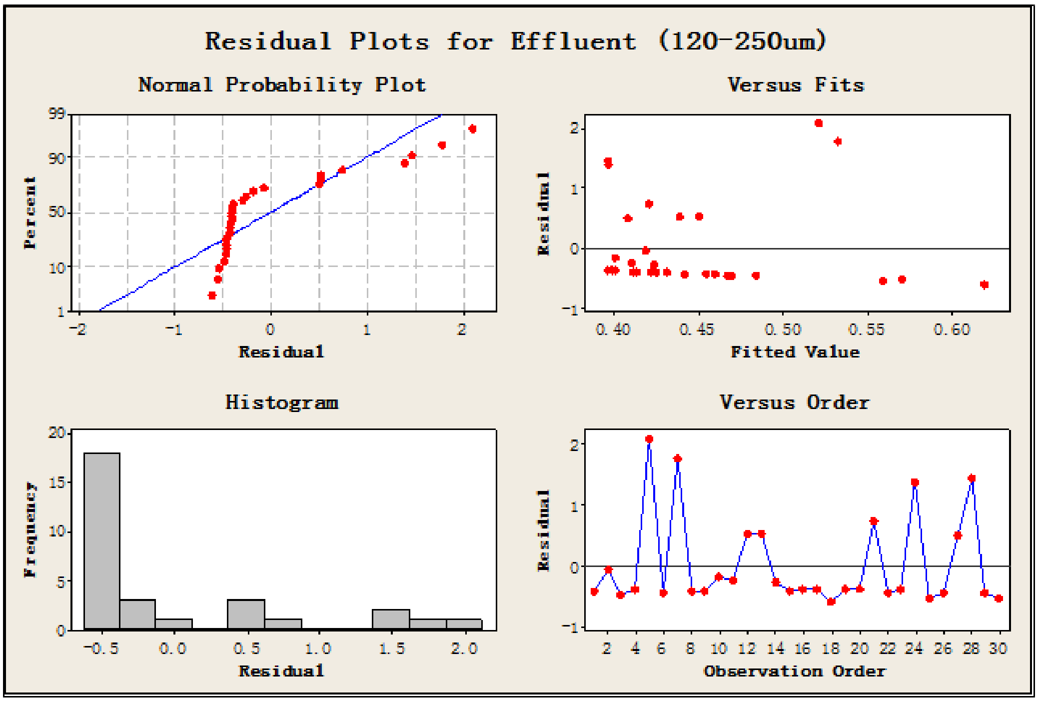
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.39
R Square	0.15
Adjusted R Square	0.12
Standard Error	0.82
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	3.54	3.54	5.25	0.03
Residual	29.00	19.52	0.67		
Total	30.00	23.06			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.10	0.04	2.29	0.03	0.01	0.19	0.01	0.19

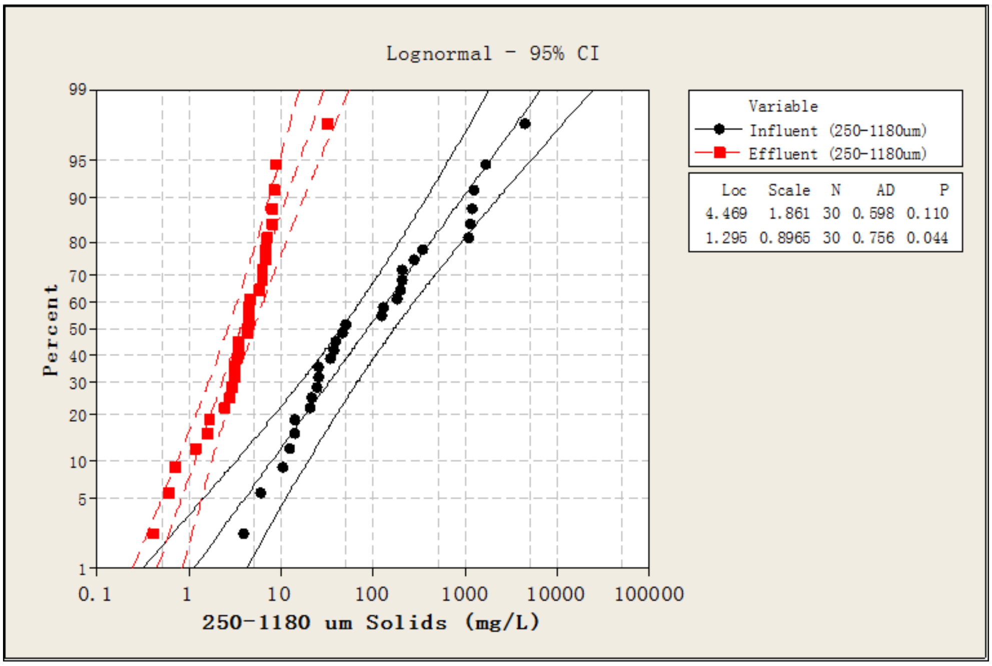


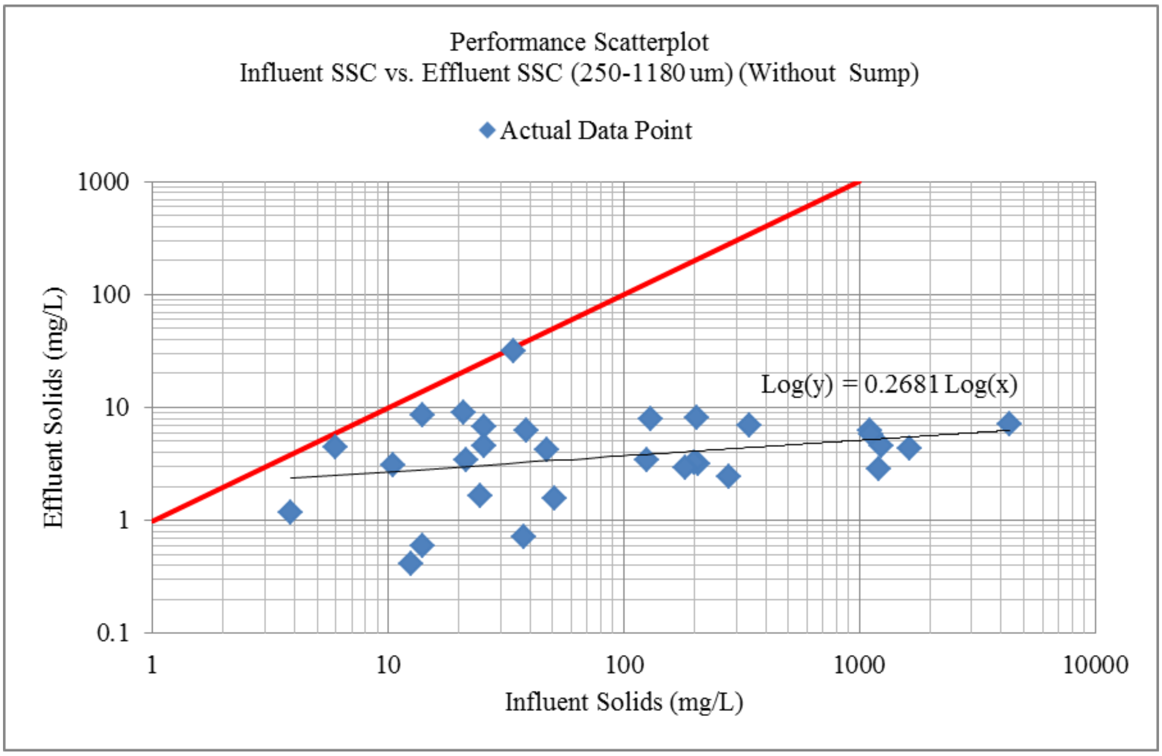
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent 120-250um	30.00	0.00	1.25	0.44	3.14
Effluent 120-250um	30.00	0.00	0.00	0.00	0.92

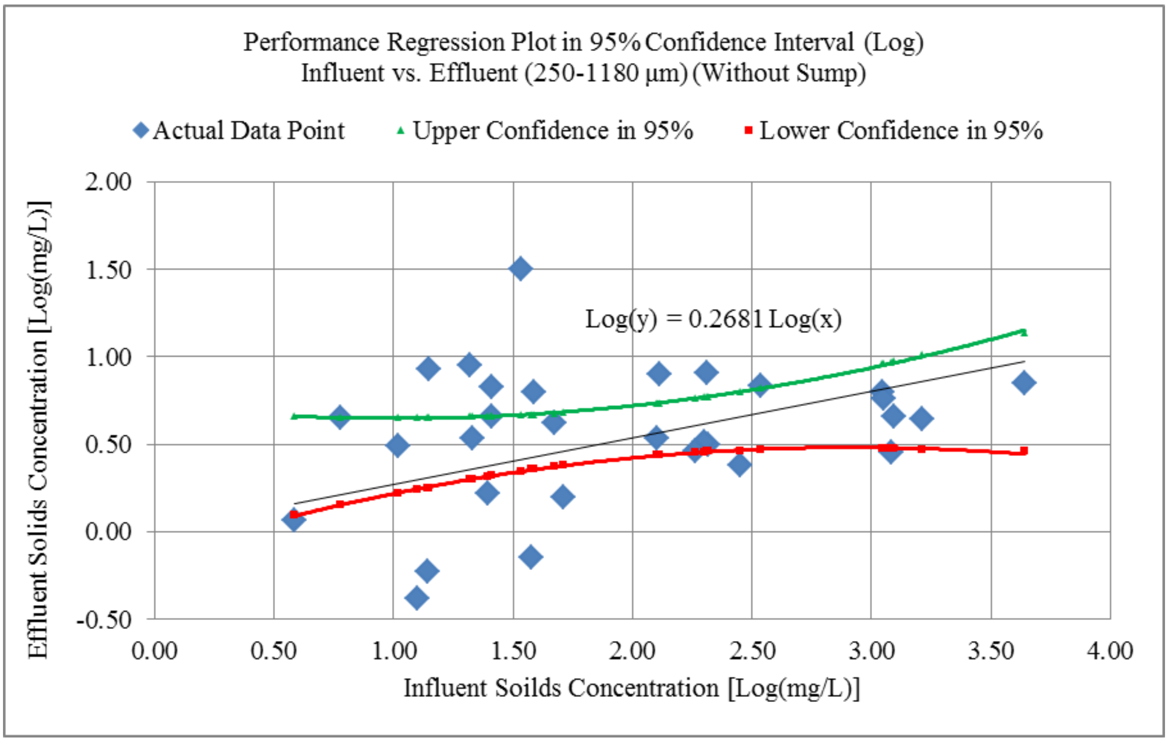
W= -347.000 T+ = 44.000 T-= -391.000
Z-Statistic (based on positive ranks) = -3.752
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.9: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 250-1180 μm Solids (30 Sampled Storms)







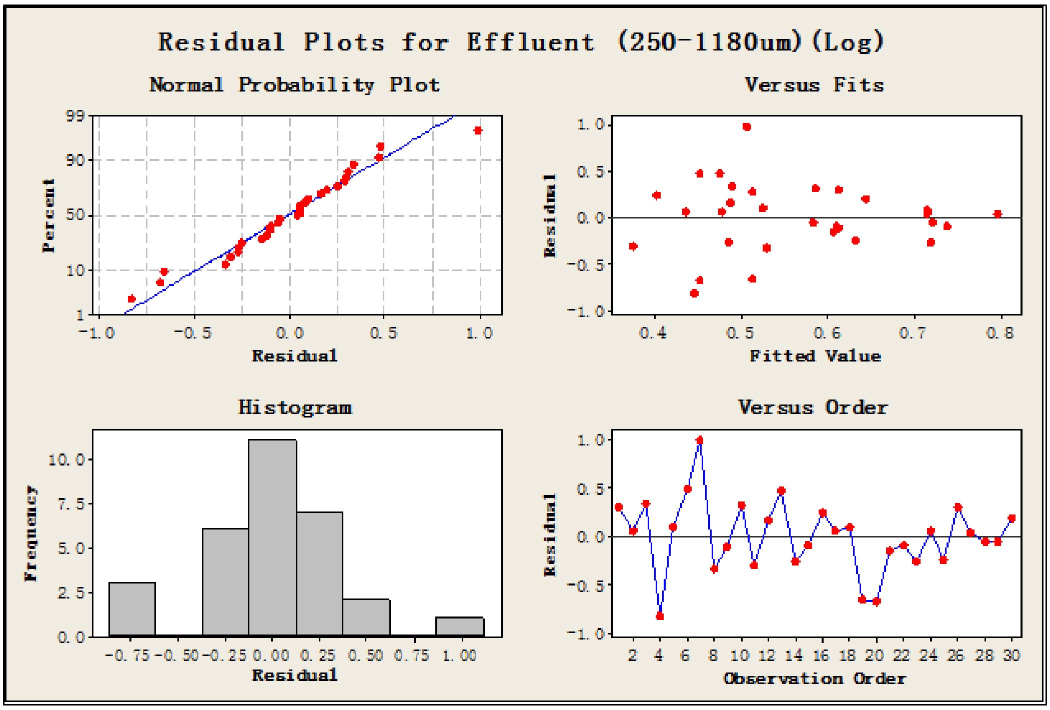
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.83
R Square	0.68
Adjusted R Square	0.65
Standard Error	0.39
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1.00	9.48	9.48	62.41	0.00
Residual	29.00	4.41	0.15		
Total	30.00	13.89			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.27	0.03	7.90	0.00	0.20	0.34	0.20	0.34



Wilcoxon Signed Rank Test

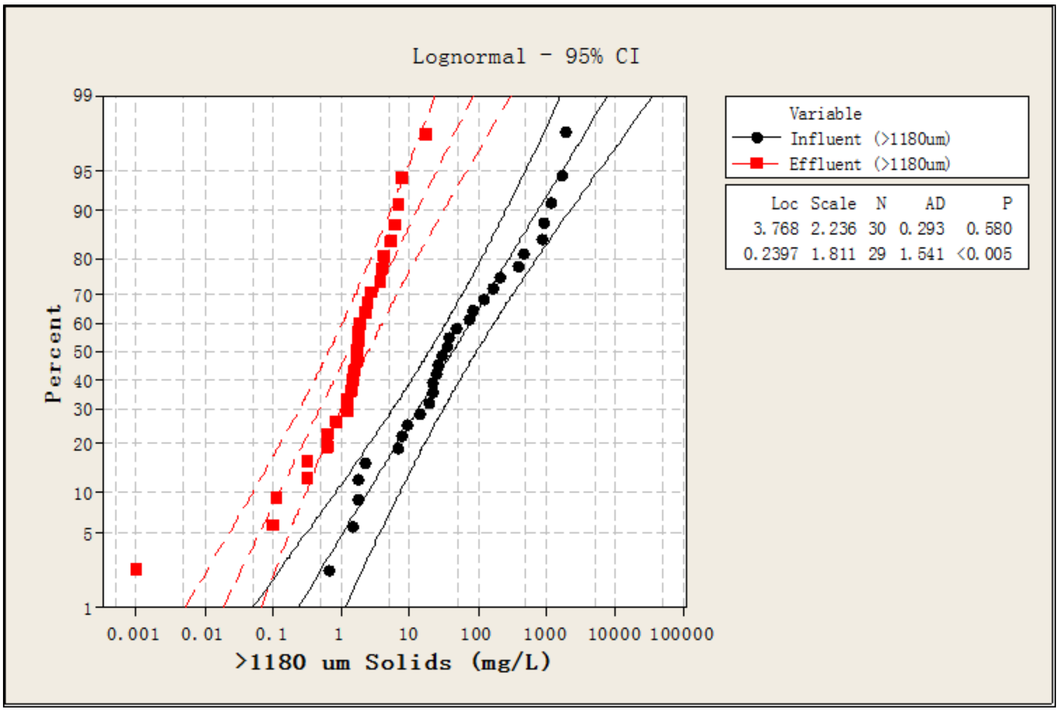
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

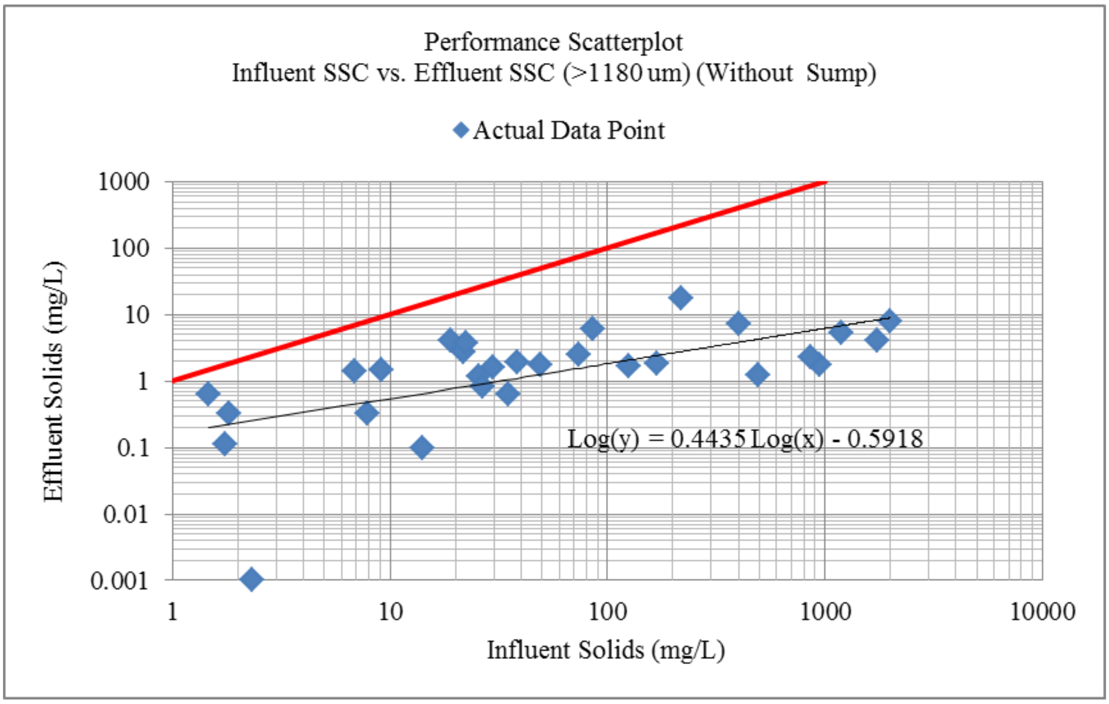
Group	N	Missing	Median	0.25	0.75
Influent 250-1180um	30.00	0.00	49.19	21.26	296.18
Effluent 250-1180um	30.00	0.00	4.29	2.72	6.79

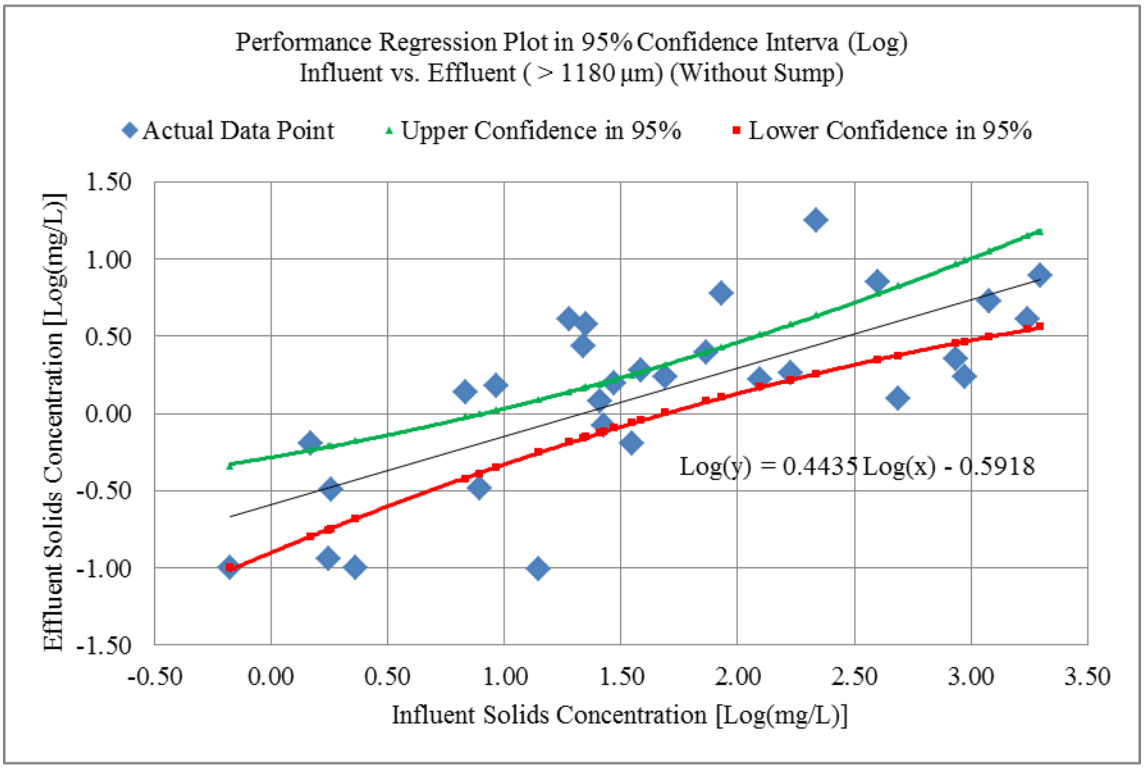
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.782
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.10: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for >1180 µm Solids (30 Sampled Storms)







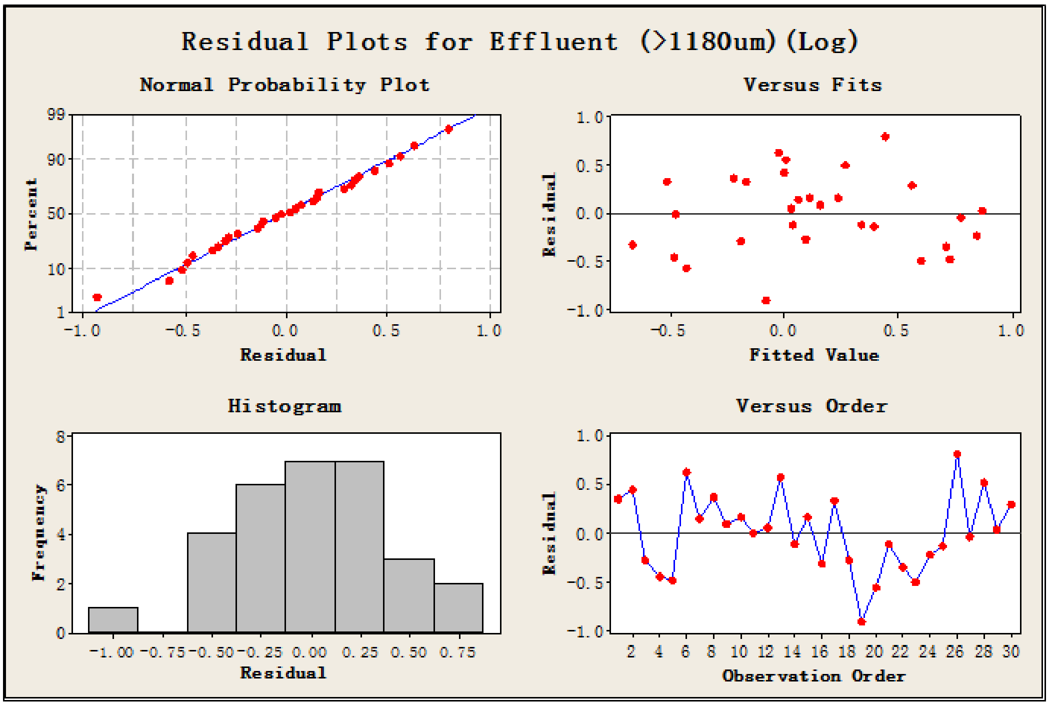
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.73
R Square	0.53
Adjusted R Square	0.52
Standard Error	0.41
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	5.38	5.38	31.94	0.00
Residual	28.00	4.71	0.17		
Total	29.00	10.09			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.59	0.15	-3.98	0.00	-0.90	-0.29	-0.90	-0.29
X Variable 1	0.44	0.08	5.65	0.00	0.28	0.60	0.28	0.60



Wilcoxon Signed Rank Test

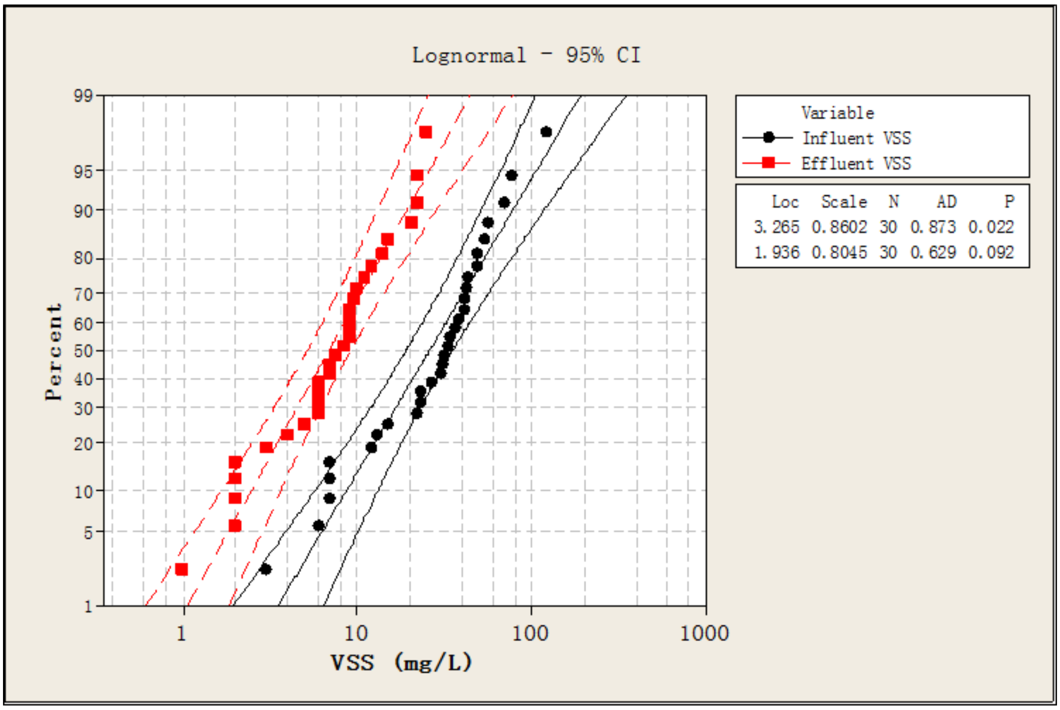
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

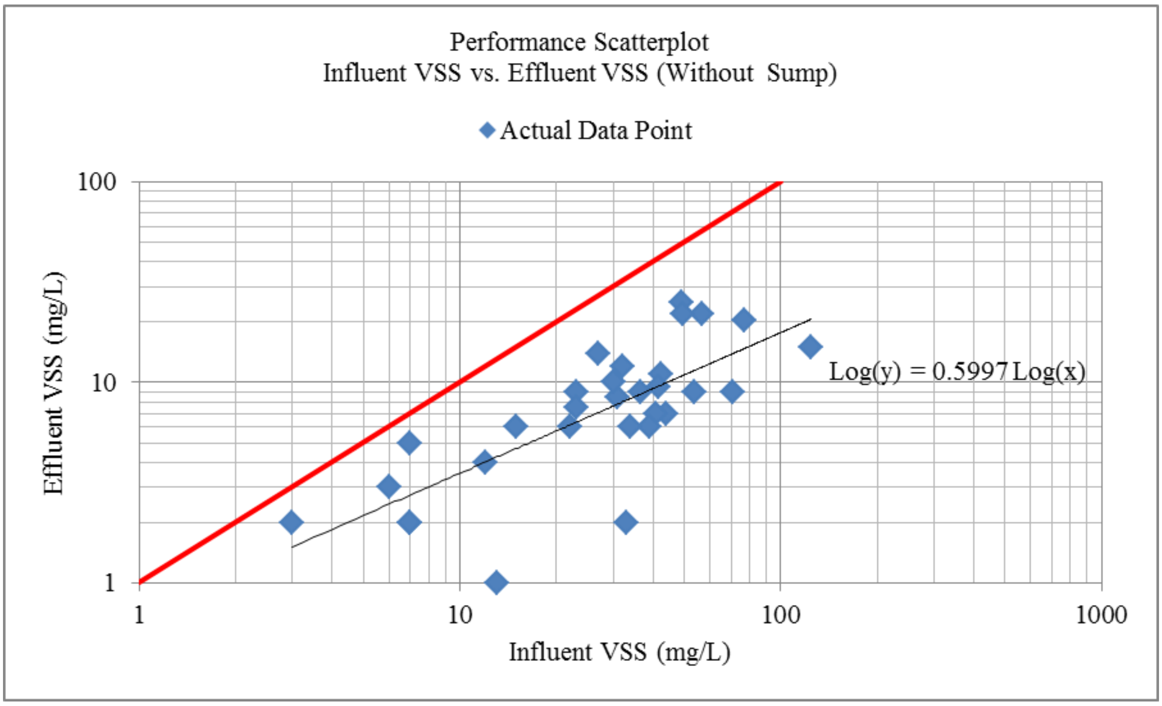
Group	N	Missing	Median	0.25	0.75
Influent >1180um	30.00	0.00	32.41	8.86	264.47
Effluent >1180um	30.00	0.00	1.70	0.65	3.84

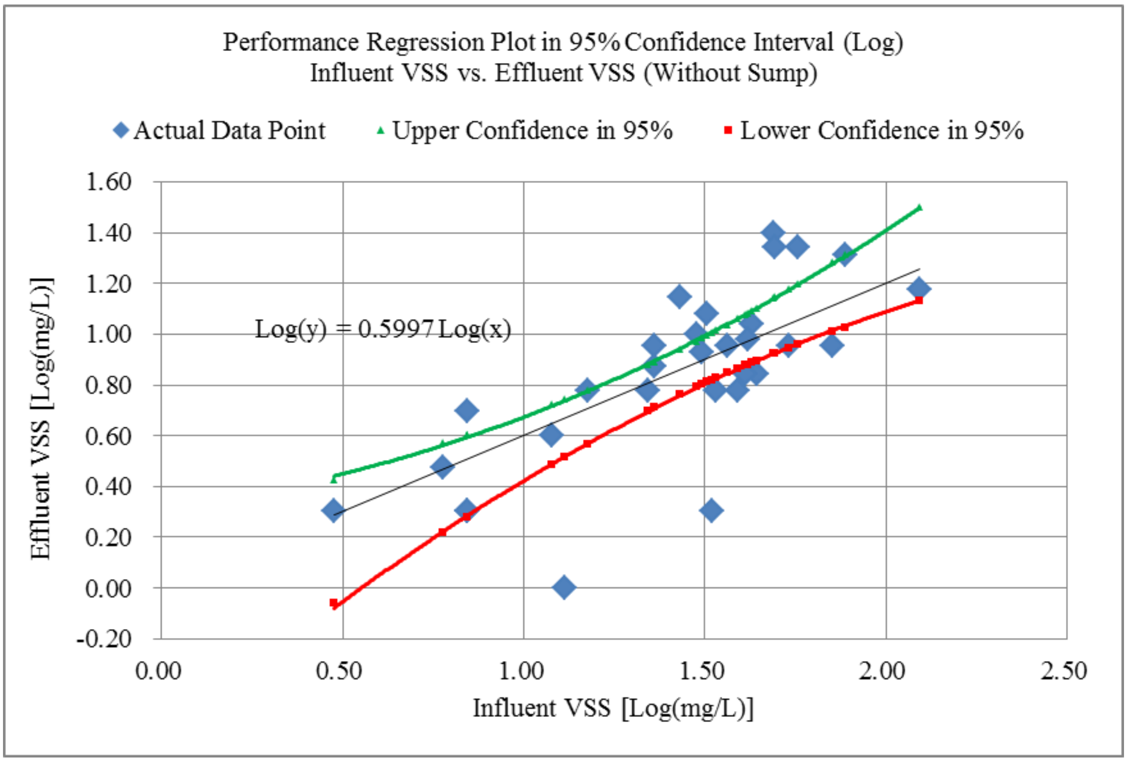
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.782
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.11: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for VSS (30 Sampled Storms)







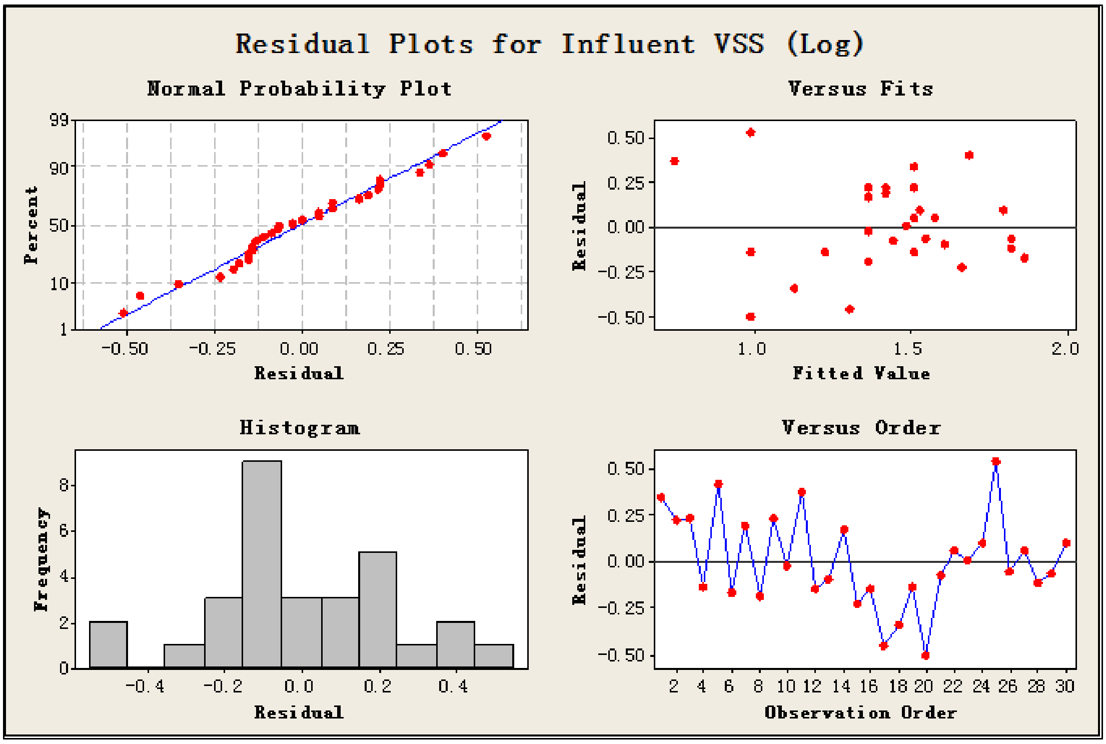
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97
R Square	0.94
Adjusted R Square	0.90
Standard Error	0.23
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	23.15	23.15	420.46	0.00
Residual	29.00	1.60	0.06		
Total	30.00	24.74			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.60	0.03	20.51	0.00	0.54	0.66	0.54	0.66



Wilcoxon Signed Rank Test

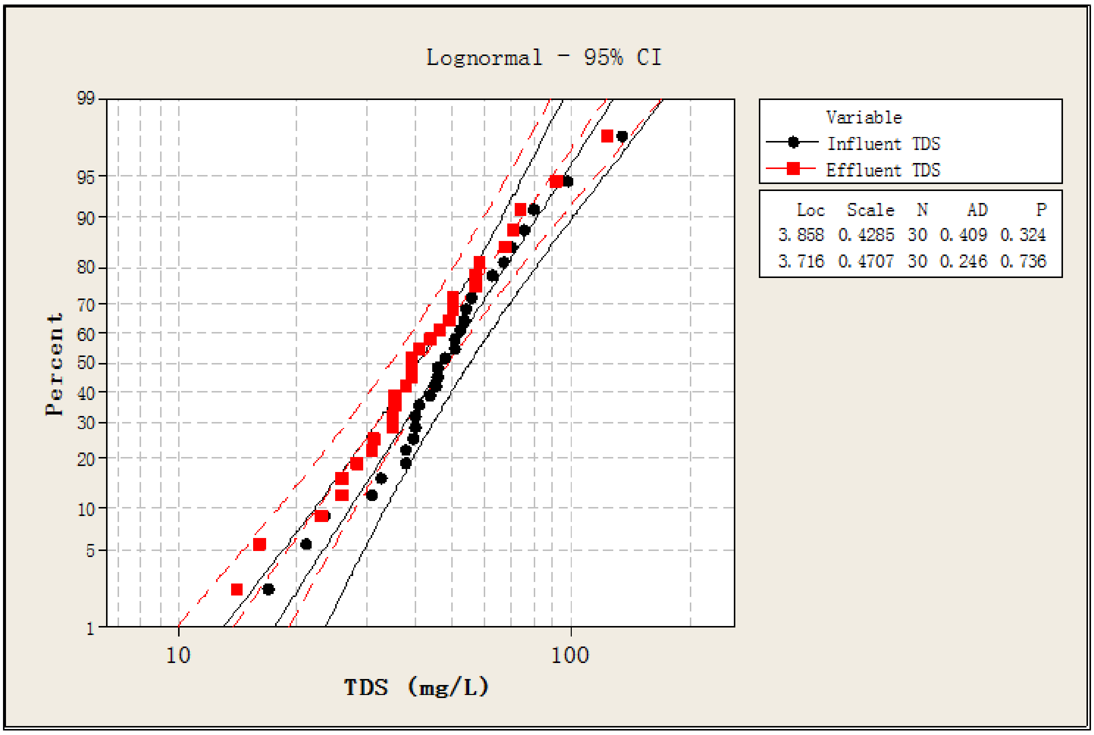
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

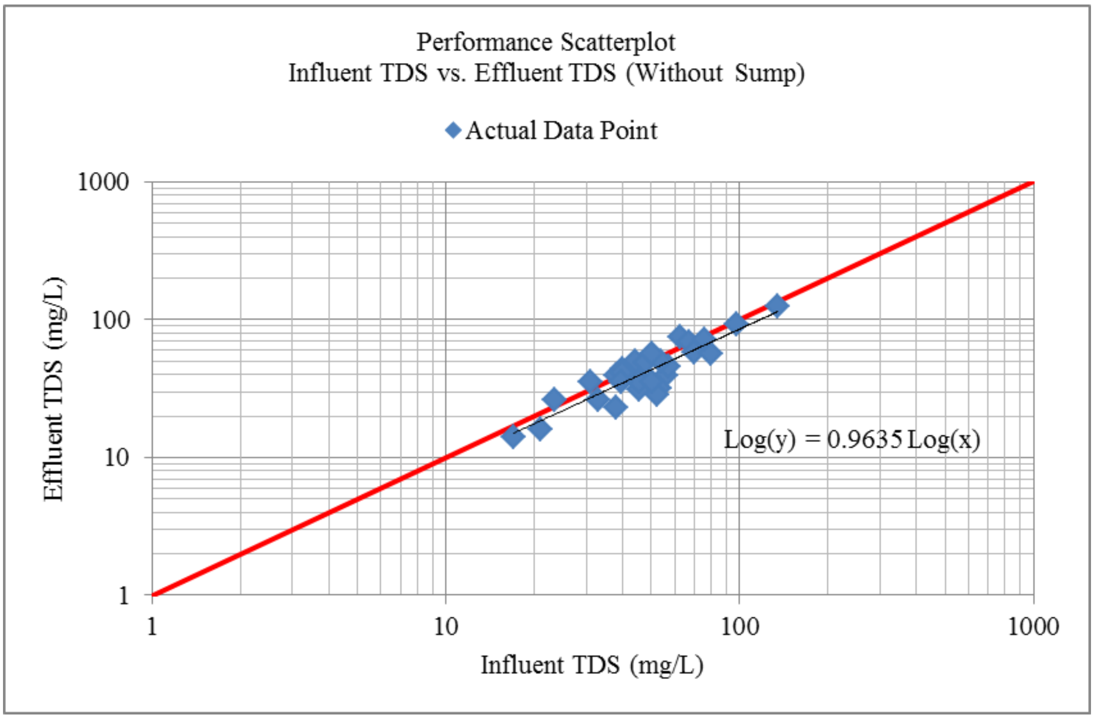
Group	N	Missing	Median	0.25	0.75
Influent VSS	30.00	0.00	32.50	14.50	45.25
Effluent VSS	30.00	0.00	8.00	4.75	11.25

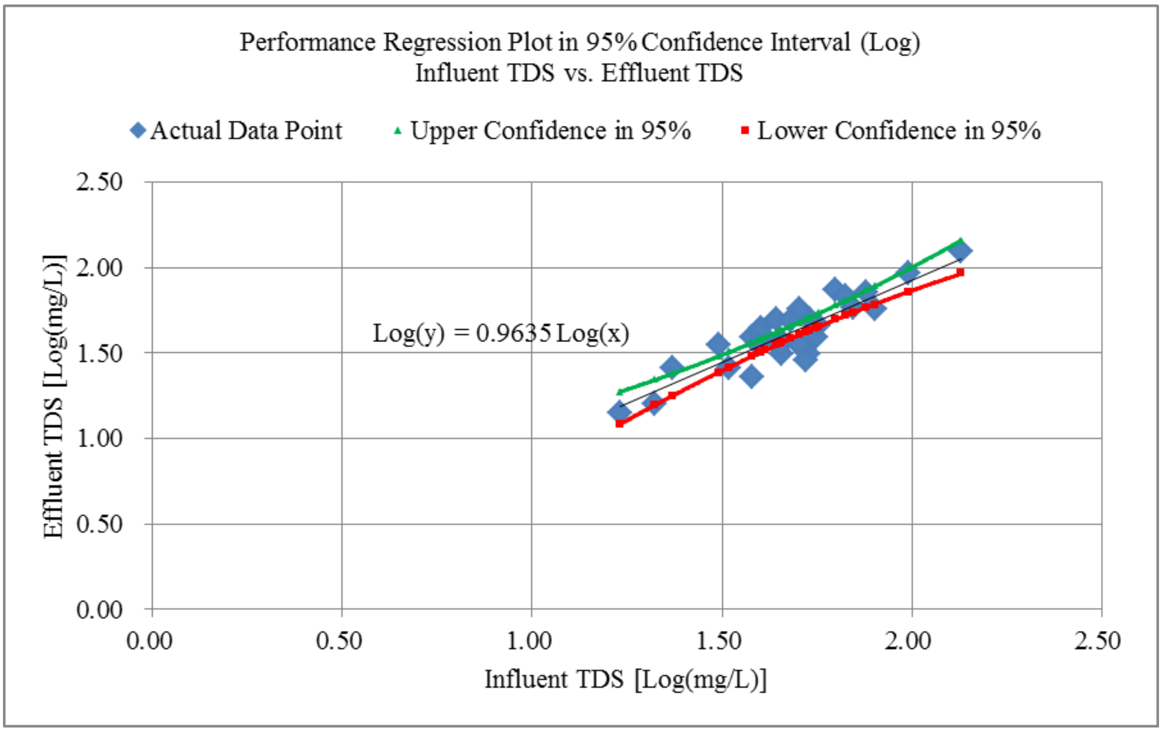
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.782
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.12: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for TDS (30 Sampled Storms)







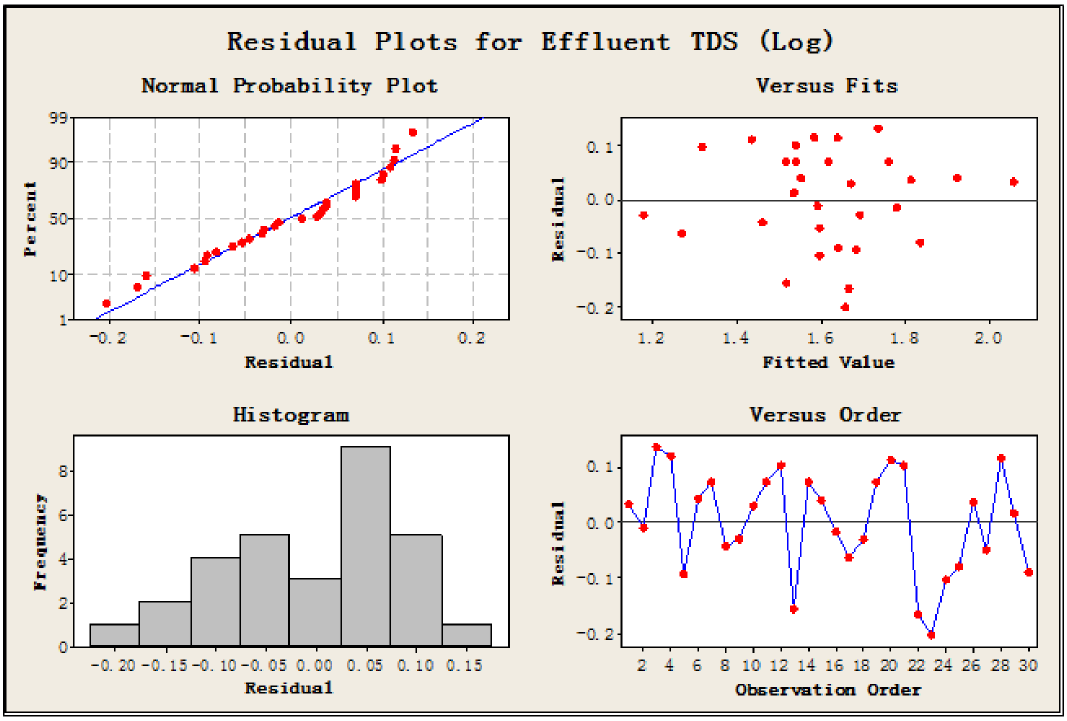
SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	1.00
Adjusted R Square	0.96
Standard Error	0.09
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	79.12	79.12	9389.41	0.00
Residual	29.00	0.24	0.01		
Total	30.00	79.36			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.96	0.01	96.90	0.00	0.94	0.98	0.94	0.98



Wilcoxon Signed Rank Test

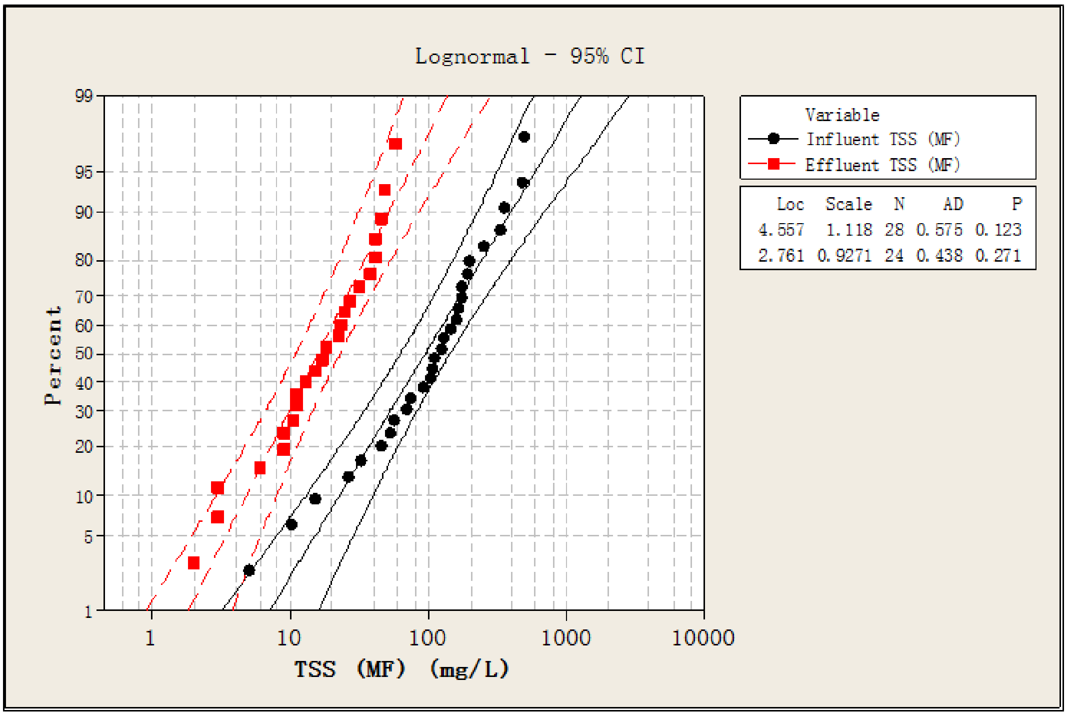
Normality Test (Shapiro-Wilk) Passed (P = 0.597)

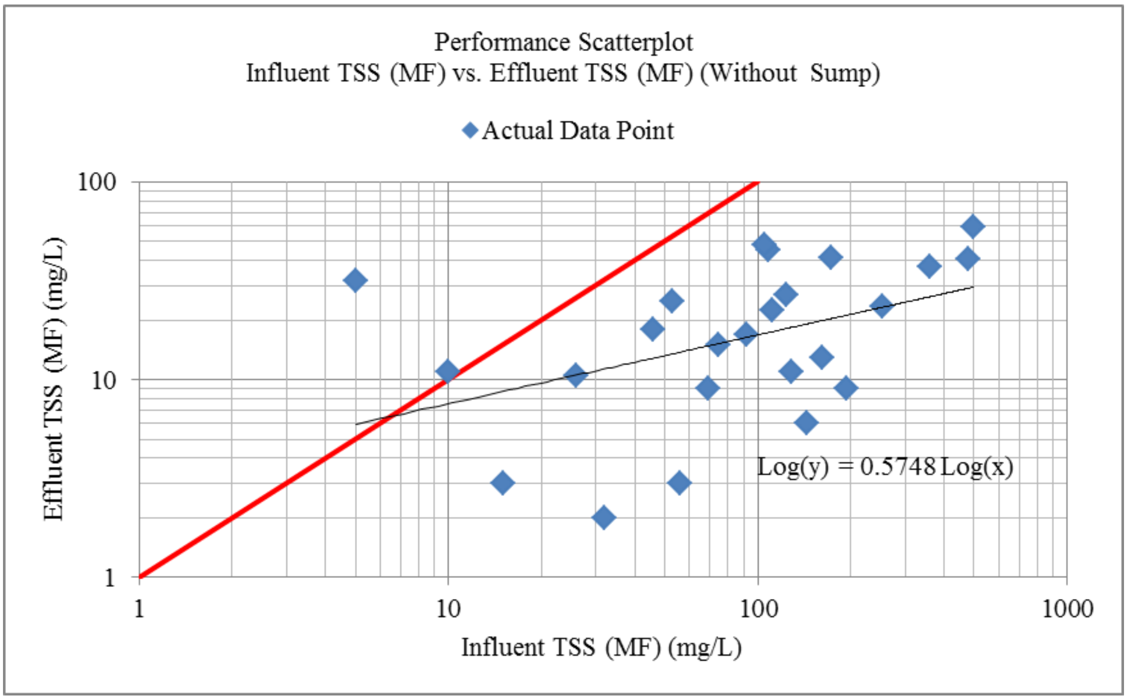
Group	N	Missing	Median	0.25	0.75
Influent TDS	30.00	0.00	46.75	39.13	58.50
Effluent TDS	30.00	0.00	39.00	31.38	57.00

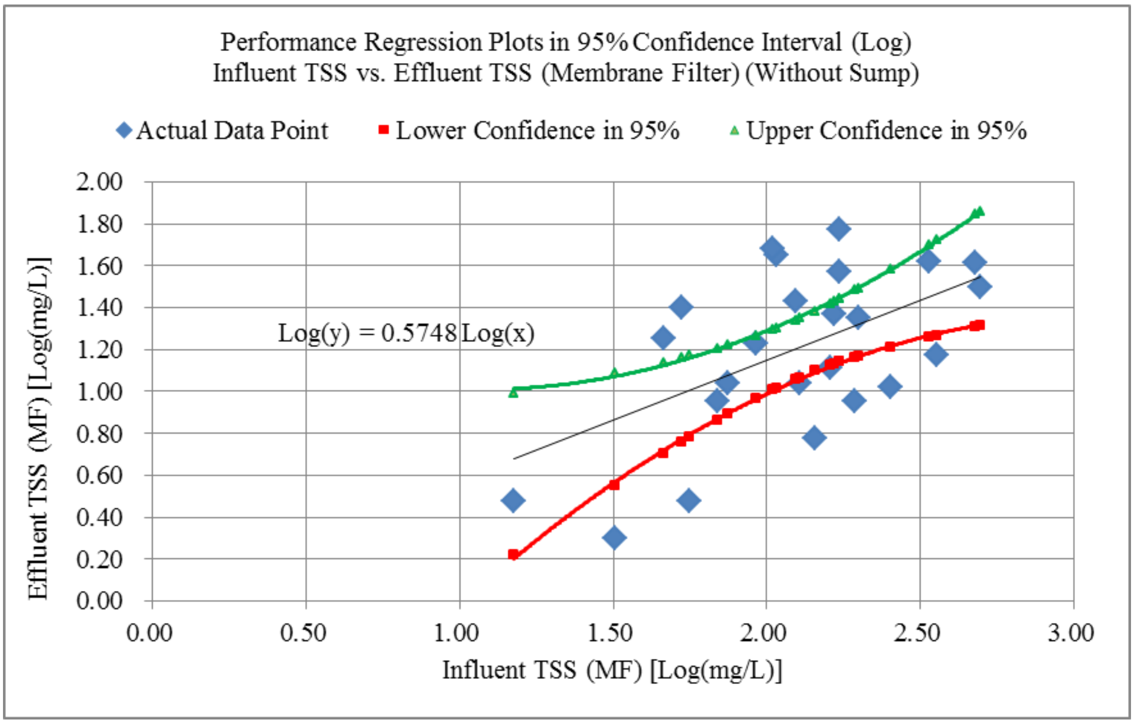
W= -294.000 T+ = 85.500 T-= -379.500
Z-Statistic (based on positive ranks) = -3.025
(P = 0.003)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.003).

Appendix A.13: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for TSS (Membrane Filter) (30 Sampled Storms)







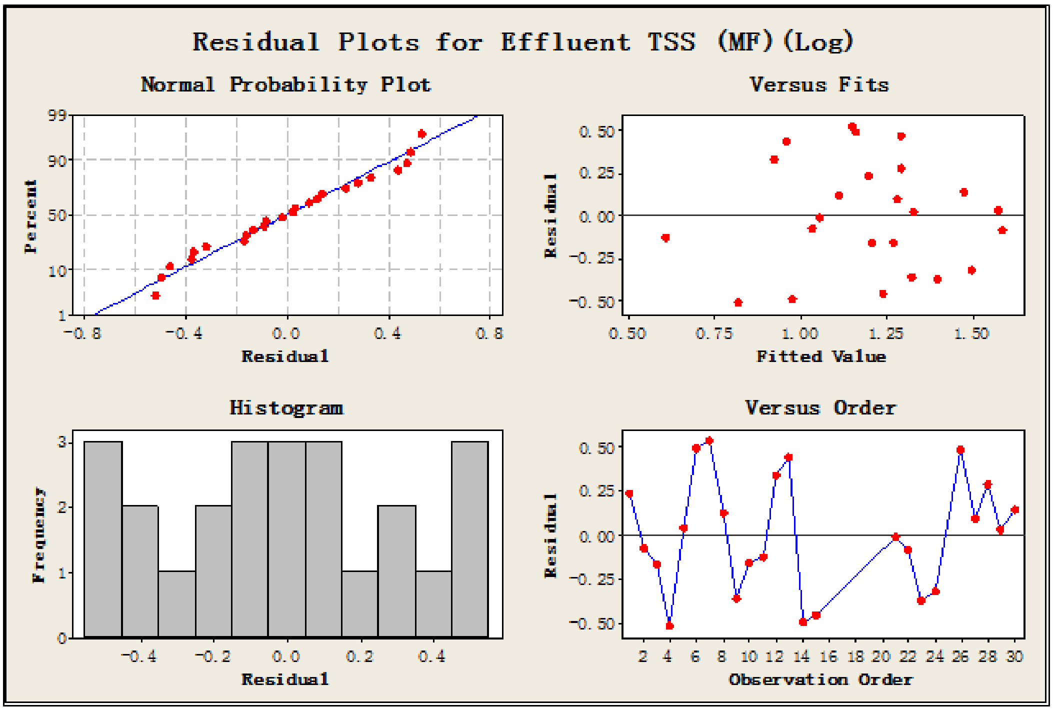
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97
R Square	0.94
Adjusted R Square	0.89
Standard Error	0.33
Observations	24.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	35.80	35.80	336.81	0.00
Residual	23.00	2.44	0.11		
Total	24.00	38.25			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.57	0.03	18.35	0.00	0.51	0.64	0.51	0.64



Wilcoxon Signed Rank Test

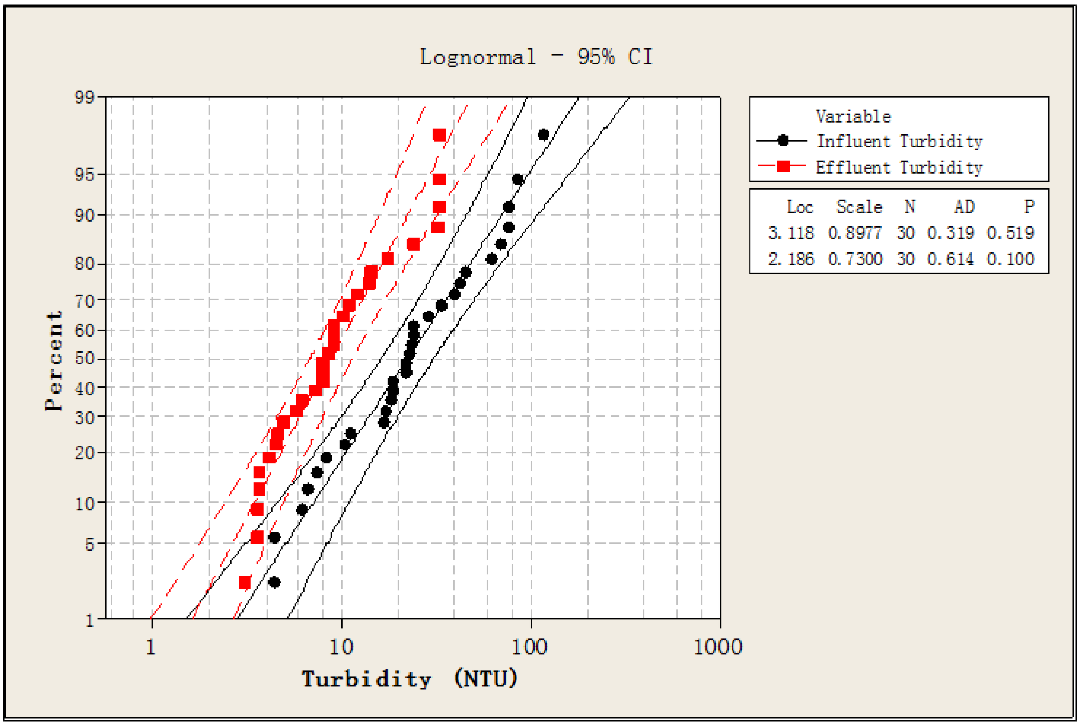
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

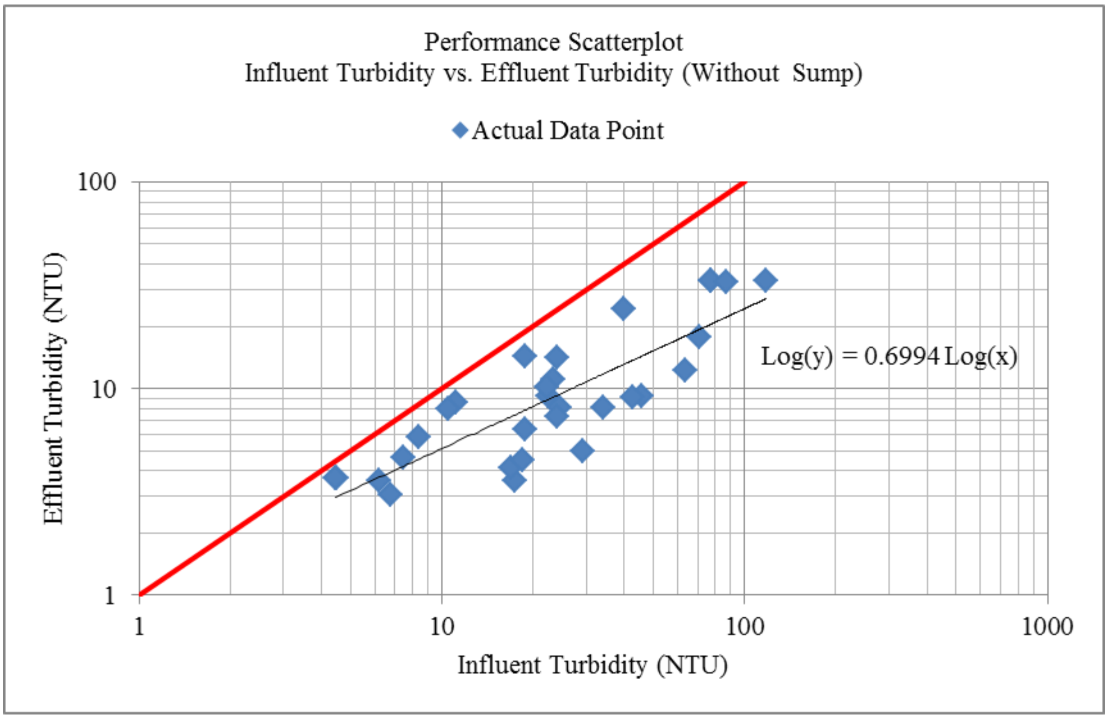
Group	N	Missing	Median	0.25	0.75
Influent TSS (MF)	30.00	2.00	117.50	53.75	188.75
Effluent TSS (MF)	30.00	6.00	17.50	9.38	36.00

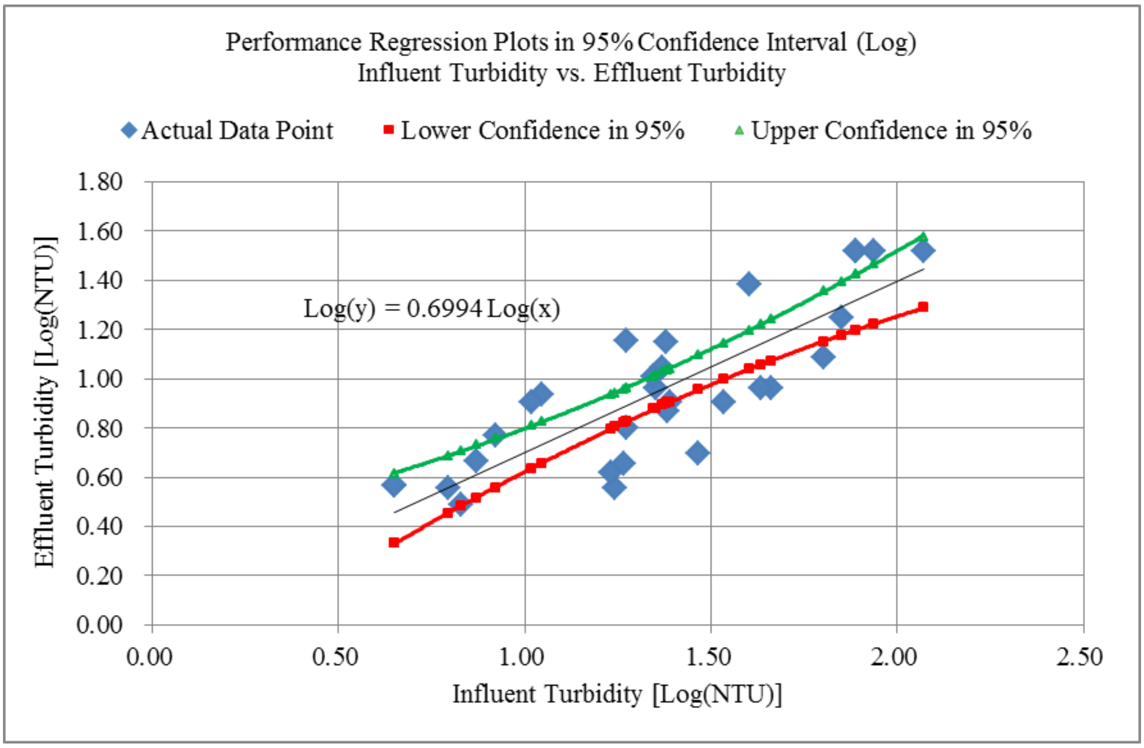
W= -300.000 T+ = 0.000 T-= -300.000
Z-Statistic (based on positive ranks) = -4.286
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix A.14: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Turbidity (30 Sampled Storms)







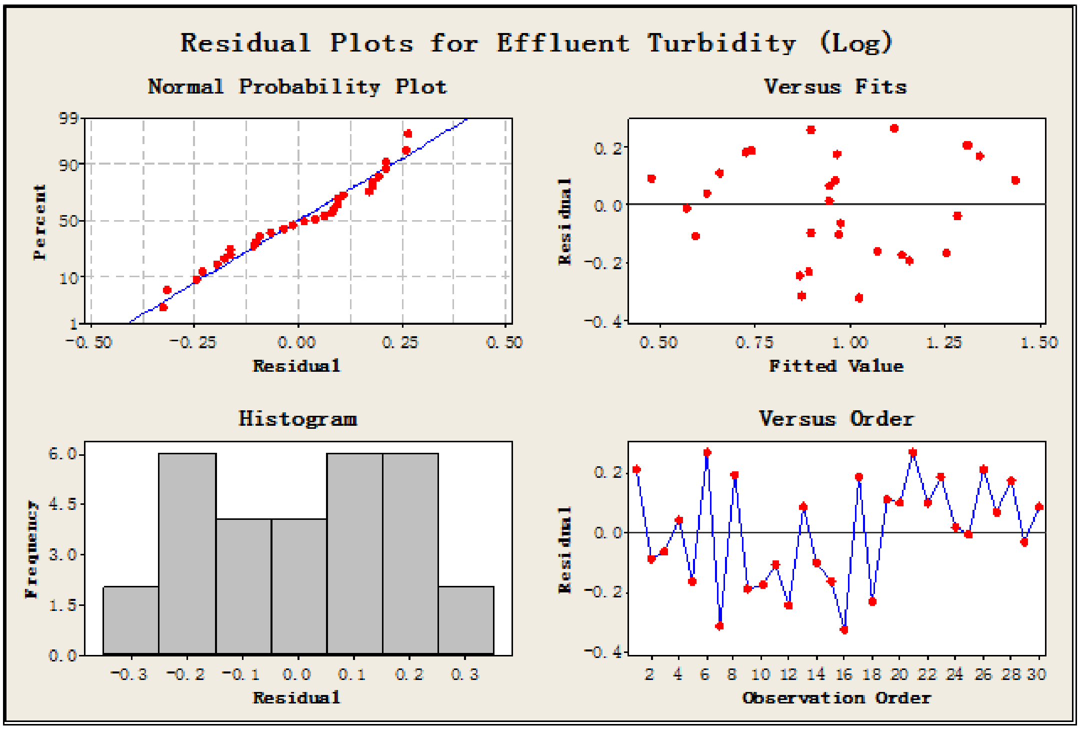
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.98
R Square	0.97
Adjusted R Square	0.94
Standard Error	0.18
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	29.06	29.06	937.11	0.00
Residual	29.00	0.90	0.03		
Total	30.00	29.96			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.70	0.02	30.61	0.00	0.65	0.75	0.65	0.75



Wilcoxon Signed Rank Test

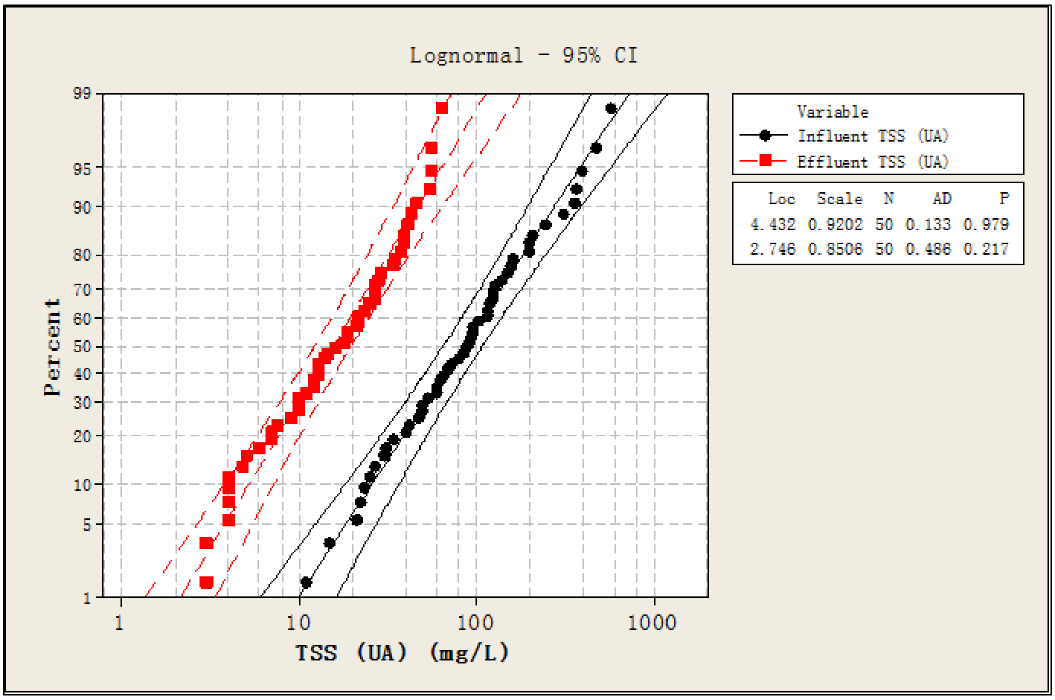
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

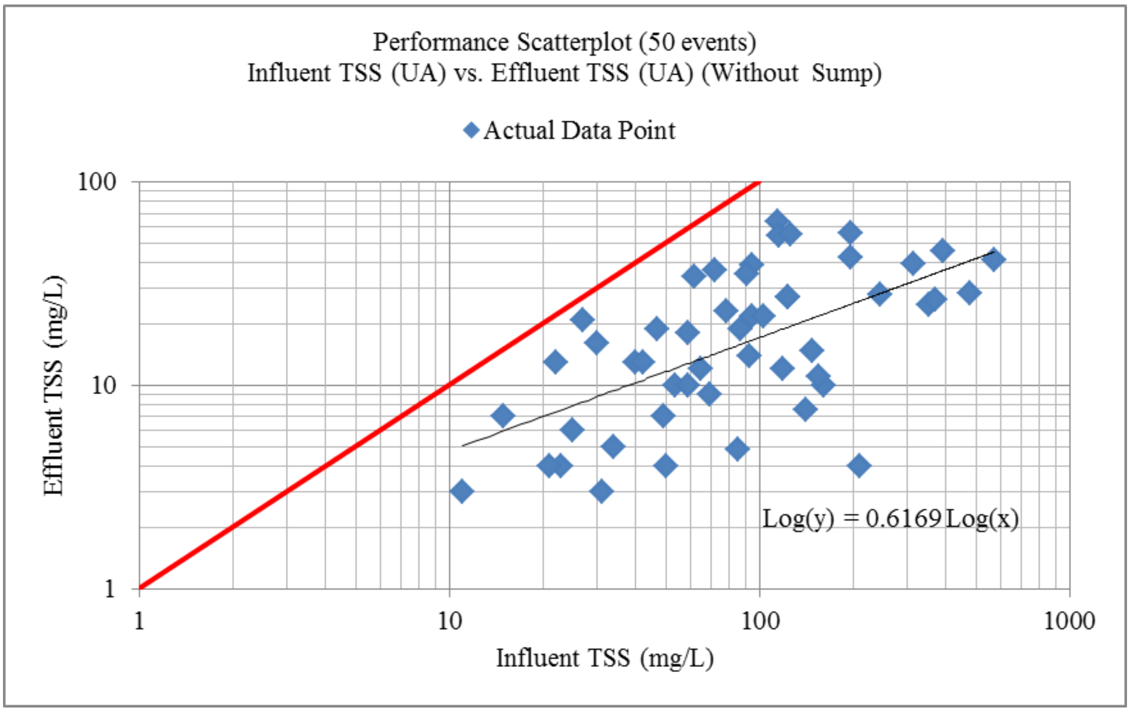
Group	N	Missing	Median	0.25	0.75
Influent Turbidity	30.00	0.00	22.93	10.98	43.63
Effluent Turbidity	30.00	0.00	8.33	4.59	14.13

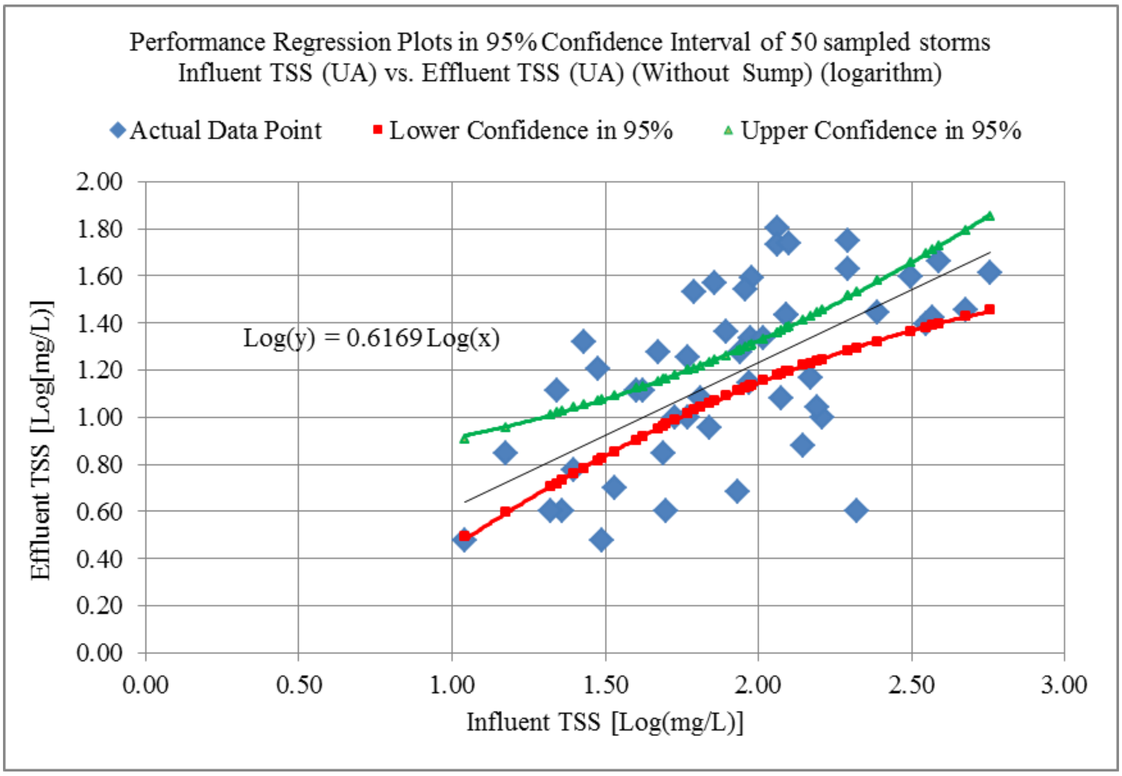
W= -465.000 T+ = 0.000 T-= -465.000
Z-Statistic (based on positive ranks) = -4.782
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.1: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for TSS (50 Sampled Storms)







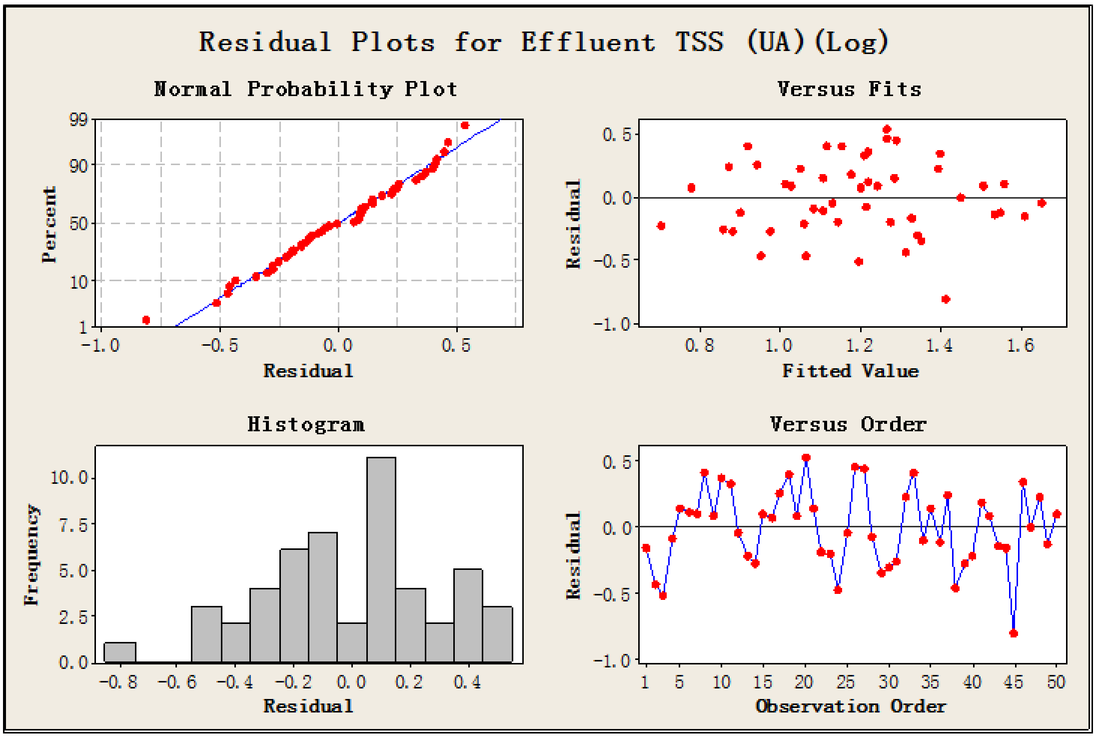
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97
R Square	0.94
Adjusted R Square	0.92
Standard Error	0.30
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	73.49	73.49	837.92	0.0000
Residual	49.00	4.30	0.09		
Total	50.00	77.79			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.6169	0.02	28.95	0.0000	0.57	0.66	0.57	0.66



Wilcoxon Signed Rank Test

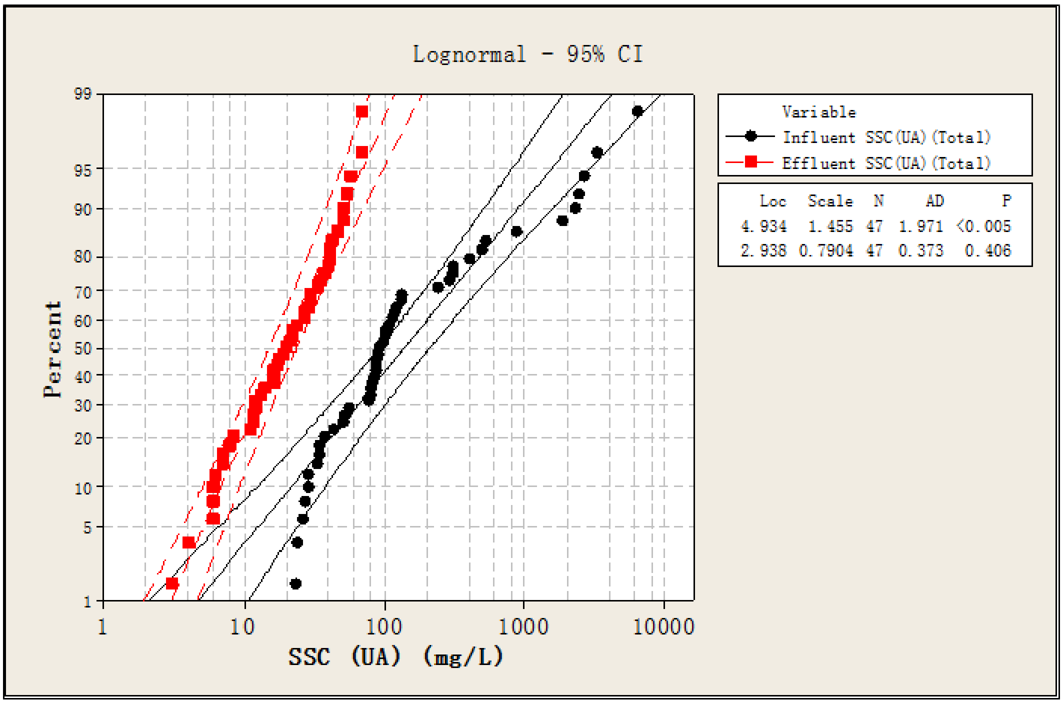
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

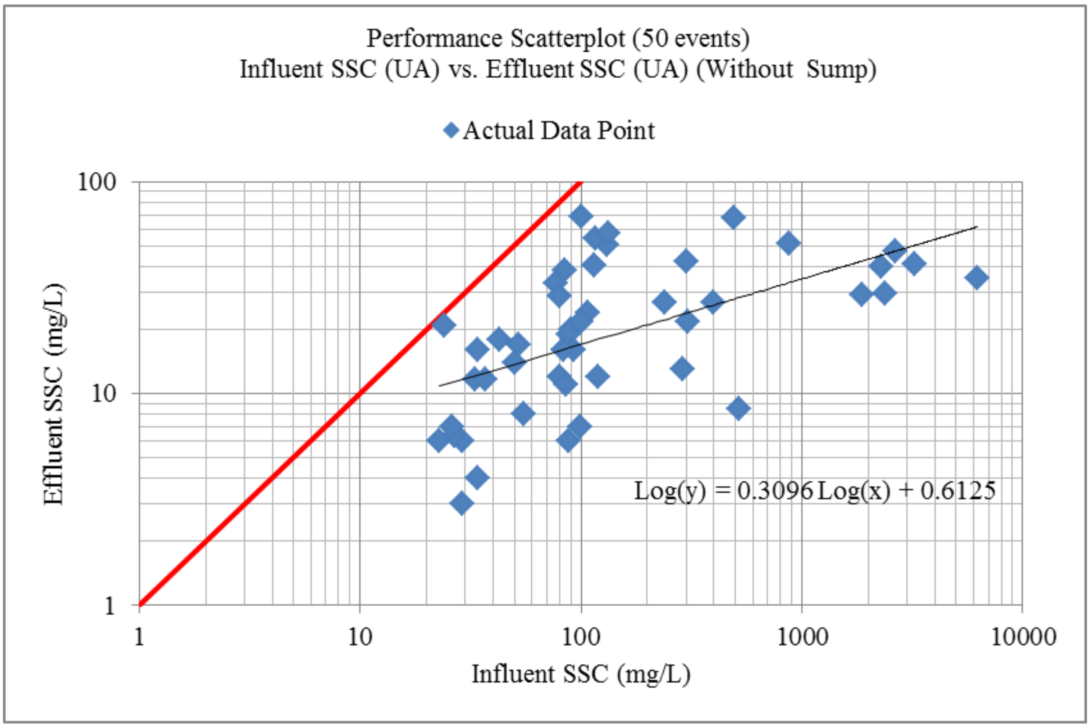
Group	N	Missing	Median	0.25	0.75
Influent TSS	50.00	0.00	89.00	45.75	150.45
Effluent TSS	50.00	0.00	17.00	8.65	29.88

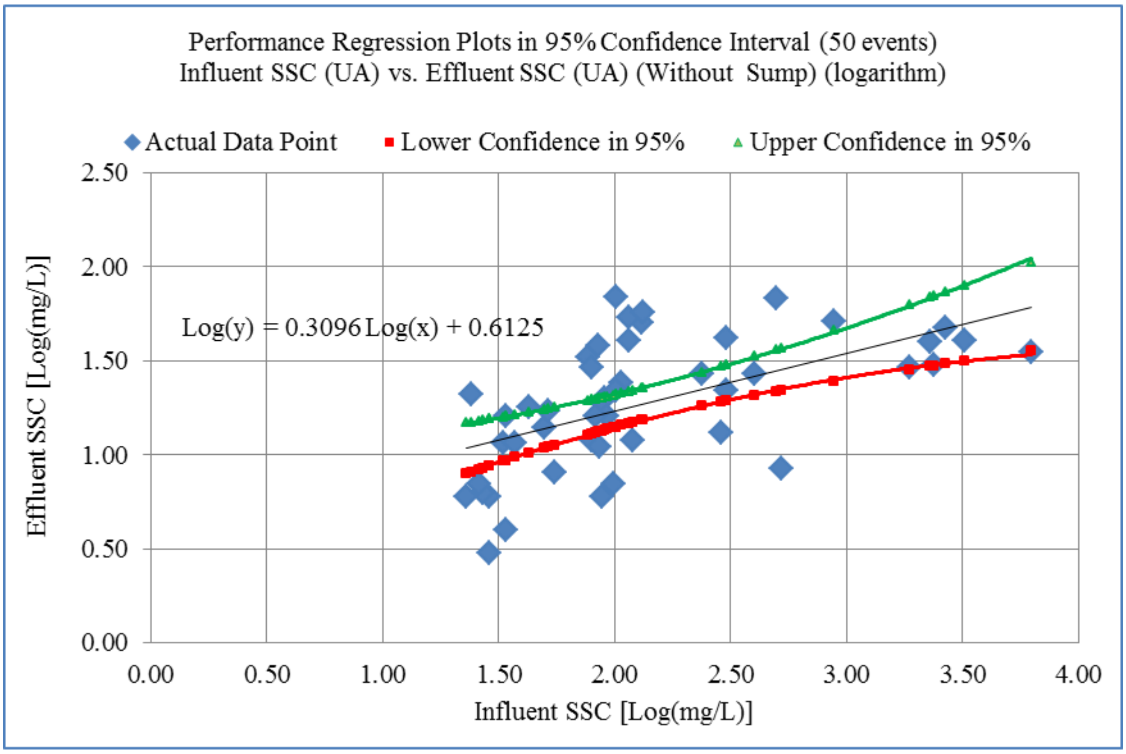
W= -1275.000 T+ = 0.000 T-= -1275.000
Z-Statistic (based on positive ranks) = -6.154
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.2: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for SSC (50 Sampled Storms)







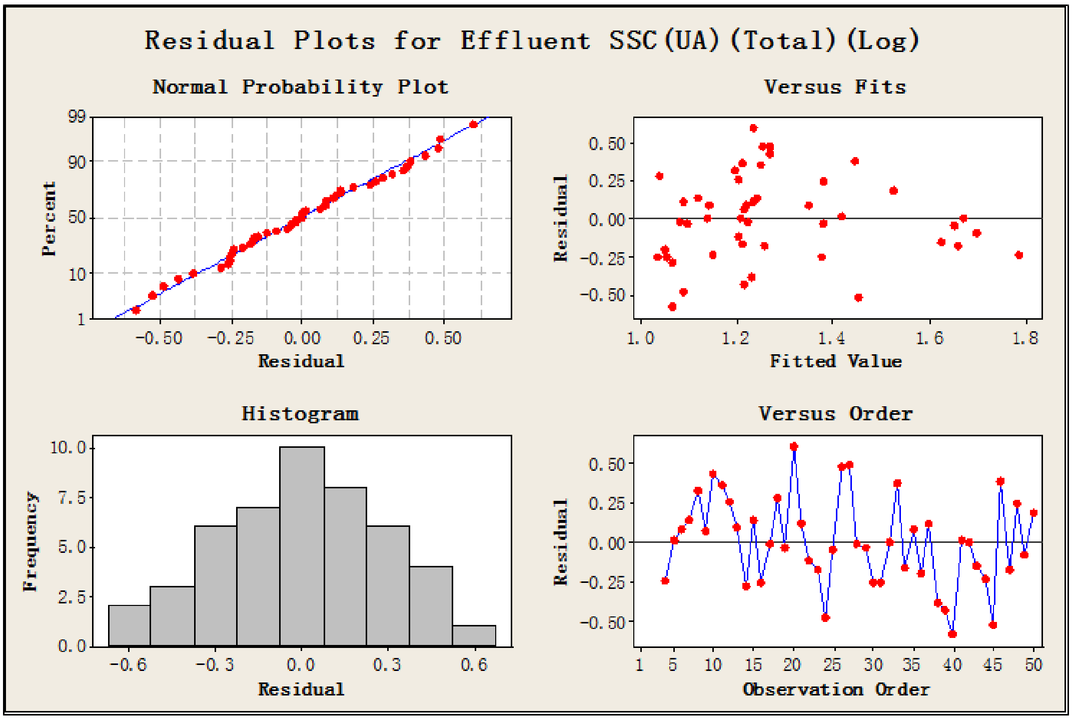
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.57
R Square	0.33
Adjusted R Square	0.31
Standard Error	0.29
Observations	47.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.76	1.76	21.67	0.0000
Residual	45.00	3.66	0.08		
Total	46.00	5.42			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.61	0.15	4.13	0.0002	0.31	0.91	0.31	0.91
X Variable 1	0.31	0.07	4.66	0.0000	0.18	0.44	0.18	0.44

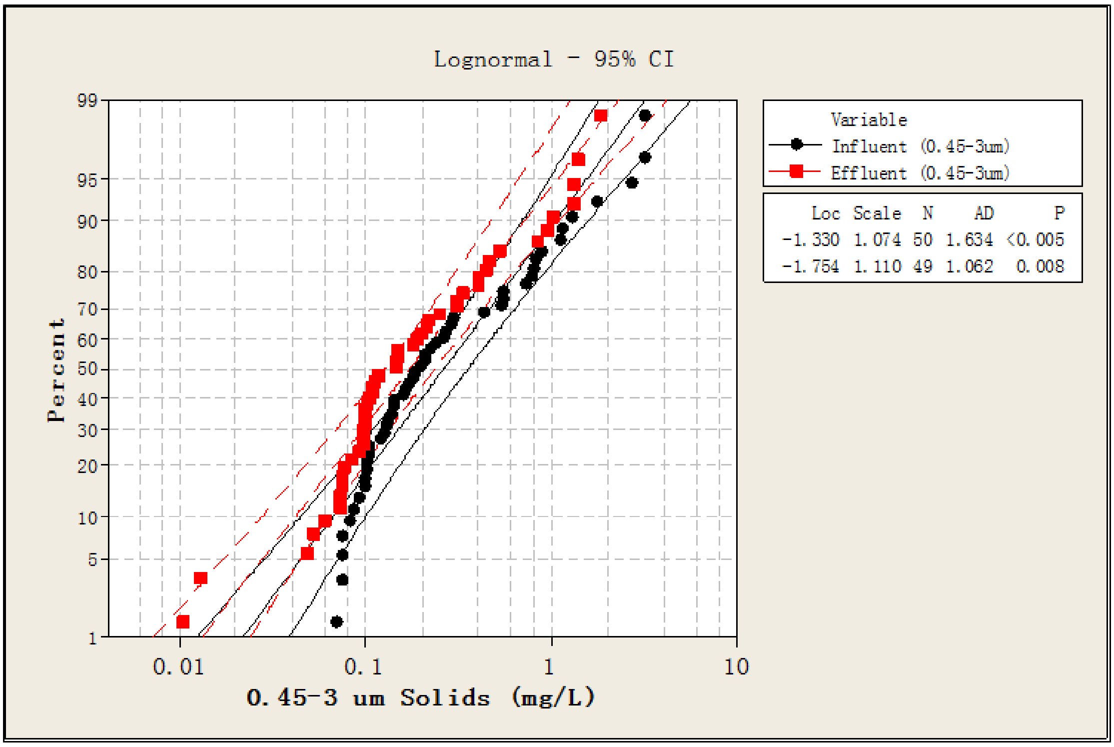


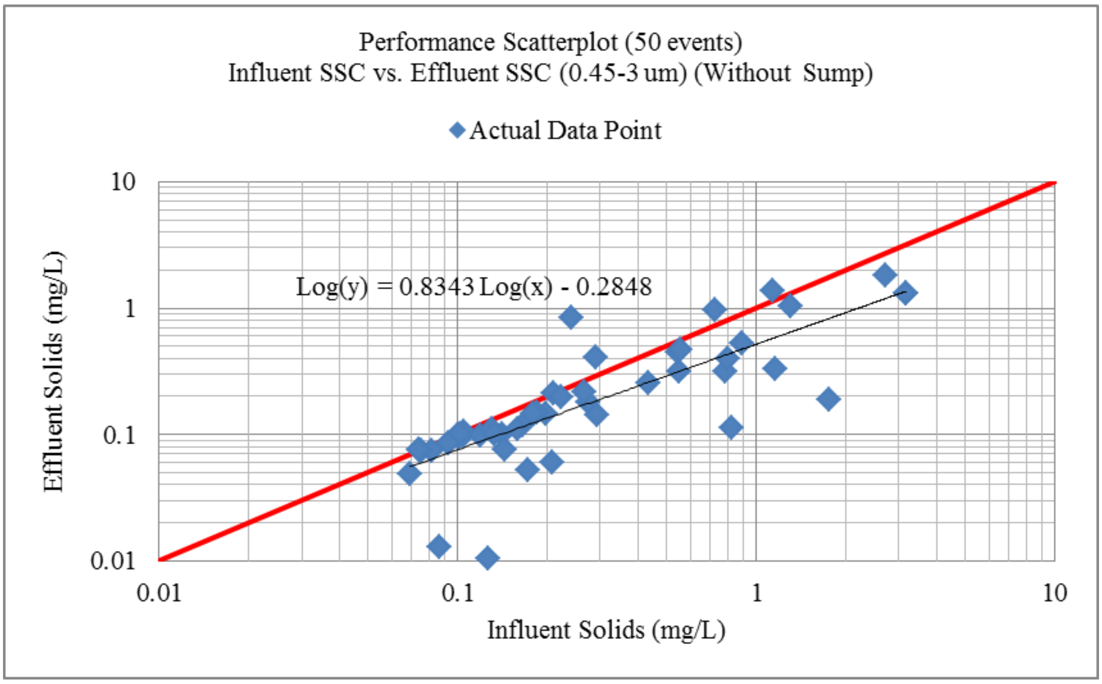
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent SSC UA	50.00	3.00	93.00	50.00	302.17
Effluent SSC UA	50.00	3.00	20.00	11.60	38.00

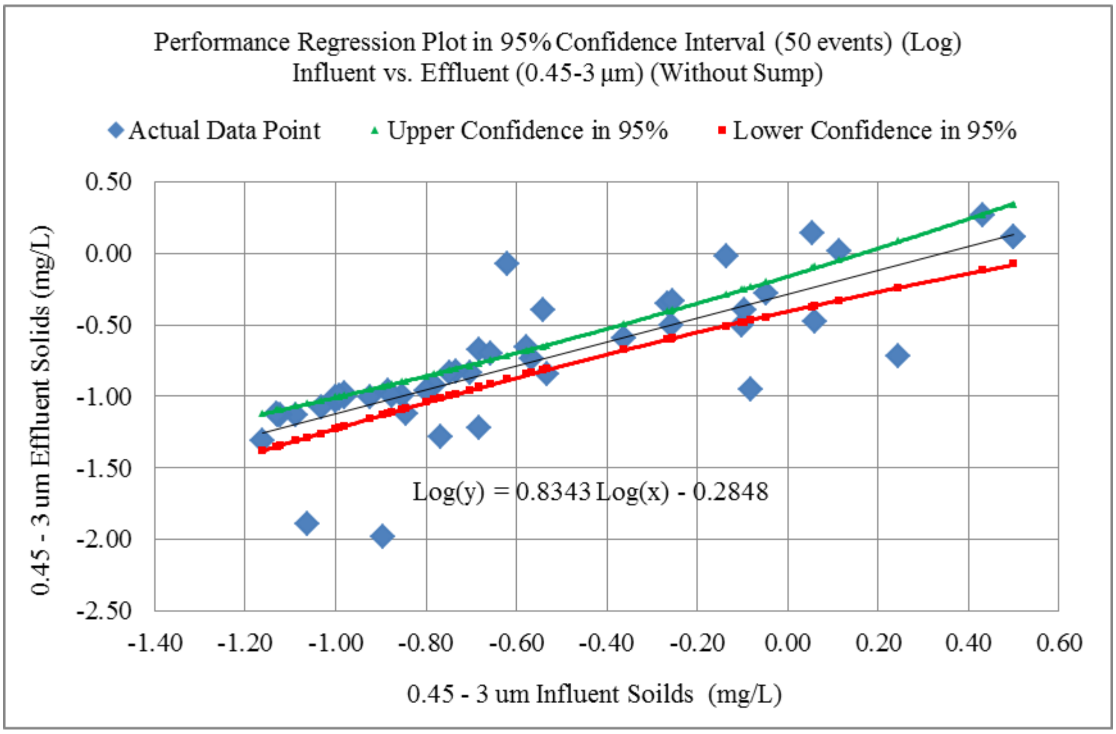
W= -1128.000 T+ = 0.000 T-= -1128.000
Z-Statistic (based on positive ranks) = -5.968
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.3: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 0.45-3 µm Solids (50 Sampled Storms)







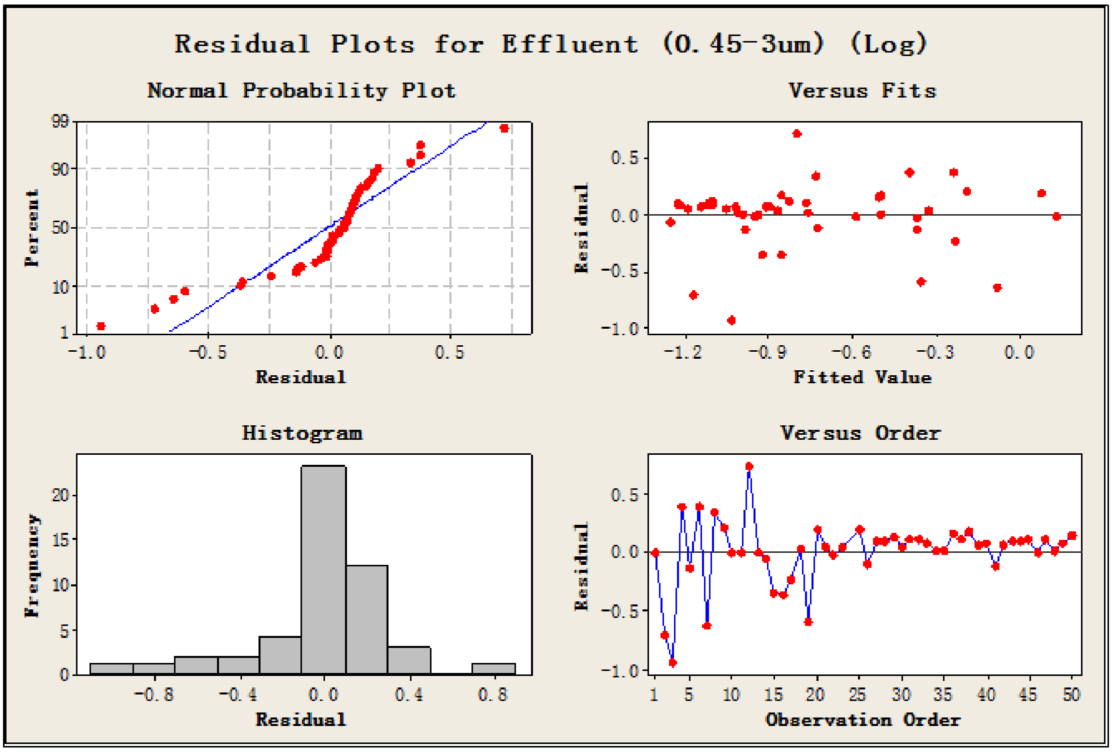
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.81
R Square	0.66
Adjusted R Square	0.65
Standard Error	0.28
Observations	49.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	7.36	7.36	90.97	0.00
Residual	47.00	3.80	0.08		
Total	48.00	11.16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.28	0.06	-4.42	0.00	-0.41	-0.16	-0.41	-0.16
X Variable 1	0.83	0.09	9.54	0.00	0.66	1.01	0.66	1.01



Wilcoxon Signed Rank Test

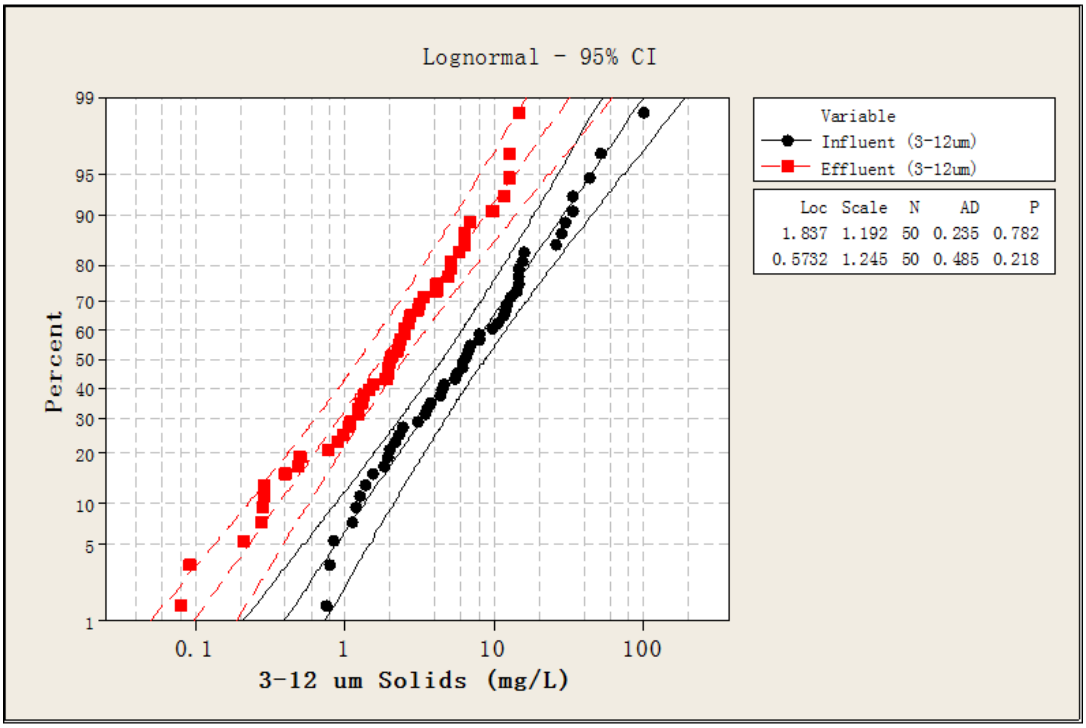
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

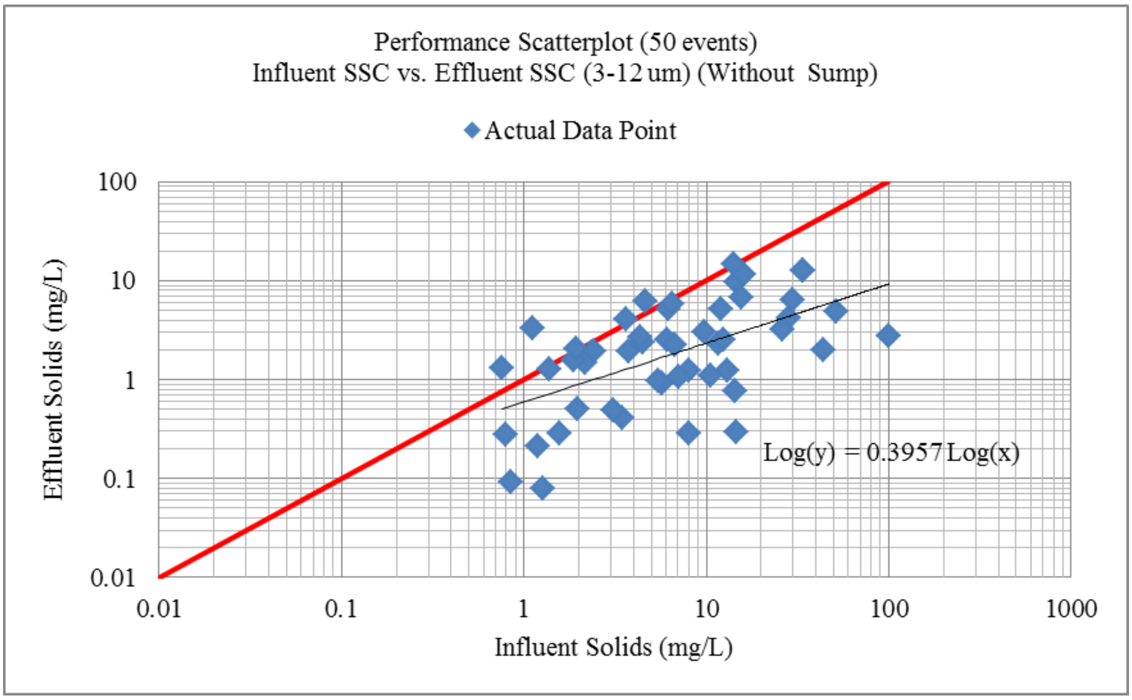
Group	N	Missing	Median	0.25	0.75
Influent 0.45-3um	50.00	0.00	0.19	0.11	0.60
Effluent 0.45-3um	50.00	0.00	0.13	0.09	0.35

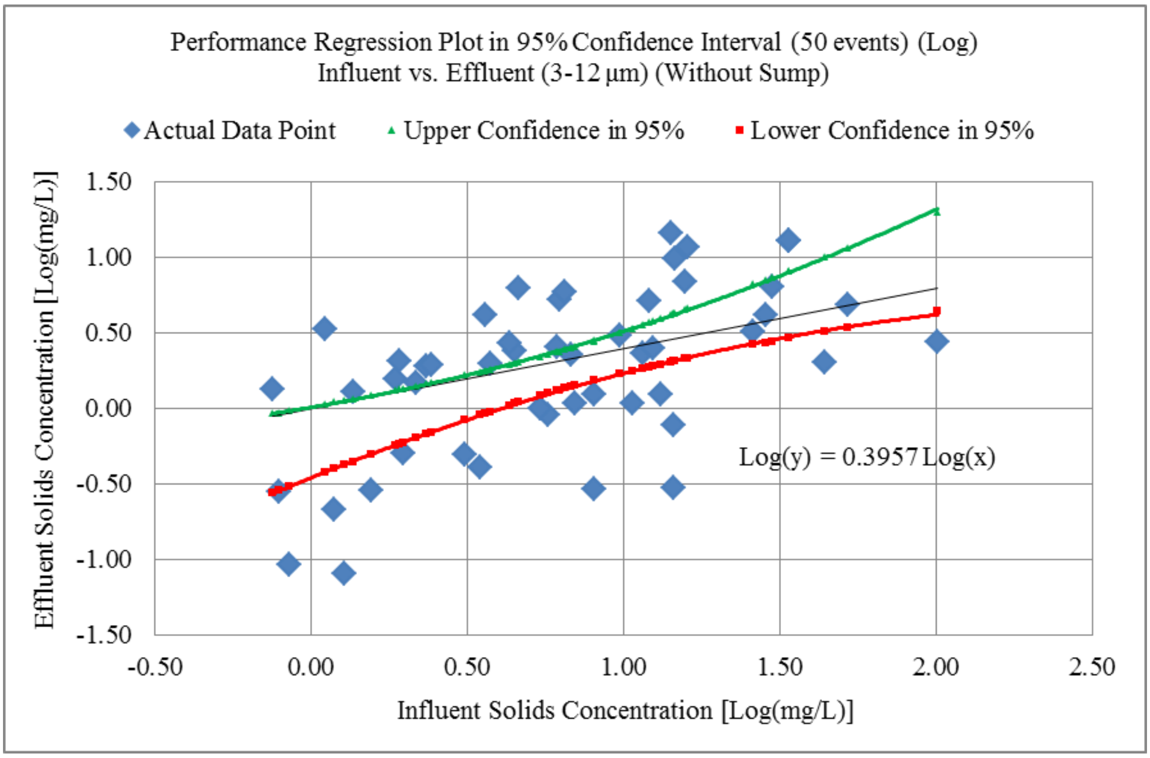
W= -951.000 T+ = 162.000 T-= -1113.000
Z-Statistic (based on positive ranks) = -4.590
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.4: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 3-12 µm Solids (50 Sampled Storms)







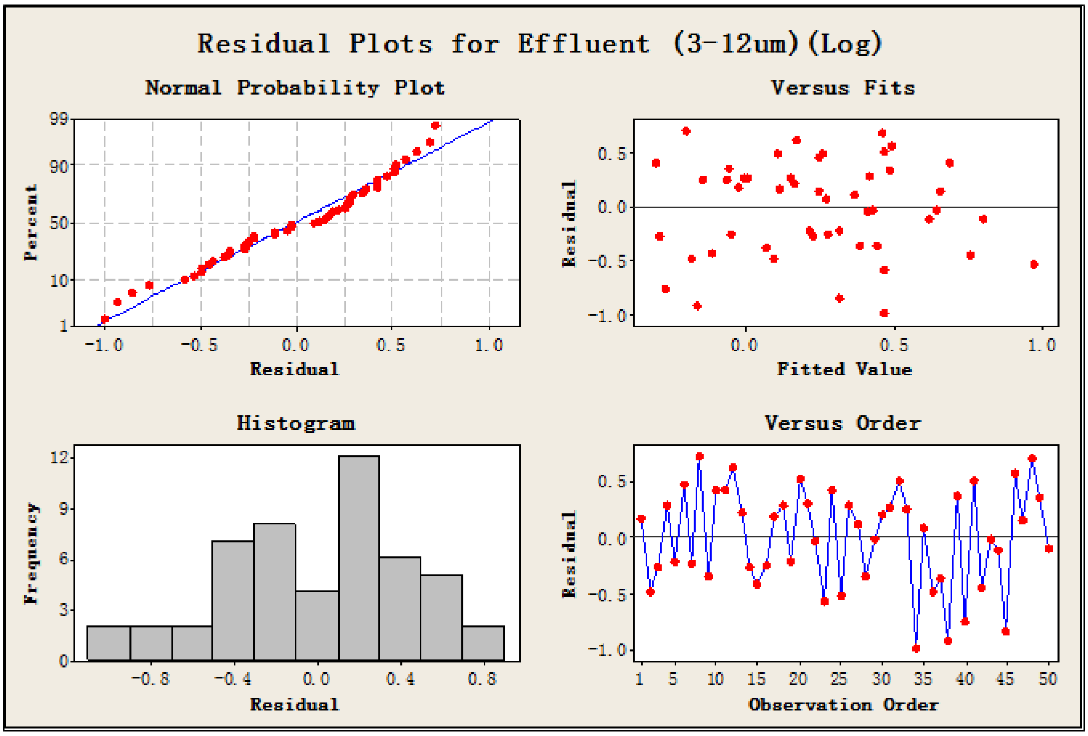
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.64
R Square	0.40
Adjusted R Square	0.38
Standard Error	0.46
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	7.04	7.04	33.19	0.00
Residual	49.00	10.39	0.21		
Total	50.00	17.42			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.40	0.07	5.76	0.00	0.26	0.53	0.26	0.53



Wilcoxon Signed Rank Test

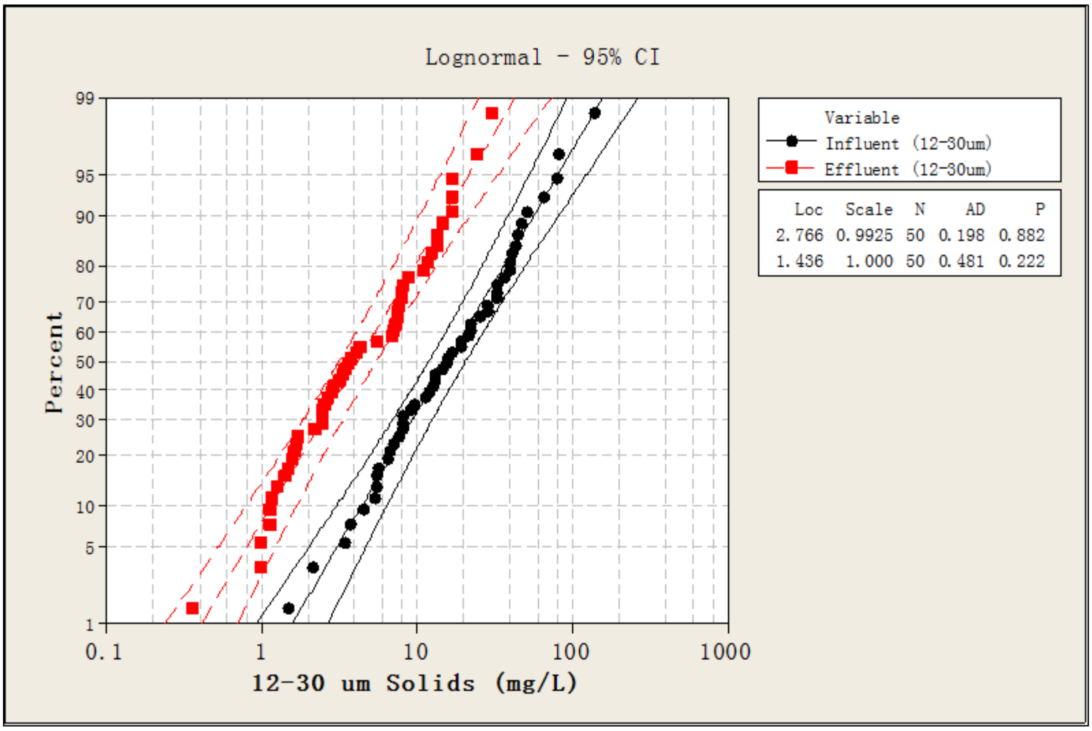
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

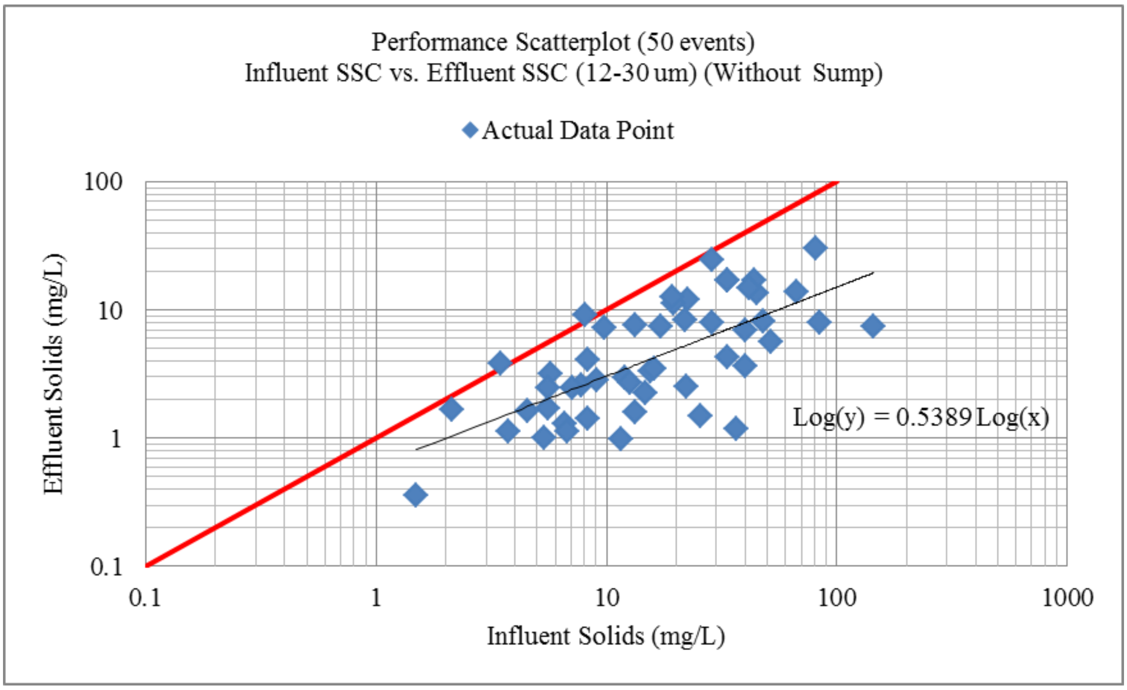
Group	N	Missing	Median	0.25	0.75
Influent 3-12um	50.00	0.00	6.36	2.30	14.49
Effluent 3-12um	50.00	0.00	2.02	0.97	4.34

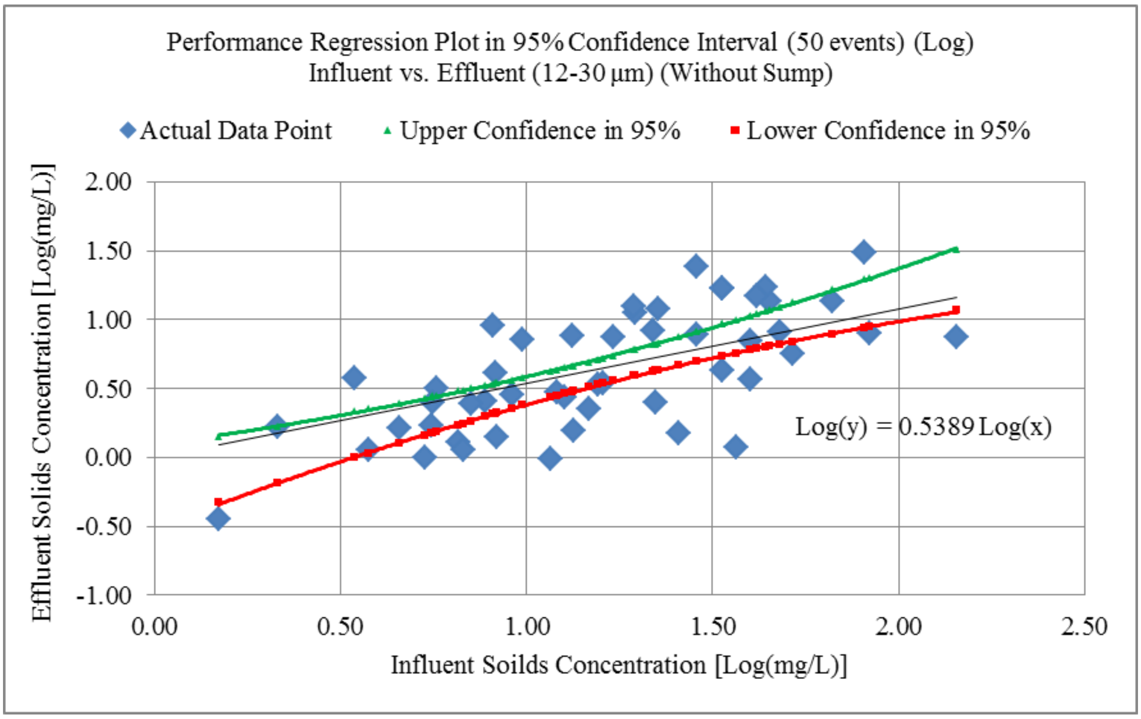
W= -1147.000 T+ = 64.000 T-= -1211.000
Z-Statistic (based on positive ranks) = -5.536
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.5: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 12-30 µm Solids (50 Sampled Storms)







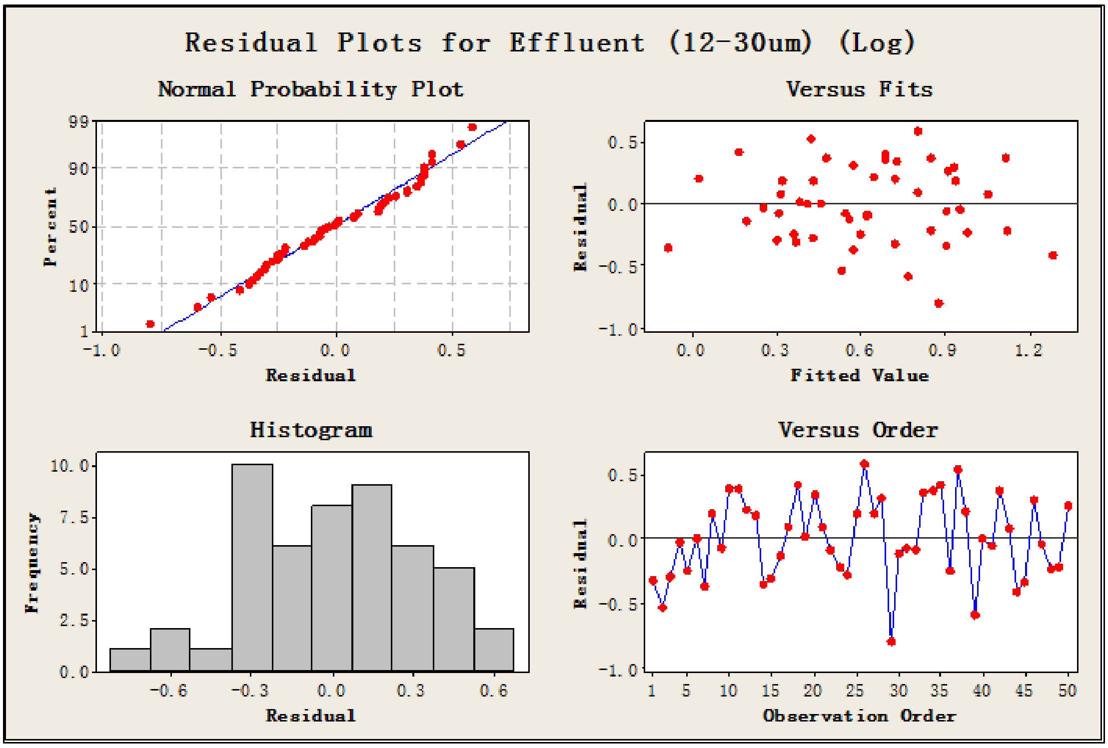
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.91
R Square	0.82
Adjusted R Square	0.80
Standard Error	0.32
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	23.59	23.59	226.22	0.00
Residual	49.00	5.11	0.10		
Total	50.00	28.70			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.54	0.04	15.04	0.00	0.47	0.61	0.47	0.61



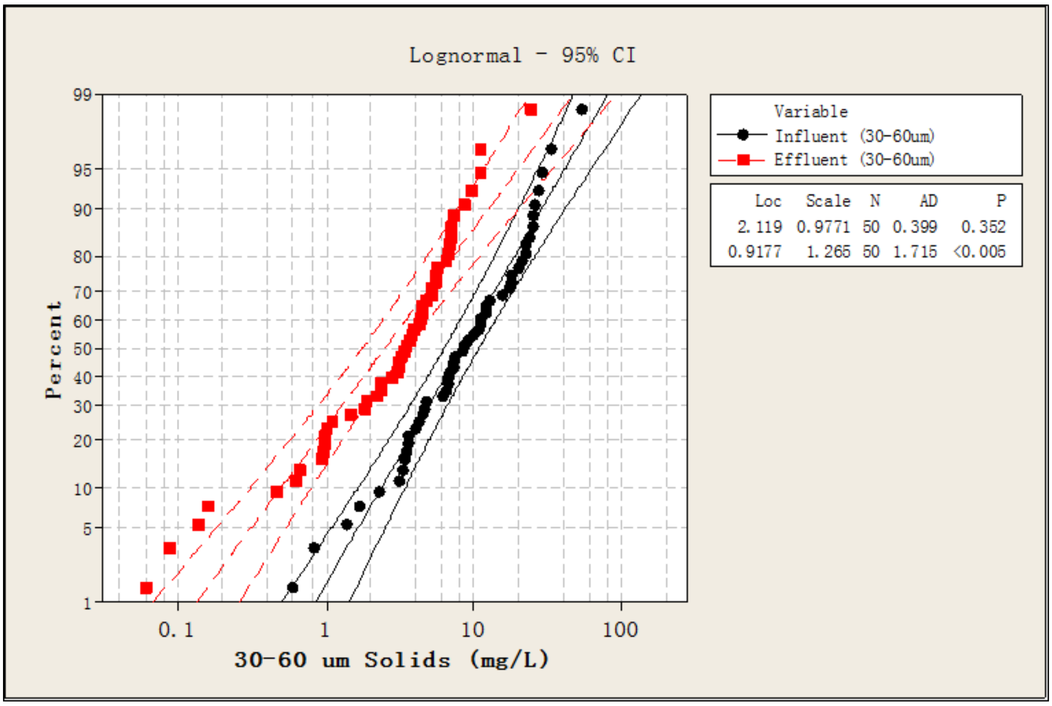
Wilcoxon Signed Rank Test

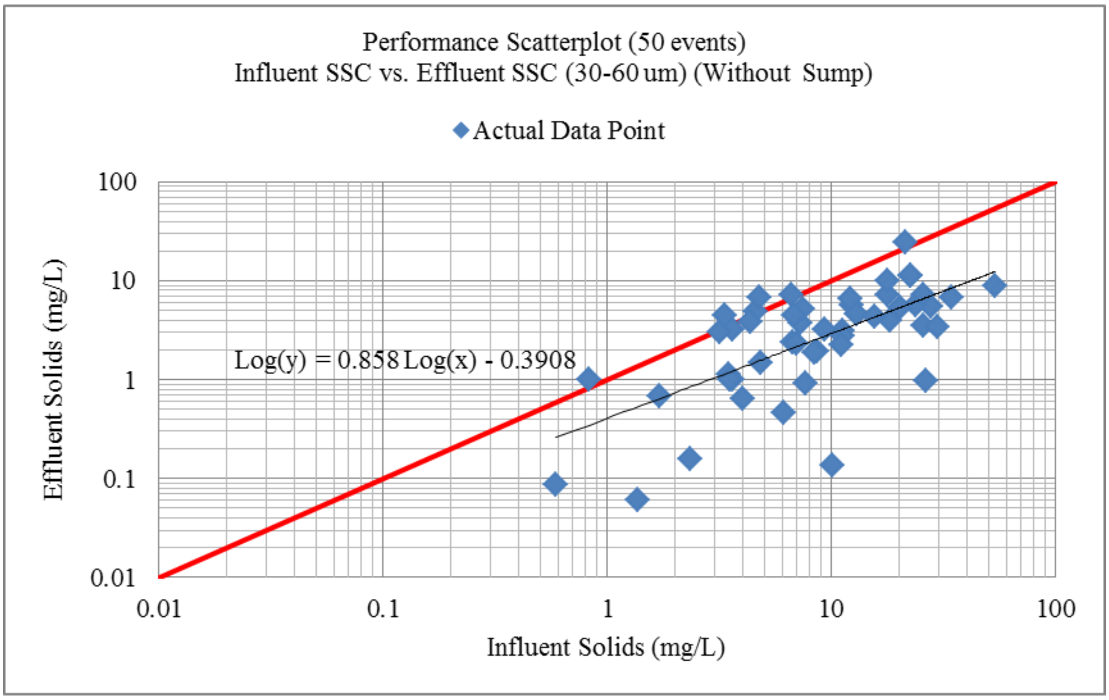
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent 12-30um	50.00	0.00	15.85	7.58	34.42
Effluent 12-30um	50.00	0.00	3.73	1.70	8.48

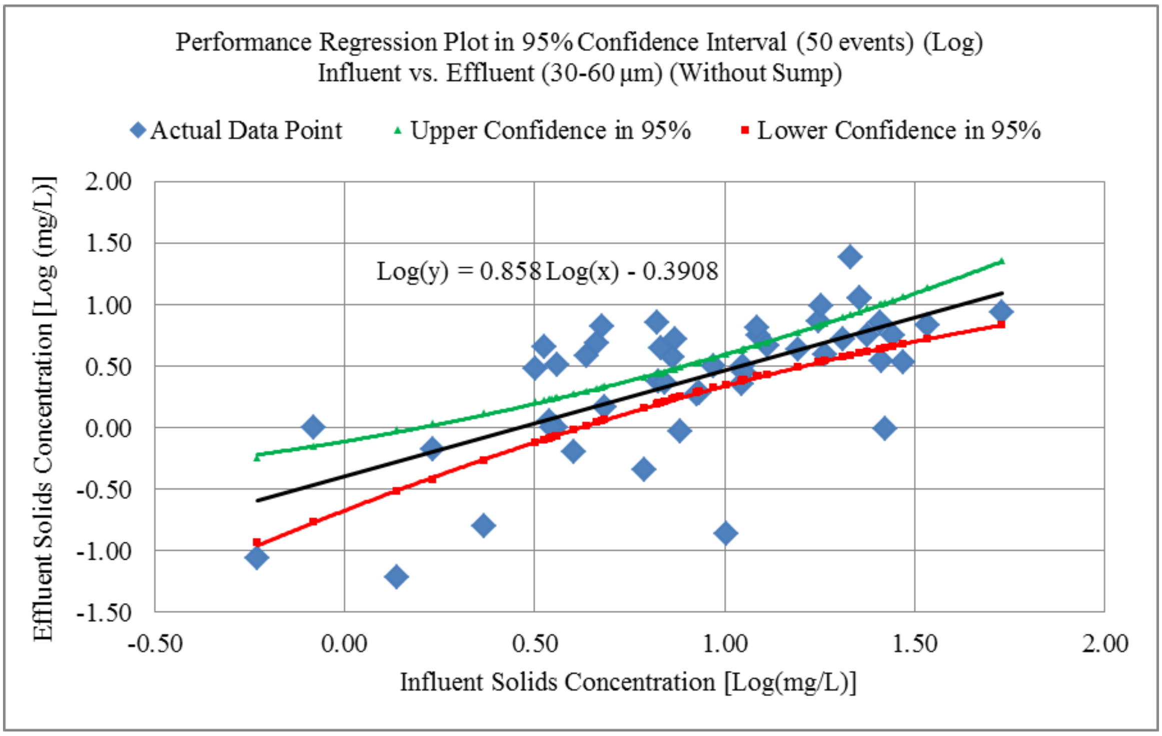
W= -1267.000 T+ = 4.000 T-= -1271.000
Z-Statistic (based on positive ranks) = -6.115
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.6: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 30-60 µm Solids (50 Sampled Storms)







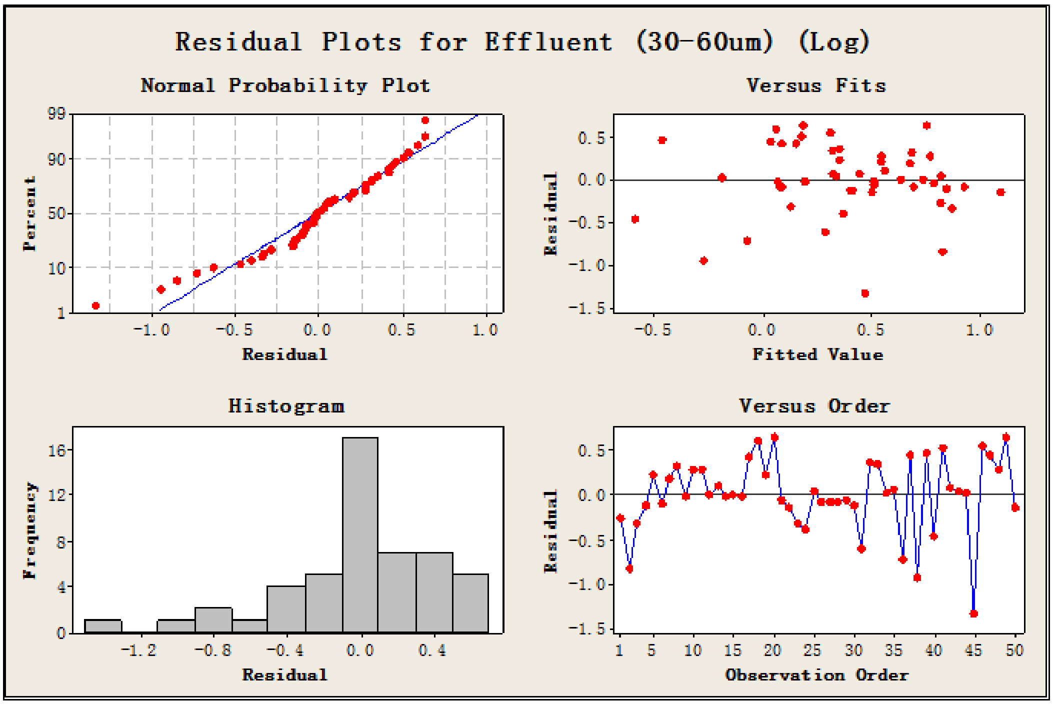
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.66
R Square	0.44
Adjusted R Square	0.43
Standard Error	0.42
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	6.50	6.50	37.61	0.00
Residual	48.00	8.29	0.17		
Total	49.00	14.79			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.39	0.14	-2.76	0.01	-0.68	-0.11	-0.68	-0.11
X Variable 1	0.86	0.14	6.13	0.00	0.58	1.14	0.58	1.14

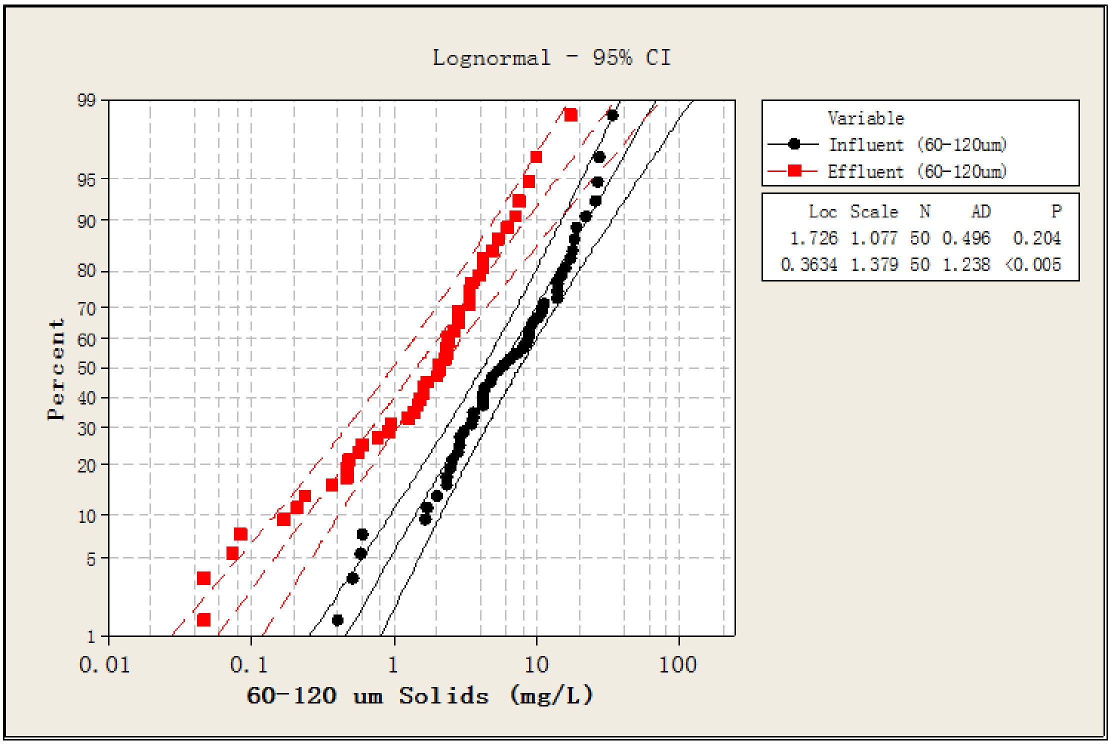


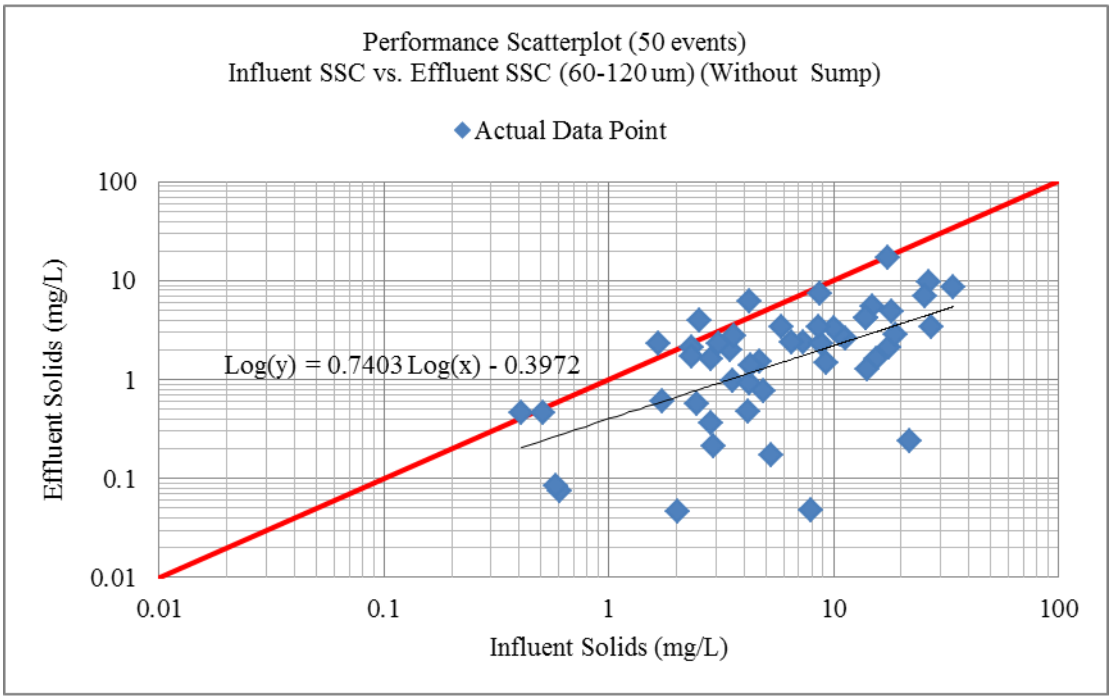
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent 30-60um	50.00	0.00	8.52	4.25	18.84
Effluent 30-60um	50.00	0.00	3.47	1.10	5.62

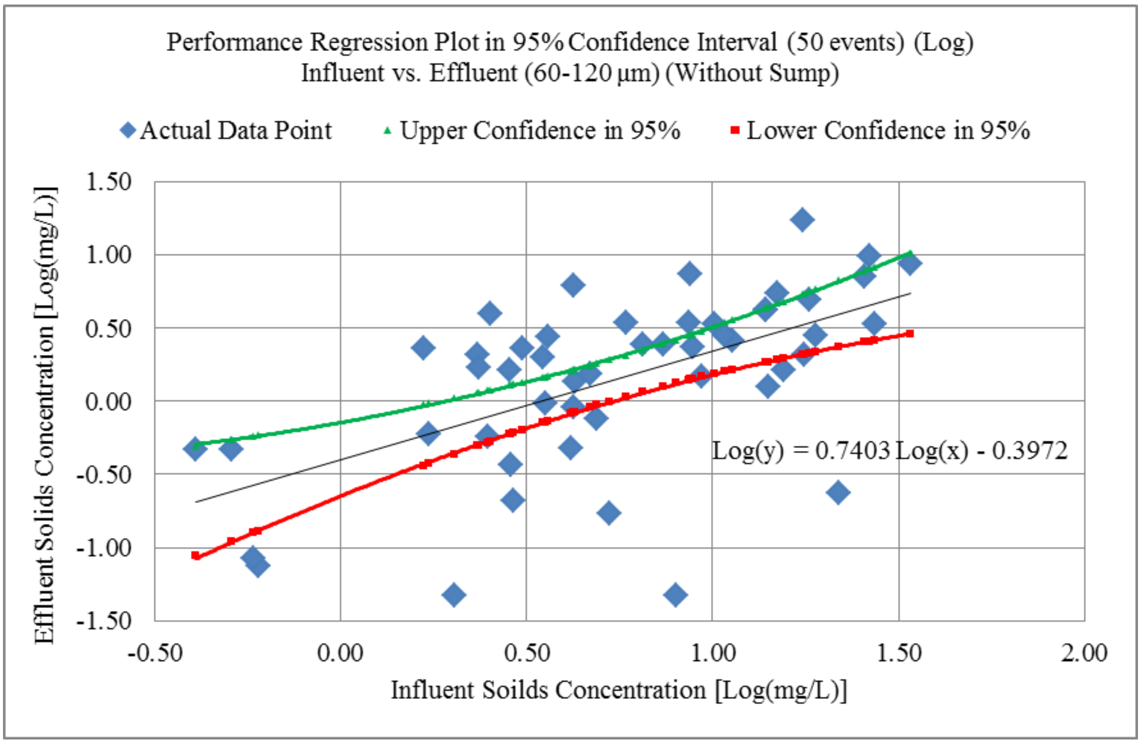
W= -1175.000 T+ = 50.000 T-= -1225.000
Z-Statistic (based on positive ranks) = -5.671
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.7: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 60-120 µm Solids (50 Sampled Storms)







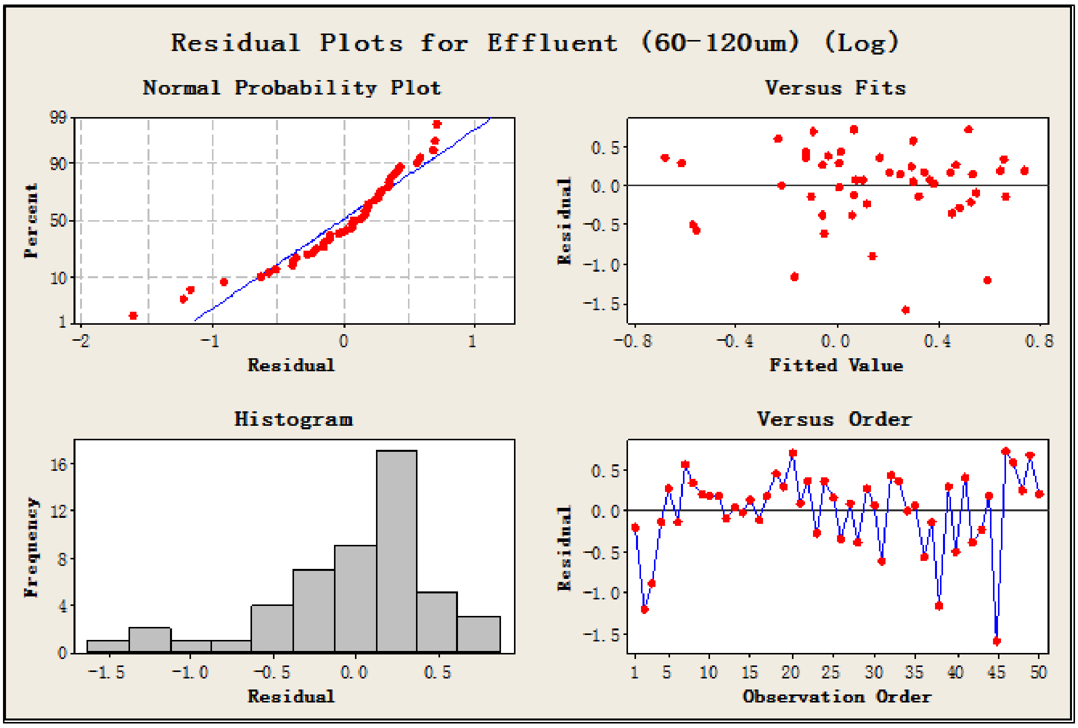
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.58
R Square	0.33
Adjusted R Square	0.32
Standard Error	0.49
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	5.87	5.87	24.09	0.00
Residual	48.00	11.70	0.24		
Total	49.00	17.58			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.40	0.13	-2.99	0.00	-0.66	-0.13	-0.66	-0.13
X Variable 1	0.74	0.15	4.91	0.00	0.44	1.04	0.44	1.04



Wilcoxon Signed Rank Test

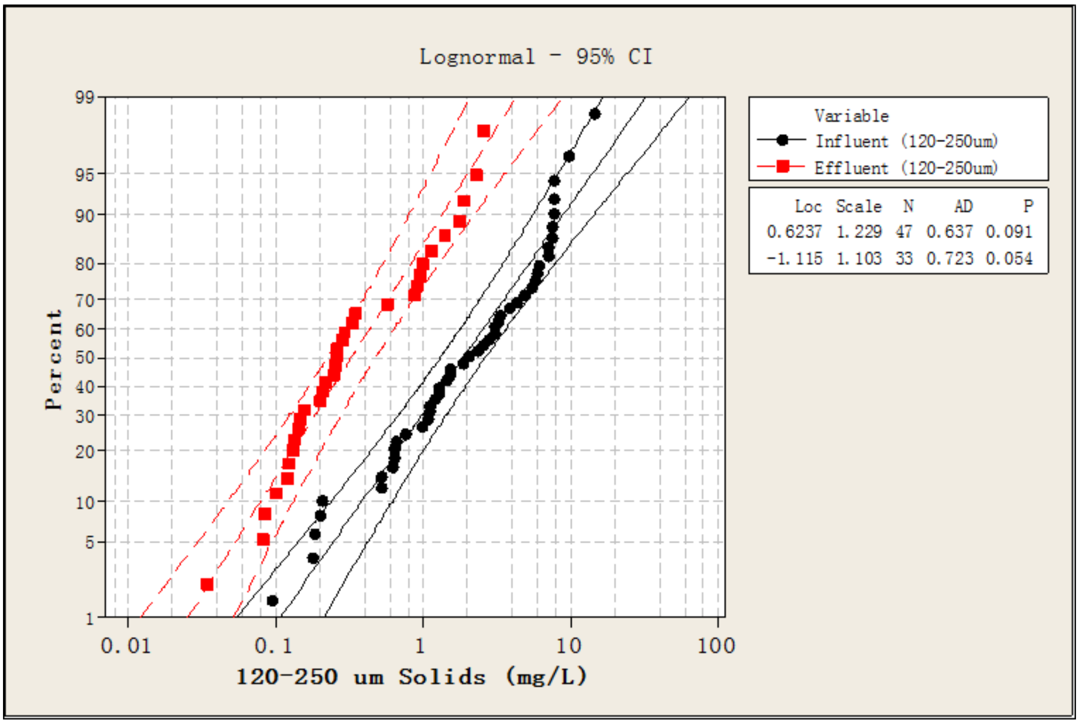
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

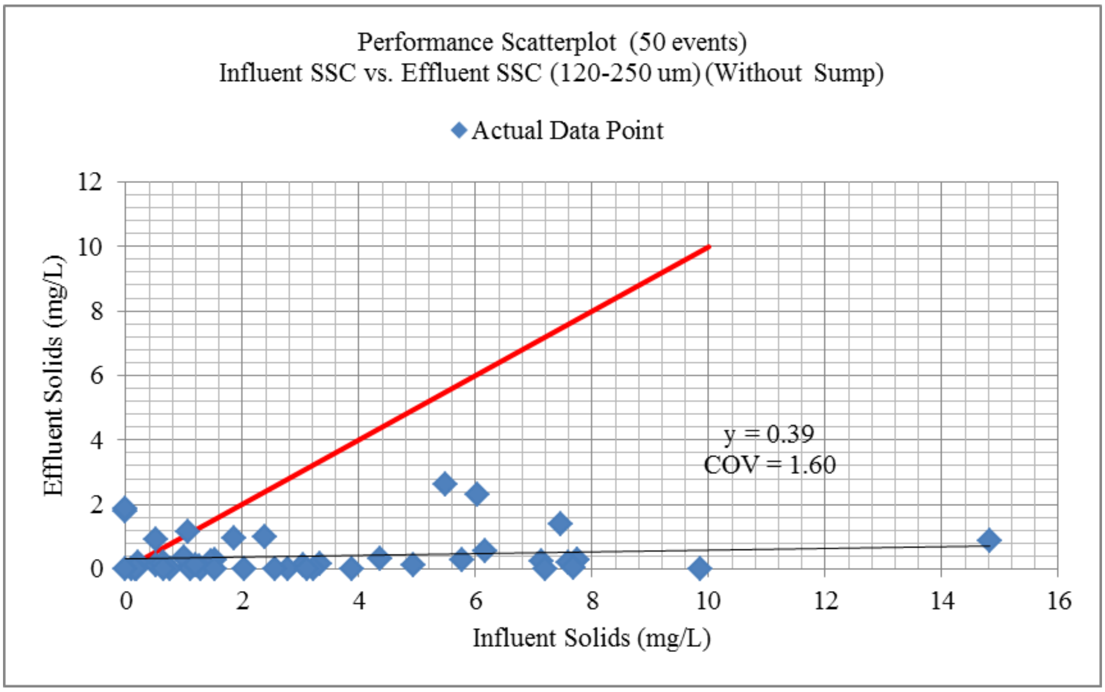
Group	N	Missing	Median	0.25	0.75
Influent 60-120um	50.00	0.00	5.56	2.86	13.97
Effluent 60-120um	50.00	0.00	2.09	0.59	3.44

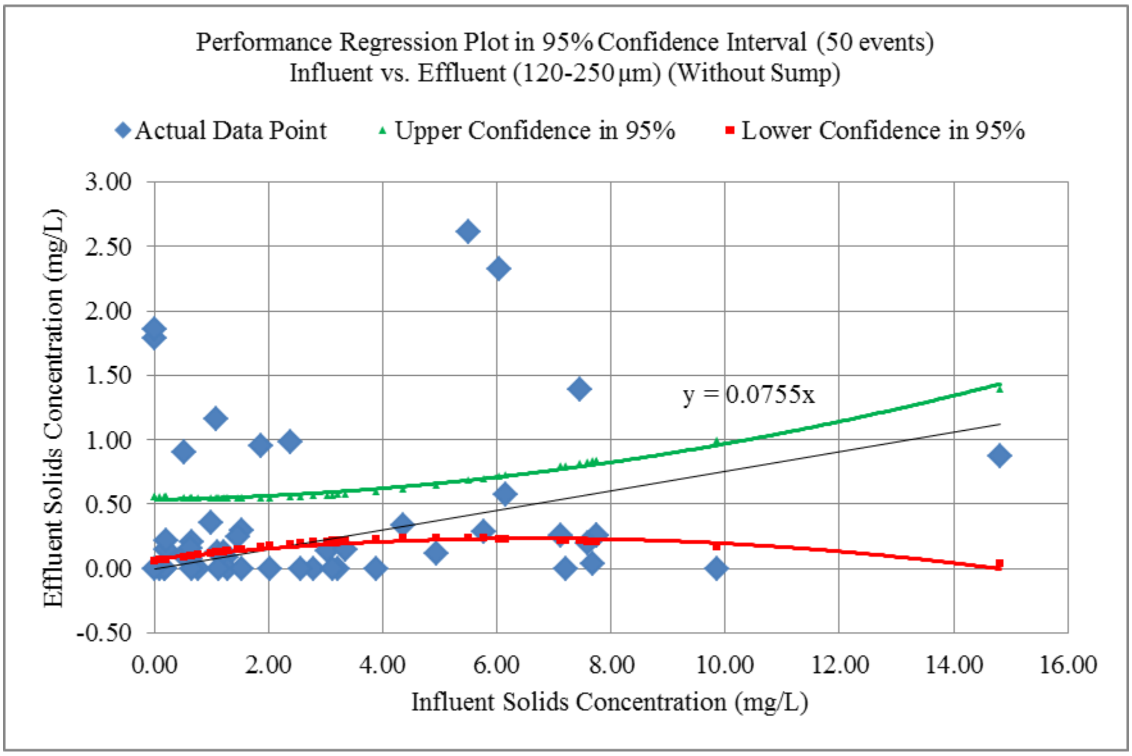
W= -1193.000 T+ = 41.000 T-= -1234.000
Z-Statistic (based on positive ranks) = -5.758
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.8: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 120-250 µm Solids (50 Sampled Storms)







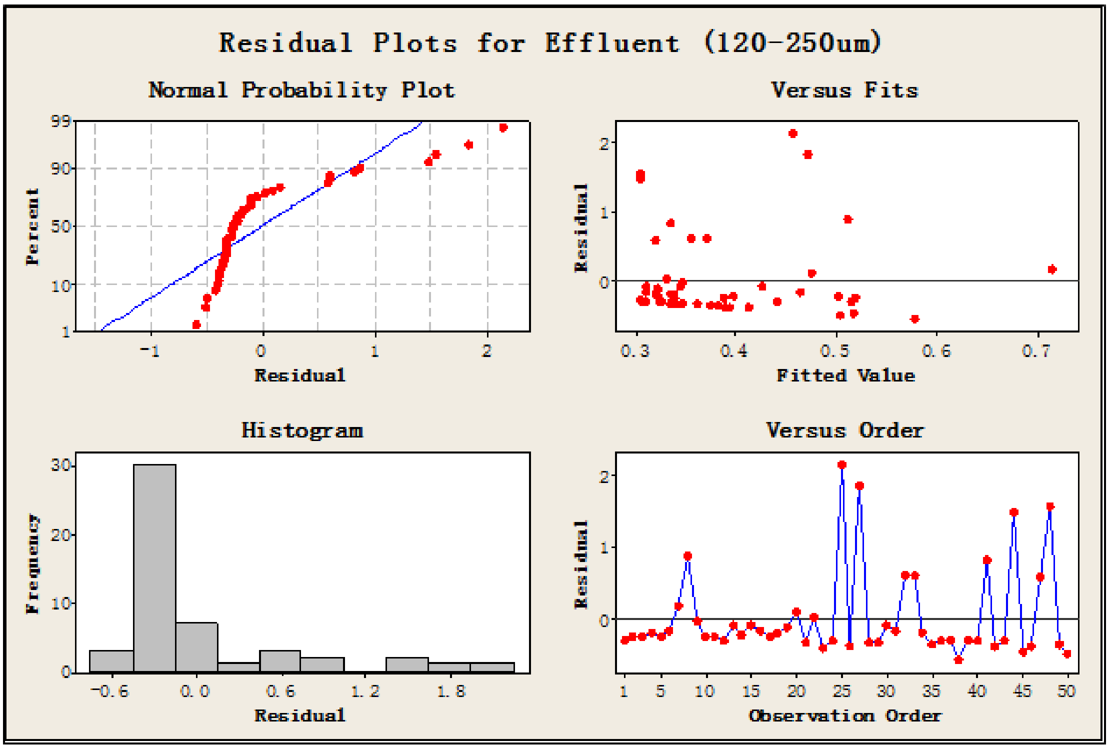
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.46
R Square	0.21
Adjusted R Square	0.19
Standard Error	0.66
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	5.67	5.67	13.15	0.00
Residual	49.00	21.14	0.43		
Total	50.00	26.82			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.08	0.02	3.63	0.00	0.03	0.12	0.03	0.12



Wilcoxon Signed Rank Test

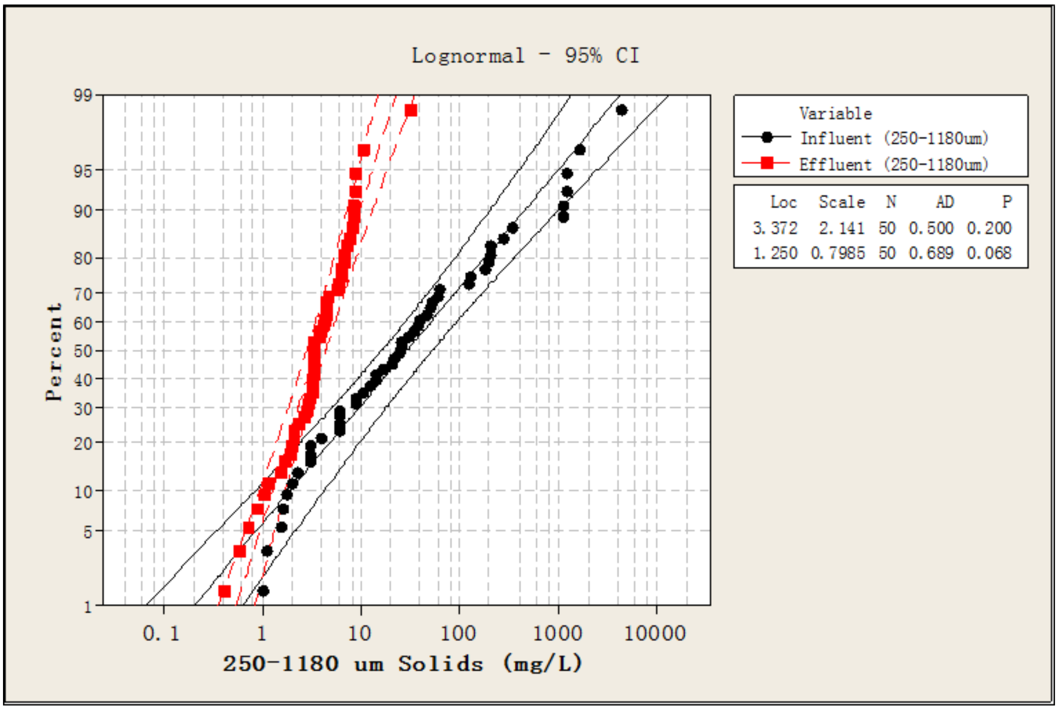
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

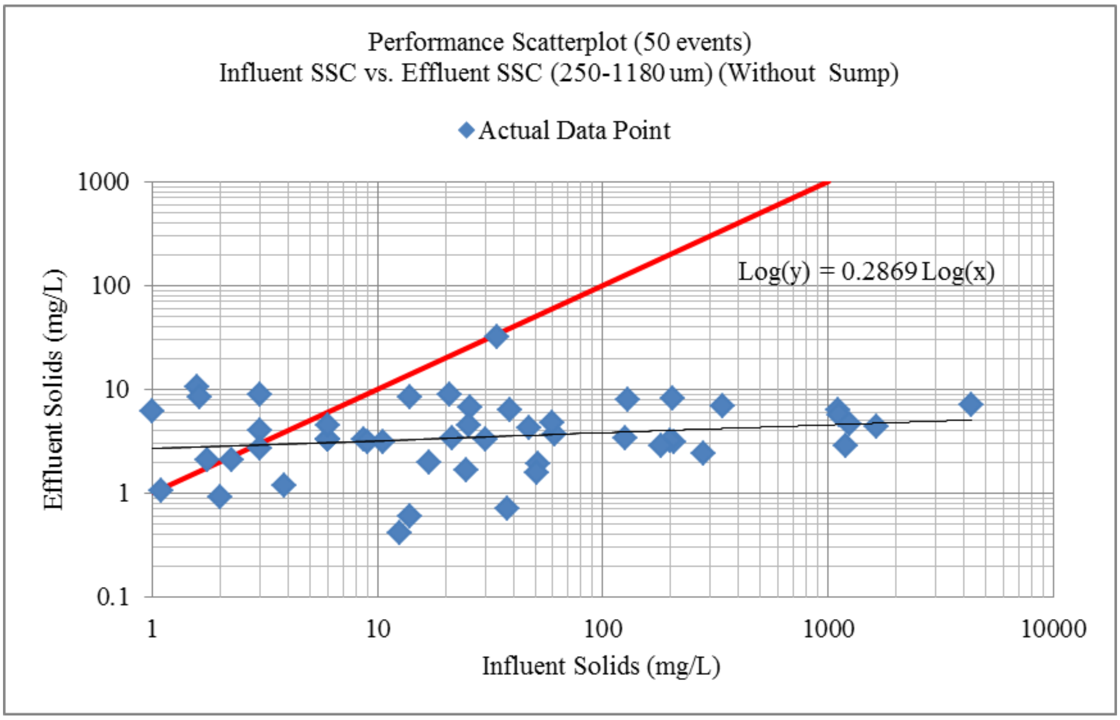
Group	N	Missing	Median	0.25	0.75
Influent 120-250um	50.00	0.00	1.70	0.65	5.57
Effluent 120-250um	50.00	0.00	0.14	0.00	0.34

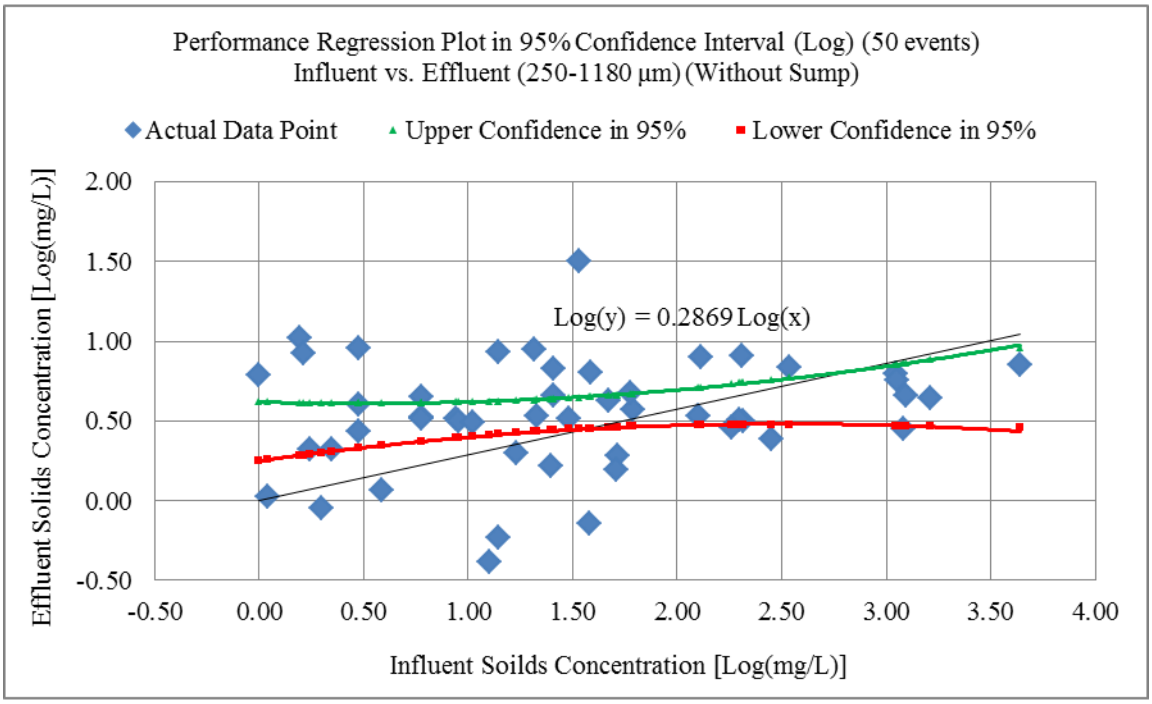
W= -1101.000 T+ = 62.000 T-= -1163.000
Z-Statistic (based on positive ranks) = -5.476
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.9: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for 250-1180 µm Solids (50 Sampled Storms)







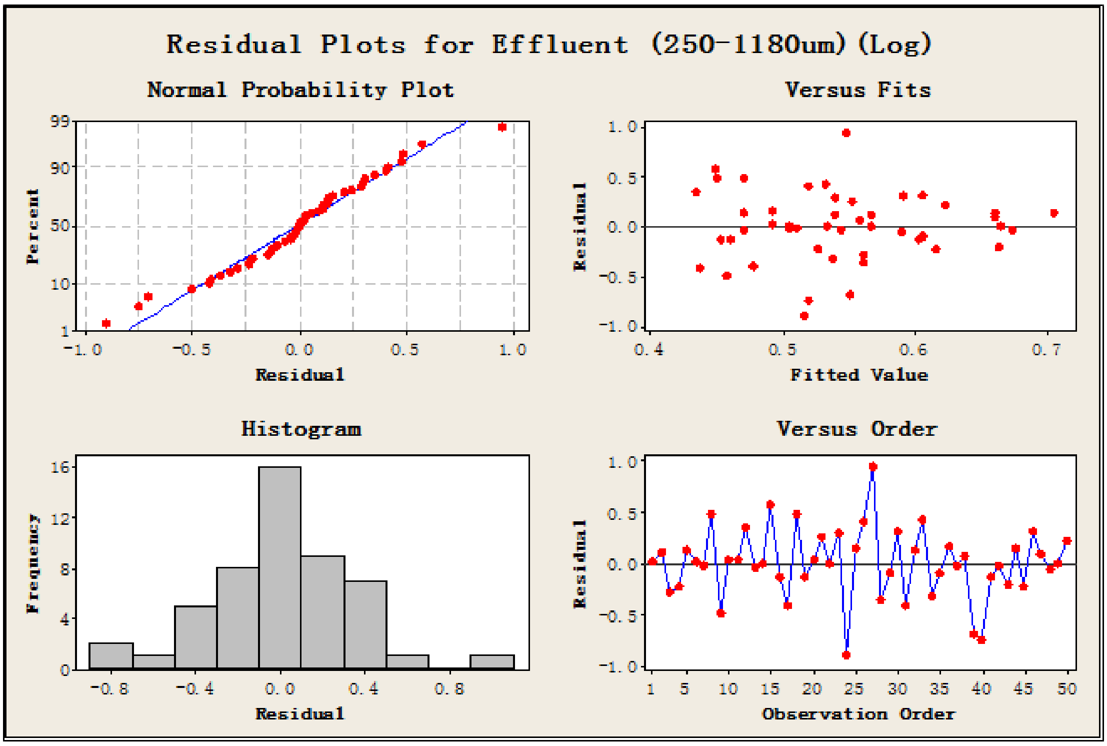
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.77
R Square	0.60
Adjusted R Square	0.58
Standard Error	0.41
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	12.31	12.31	72.48	0.00
Residual	49.00	8.32	0.17		
Total	50.00	20.63			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.29	0.03	8.51	0.00	0.22	0.35	0.22	0.35



Wilcoxon Signed Rank Test

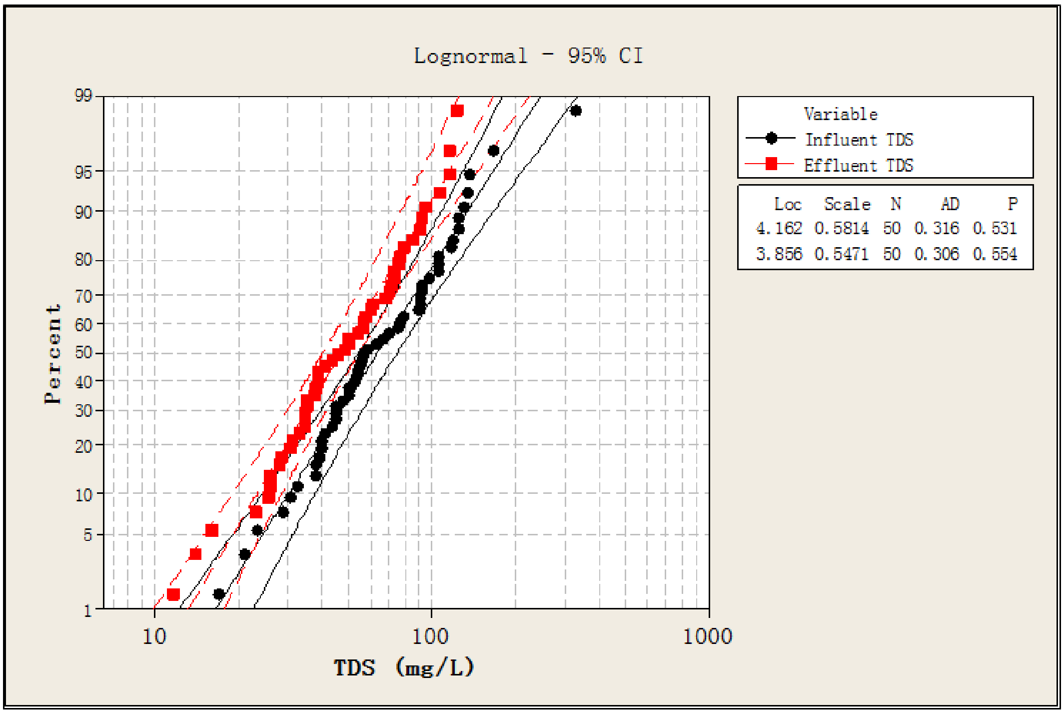
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

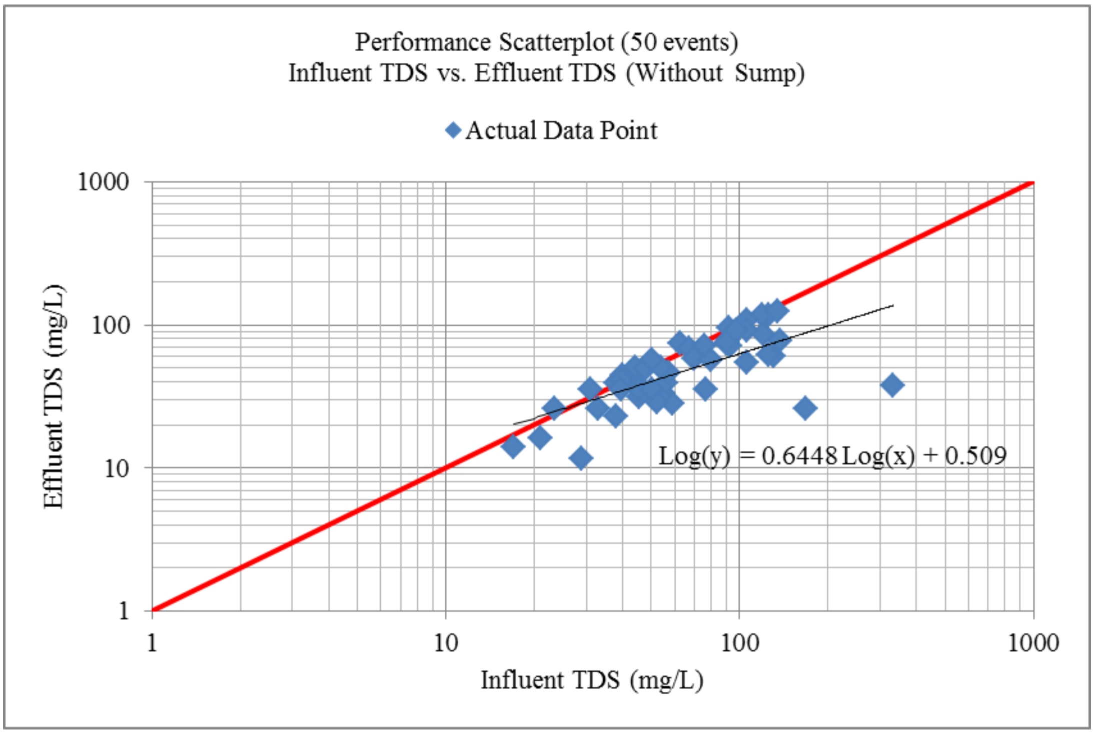
Group	N	Missing	Median	0.25	0.75
Influent 250-1180um	50.00	0.00	25.20	6.00	142.90
Effluent 250-1180um	50.00	0.00	3.37	2.34	6.27

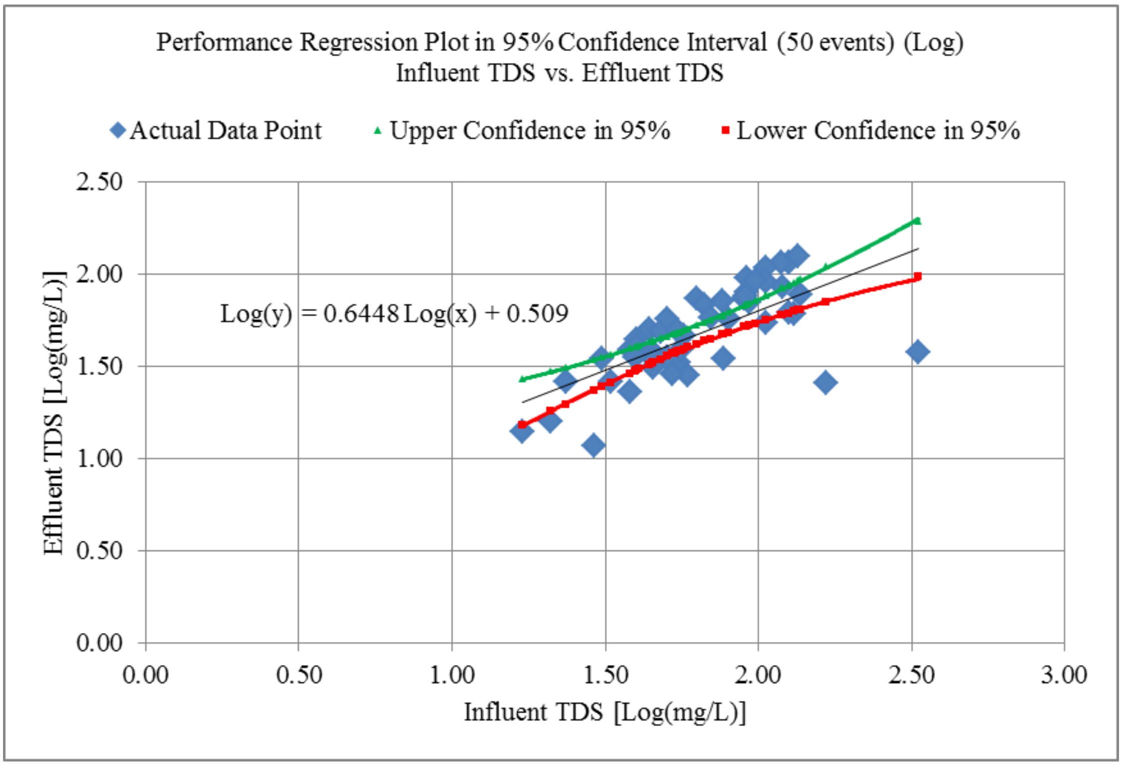
W= -1121.000 T+ = 77.000 T-= -1198.000
Z-Statistic (based on positive ranks) = -5.411
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.10: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for TDS (50 Sampled Storms)







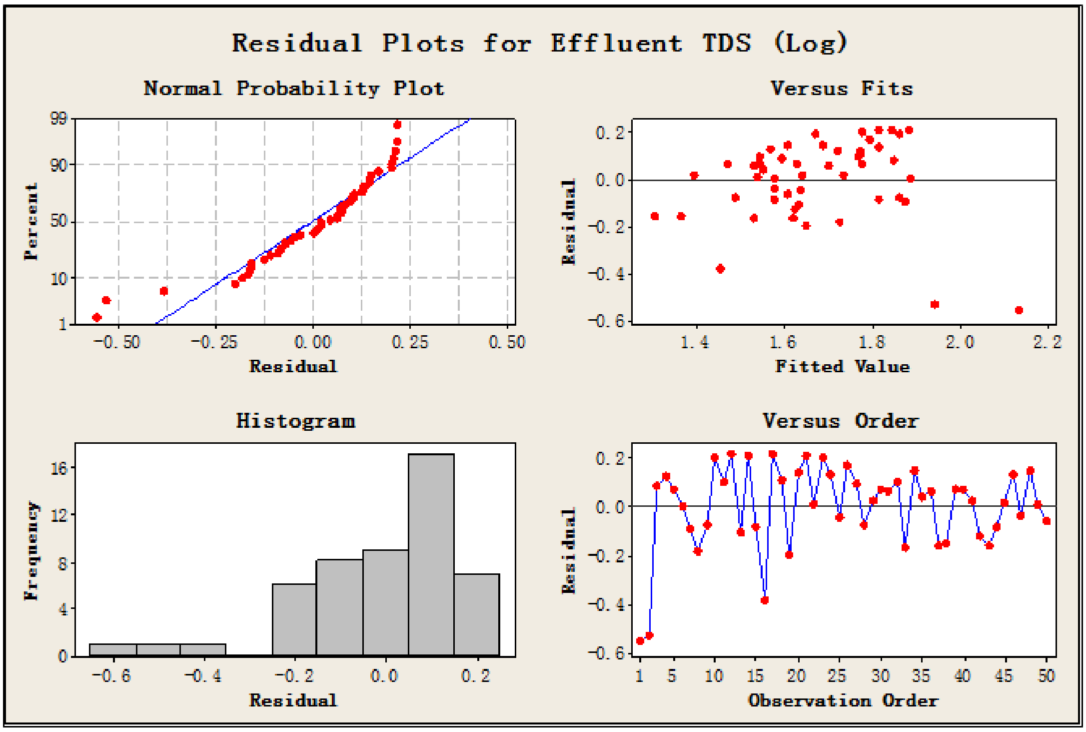
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.69
R Square	0.47
Adjusted R Square	0.46
Standard Error	0.17
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.30	1.30	42.49	0.00
Residual	48.00	1.47	0.03		
Total	49.00	2.77			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.51	0.18	2.82	0.01	0.15	0.87	0.15	0.87
X Variable 1	0.64	0.10	6.52	0.00	0.45	0.84	0.45	0.84



Wilcoxon Signed Rank Test

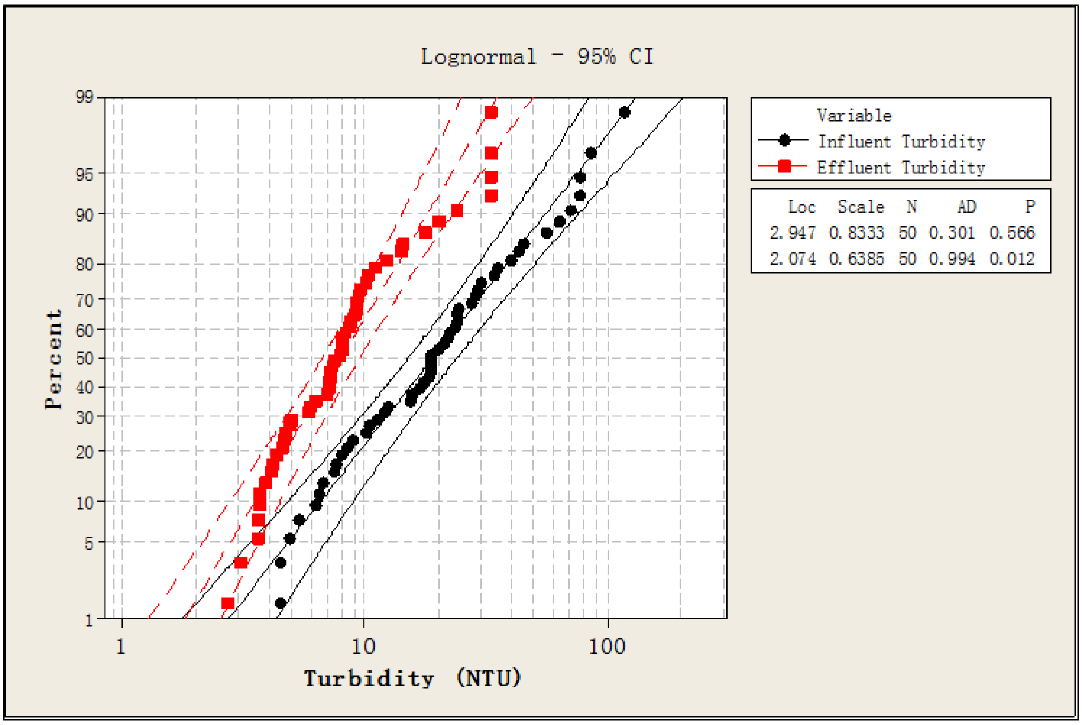
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

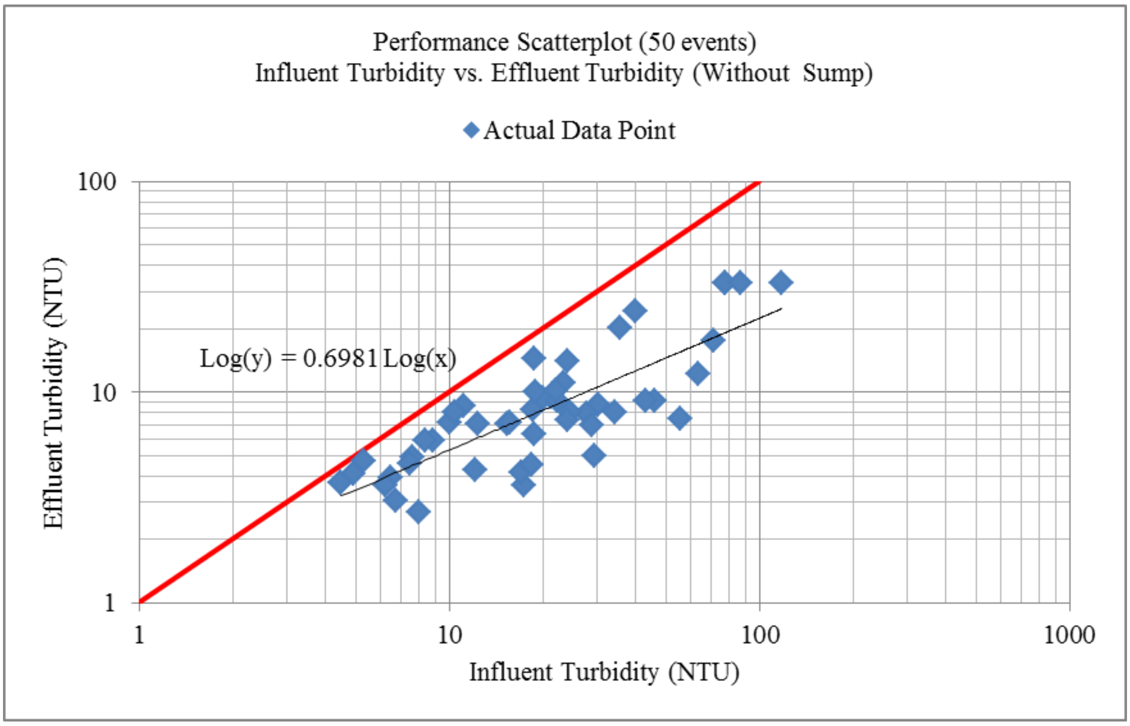
Group	N	Missing	Median	0.25	0.75
Influent TDS	50.00	0.00	58.00	43.25	100.00
Effluent TDS	50.00	0.00	47.50	34.58	74.05

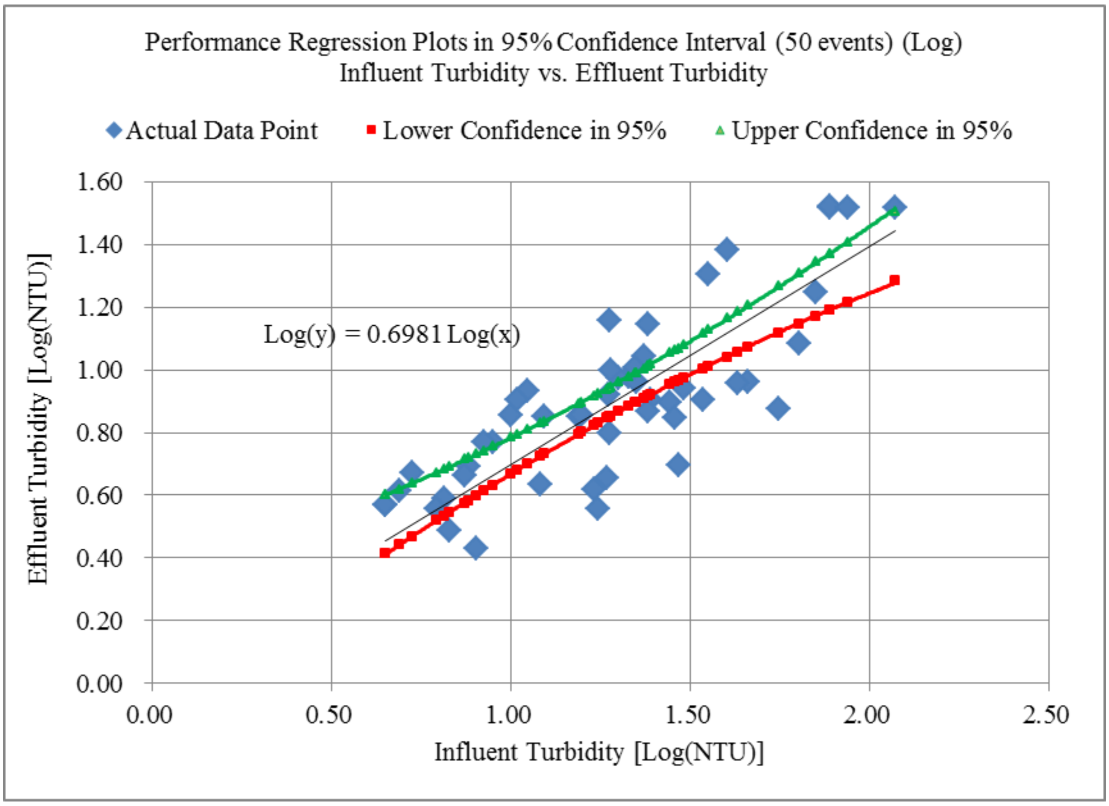
W= -1040.000 T+ = 117.500 T-= -1157.500
Z-Statistic (based on positive ranks) = -5.020
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix B.11: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Turbidity (50 Sampled Storms)







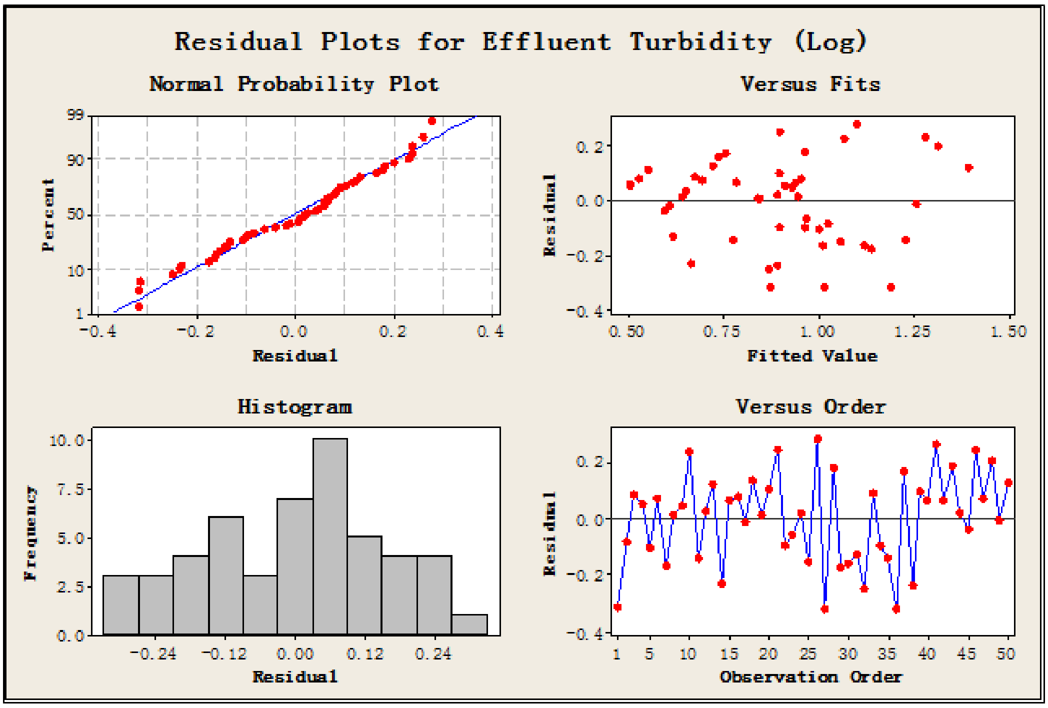
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.97
Adjusted R Square	0.95
Standard Error	0.16
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	43.04	43.04	1636.27	0.00
Residual	49.00	1.29	0.03		
Total	50.00	44.33			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.70	0.02	40.45	0.00	0.66	0.73	0.66	0.73



Wilcoxon Signed Rank Test

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Group	N	Missing	Median	0.25	0.75
Influent Turbidity	50.00	0.00	18.83	9.73	31.21
Effluent Turbidity	50.00	0.00	7.70	4.68	10.05

W= -1275.000 T+ = 0.000 T-= -1275.000
Z-Statistic (based on positive ranks) = -6.154
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix C.1: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent SSC

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent SSC (Controlled)	12	37.50	40.0	2.27
Effluent SSC(Initial 20)	17	19.00	26.6	-0.97
Effluent SSC(Current 30)	30	22.00	27.9	-0.95
Overall	59		30.0	

H = 5.21 DF = 2 P = 0.074

H = 5.22 DF = 2 P = 0.074 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	13
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent SSC (Controlled)	0.00000	*	*
Effluent SSC(Initial 20)	2.07749	0.000000	*
Effluent SSC(Current 30)	2.06679	0.254779	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent SSC (Controlled)	0.00000	*	*
Effluent SSC(Initial 20)	2.07806	0.000000	*
Effluent SSC(Current 30)	2.06737	0.254850	0

2. Table of P-values

Effluent SSC (Controlled)	1.00000	*	*
Effluent SSC(Initial 20)	0.03770	1.00000	*
Effluent SSC(Current 30)	0.03870	0.79884	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

				Confidence Interval		
	N	Median	Achieved Confidence	Lower	Upper	Position
Effluent SSC (Controlled)	12	37.50	0.6123	22.00	53.00	5
			0.8053	20.01	56.32	NLI
			0.8540	19.00	58.00	4
Effluent SSC(Initial 20)	17	19.00	0.6677	17.00	21.10	7
			0.8053	15.22	22.82	NLI
			0.8565	14.00	24.00	6
Effluent SSC(Current 30)	30	22.00	0.7995	16.00	29.31	12
			0.8053	15.90	29.32	NLI
			0.9013	13.00	29.85	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent SSC (Controlled) vs. Effluent SSC (Initial 20)
Effluent SSC (Controlled) vs. Effluent SSC (Current 30)

Z vs. Critical value	P-value
2.07806 >= 1.834	0.0377
2.06737 >= 1.834	0.0387

Appendix C.2: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 0.45-3 µm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (0.45-3um)(Controlled)	12	4.0500	56.3	5.31
Effluent (0.45-3um)(Initial 20)	20	0.3138	31.1	-0.12
Effluent (0.45-3um)(Current 30)	30	0.1030	21.8	-4.08
Overall	62		31.5	

H = 31.36 DF = 2 P = 0.000

H = 31.36 DF = 2 P = 0.000 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	3
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (0.45-3um)(Controlled)	0.00000	*	*
Effluent (0.45-3um)(Initial 20)	3.83027	0.00000	*
Effluent (0.45-3um)(Current 30)	5.59848	1.77926	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (0.45-3um)(Controlled)	0.00000	*	*
Effluent (0.45-3um)(Initial 20)	3.83042	0.00000	*
Effluent (0.45-3um)(Current 30)	5.59869	1.77932	0

2. Table of P-values

Effluent (0.45-3um)(Controlled)	1.00000	*	*
Effluent (0.45-3um)(Initial 20)	0.00013	1.00000	*
Effluent (0.45-3um)(Current 30)	0.00000	0.07519	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

				Confidence Interval	
	N	Median	Achieved Confidence	Lower	Upper
Effluent (0.45-3um)(Controlled)	12	4.050	0.6123	2.700	6.300
			0.8053	2.700	6.632
			0.8540	2.700	6.800
Effluent (0.45-3um)(Initial 20)	20	0.3138	0.7368	0.1891	0.4032
			0.8053	0.1868	0.5432
			0.8847	0.1818	0.8447
Effluent (0.45-3um)(Current 30)	30	0.1030	0.7995	0.0987	0.1185
			0.8053	0.0987	0.1193
			0.9013	0.0983	0.1439

	Position
Effluent (0.45-3um)(Controlled)	5
	NLI
	4
Effluent (0.45-3um)(Initial 20)	8
	NLI
	7
Effluent (0.45-3um)(Current 30)	12
	NLI
	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups	Z vs. Critical value	P-value
Effluent (0.45-3um)(Controlled) vs. Effluent (0.45-3um)(Current 30)	5.59869 >= 1.834	0.0000
Effluent (0.45-3um)(Controlled) vs. Effluent (0.45-3um)(Initial 20)	3.83042 >= 1.834	0.0001

Appendix C.3: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 3-12 μm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (3-12um)(Controlled)	12	16.500	54.2	4.85
Effluent (3-12um)(Initial 20)	20	1.907	25.3	-1.87
Effluent (3-12um)(Current 30)	30	2.298	26.6	-2.08
Overall	62		31.5	

H = 23.55 DF = 2 P = 0.000

H = 23.55 DF = 2 P = 0.000 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	3
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (3-12um)(Controlled)	0.00000	*	*
Effluent (3-12um)(Initial 20)	4.38179	0.000000	*
Effluent (3-12um)(Current 30)	4.47878	0.243208	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (3-12um)(Controlled)	0.00000	*	*
Effluent (3-12um)(Initial 20)	4.38196	0.000000	*
Effluent (3-12um)(Current 30)	4.47895	0.243217	0

2. Table of P-values

Effluent (3-12um)(Controlled)	1.00000	*	*
Effluent (3-12um)(Initial 20)	0.00001	1.00000	*
Effluent (3-12um)(Current 30)	0.00001	0.80784	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

				Confidence Interval		
			Achieved			
	N	Median	Confidence	Lower	Upper	Position
Effluent (3-12um)(Controlled)	12	16.50	0.6123	12.00	23.00	5
			0.8053	10.21	24.33	NLI
			0.8540	9.30	25.00	4
Effluent (3-12um)(Initial 20)	20	1.907	0.7368	1.087	2.410	8
			0.8053	1.083	2.452	NLI
			0.8847	1.074	2.542	7
Effluent (3-12um)(Current 30)	30	2.298	0.7995	1.560	2.769	12
			0.8053	1.557	2.779	NLI
			0.9013	1.471	3.051	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent (3-12um)(Controlled) vs. Effluent (3-12um)(Current 30)
Effluent (3-12um)(Controlled) vs. Effluent (3-12um)(Initial 20)

Z vs. Critical value	P-value
4.47895 >= 1.834	0
4.38196 >= 1.834	0

Appendix C.4: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 12-30 µm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (12-30um)(Controlled)	12	10.950	43.9	2.65
Effluent (12-30um)(Initial 20)	20	2.499	20.3	-3.39
Effluent (12-30um)(Current 30)	30	7.336	34.0	1.07
Overall	62		31.5	

H = 14.05 DF = 2 P = 0.001
H = 14.05 DF = 2 P = 0.001 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons: 3
Ties: 2
Family Alpha: 0.2
Bonferroni Individual Alpha: 0.067
Bonferroni Z-value (2-sided): 1.834

Standardized Absolute Mean Rank Differences
|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n
Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (12-30um)(Controlled)	0.00000	*	*
Effluent (12-30um)(Initial 20)	3.59246	0.00000	*
Effluent (12-30um)(Current 30)	1.60382	2.64648	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (12-30um)(Controlled)	0.00000	*	*
Effluent (12-30um)(Initial 20)	3.59255	0.00000	*
Effluent (12-30um)(Current 30)	1.60386	2.64655	0

2. Table of P-values

Effluent (12-30um)(Controlled)	1.00000	*	*
Effluent (12-30um)(Initial 20)	0.00033	1.00000	*
Effluent (12-30um)(Current 30)	0.10875	0.00813	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

	N	Median	Achieved Confidence	Confidence Interval Lower	Confidence Interval Upper	Position
Effluent (12-30um)(Controlled)	12	10.95	0.6123	5.00	16.00	5
			0.8053	4.34	18.66	NLI
			0.8540	4.00	20.00	4
Effluent (12-30um)(Initial 20)	20	2.499	0.7368	1.639	2.956	8
			0.8053	1.620	3.028	NLI
			0.8847	1.580	3.184	7
Effluent (12-30um)(Current 30)	30	7.336	0.7995	4.303	8.039	12
			0.8053	4.281	8.040	NLI
			0.9013	3.658	8.064	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent (12-30um)(Controlled) vs. Effluent (12-30um)(Initial 20)
Effluent (12-30um)(Initial 20) vs. Effluent (12-30um)(Current 30)

Z vs. Critical value	P-value
3.59255 >= 1.834	0.0003
2.64655 >= 1.834	0.0081

Appendix C.5: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 30-60 μm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (30-60um)(Controlled)	12	4.200	37.1	1.19
Effluent (30-60um)(Initial 20)	20	4.563	36.1	1.39
Effluent (30-60um)(Current 30)	30	2.913	26.2	-2.24
Overall	62		31.5	

H = 5.04 DF = 2 P = 0.081

H = 5.04 DF = 2 P = 0.081 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	1
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (30-60um)(Controlled)	0.00000	*	*
Effluent (30-60um)(Initial 20)	0.14926	0.00000	*
Effluent (30-60um)(Current 30)	1.76609	1.90086	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (30-60um)(Controlled)	0.00000	*	*
Effluent (30-60um)(Initial 20)	0.14927	0.00000	*
Effluent (30-60um)(Current 30)	1.76611	1.90088	0

2. Table of P-values

Effluent (30-60um)(Controlled)	1.00000	*	*
Effluent (30-60um)(Initial 20)	0.88134	1.00000	*
Effluent (30-60um)(Current 30)	0.07738	0.05732	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

				Confidence Interval		
	N	Median	Achieved Confidence	Lower	Upper	Position
Effluent (30-60um)(Controlled)	12	4.200	0.6123	2.400	5.700	5
			0.8053	2.201	7.893	NLI
			0.8540	2.100	9.000	4
Effluent (30-60um)(Initial 20)	20	4.563	0.7368	3.489	5.575	8
			0.8053	3.410	5.582	NLI
			0.8847	3.240	5.599	7
Effluent (30-60um)(Current 30)	30	2.913	0.7995	2.250	3.822	12
			0.8053	2.237	3.827	NLI
			0.9013	1.858	3.965	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent (30-60um)(Initial 20) vs. Effluent (30-60um)(Current 30)

Z vs. Critical value	P-value
1.90088 >= 1.834	0.0573

Appendix C.6: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 60-120 µm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (60-120um)(Controlled)	12	0.7250	22.7	-1.89
Effluent (60-120um)(Initial 20)	20	2.5139	40.6	2.74
Effluent (60-120um)(Current 30)	30	1.5782	29.0	-1.07
Overall	62		31.5	

H = 8.56 DF = 2 P = 0.014

H = 8.56 DF = 2 P = 0.014 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	3
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (60-120um)(Controlled)	0.00000	*	*
Effluent (60-120um)(Initial 20)	2.72218	0.00000	*
Effluent (60-120um)(Current 30)	1.02233	2.23367	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (60-120um)(Controlled)	0.00000	*	*
Effluent (60-120um)(Initial 20)	2.72228	0.00000	*
Effluent (60-120um)(Current 30)	1.02237	2.23376	0

2. Table of P-values

Effluent (60-120um)(Controlled)	1.00000	*	*
Effluent (60-120um)(Initial 20)	0.00648	1.00000	*
Effluent (60-120um)(Current 30)	0.30661	0.02550	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

			Achieved	Confidence Interval		
	N	Median	Confidence	Lower	Upper	Position
Effluent (60-120um)(Controlled)	12	0.725	0.6123	0.600	0.820	5
			0.8053	0.580	1.205	NLI
			0.8540	0.570	1.400	4
Effluent (60-120um)(Initial 20)	20	2.514	0.7368	2.090	3.390	8
			0.8053	2.090	3.649	NLI
			0.8847	2.089	4.207	7
Effluent (60-120um)(Current 30)	30	1.578	0.7995	0.762	2.298	12
			0.8053	0.756	2.299	NLI
			0.9013	0.595	2.315	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent (60-120um)(Controlled) vs. Effluent (60-120um)(Initial 20)
Effluent (60-120um)(Initial 20) vs. Effluent (60-120um)(Current 30)

Z vs. Critical value	P-value
2.72228 >= 1.834	0.0065
2.23376 >= 1.834	0.0255

Appendix C.7: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 120-250 µm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (120-250um)(Controlled)	12	0.088500000	29.3	-0.48
Effluent (120-250um)(Initial 20)	20	0.227452143	40.1	2.61
Effluent (120-250um)(Current 30)	30	0.000000000	26.6	-2.06
Overall	62		31.5	

H = 6.97 DF = 2 P = 0.031

H = 7.11 DF = 2 P = 0.029 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	18
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences

|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n

Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (120-250um)(Controlled)	0.00000	*	*
Effluent (120-250um)(Initial 20)	1.65456	0.00000	*
Effluent (120-250um)(Current 30)	0.42462	2.59528	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (120-250um)(Controlled)	0.00000	*	*
Effluent (120-250um)(Initial 20)	1.67187	0.00000	*
Effluent (120-250um)(Current 30)	0.42906	2.62243	0

2. Table of P-values

Effluent (120-250um)(Controlled)	1.00000	*	*
Effluent (120-250um)(Initial 20)	0.09455	1.00000	*
Effluent (120-250um)(Current 30)	0.66788	0.00873	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

				Confidence Interval	
	N	Median	Achieved Confidence	Lower	Upper
Effluent (120-250um)(Controlled)	12	0.0885	0.6123	0.0820	0.1400
			0.8053	0.0561	0.1466
			0.8540	0.0430	0.1500
Effluent (120-250um)(Initial 20)	20	0.2275	0.7368	0.1474	0.2603
			0.8053	0.1461	0.2603
			0.8847	0.1433	0.2603
Effluent (120-250um)(Current 30)	30	0.0000	0.7995	0.0000	0.1314
			0.8053	0.0000	0.1323
			0.9013	0.0000	0.1573

	Position
Effluent (120-250um)(Controlled)	5
	NLI
	4
Effluent (120-250um)(Initial 20)	8
	NLI
	7
Effluent (120-250um)(Current 30)	12
	NLI
	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups	
Effluent (120-250um)(Initial 20) vs. Effluent (120-250um)(Current 30)	
Z vs. Critical value	P-value
2.62243 >= 1.834	0.0087

Appendix C.8: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent 250-1180 μm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (250-1180um)(Controlled)	12	0.000000000	6.5	-5.35
Effluent (250-1180um)(Initial 20)	20	3.276190476	35.5	1.19
Effluent (250-1180um)(Current 30)	30	4.289499806	38.9	3.11
Overall	62		31.5	

H = 29.00 DF = 2 P = 0.000
H = 29.21 DF = 2 P = 0.000 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	13
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences
|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n
Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (250-1180um)(Controlled)	0.00000	*	*
Effluent (250-1180um)(Initial 20)	4.39444	0.000000	*
Effluent (250-1180um)(Current 30)	5.25229	0.656021	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (250-1180um)(Controlled)	0.00000	*	*
Effluent (250-1180um)(Initial 20)	4.41046	0.000000	*
Effluent (250-1180um)(Current 30)	5.27144	0.658413	0

2. Table of P-values

Effluent (250-1180um)(Controlled)	1.00000	*	*
Effluent (250-1180um)(Initial 20)	0.00001	1.00000	*
Effluent (250-1180um)(Current 30)	0.00000	0.51027	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

	N	Median	Achieved Confidence	Confidence Interval Lower	Upper
Effluent (250-1180um)(Controlled)	12	0.00000	0.6123	0.00000	0.00000
			0.8053	0.00000	0.00000
			0.8540	0.00000	0.00000
Effluent (250-1180um)(Initial 20)	20	3.276	0.7368	3.143	3.333
			0.8053	3.007	3.461
			0.8847	2.714	3.737
Effluent (250-1180um)(Current 30)	30	4.289	0.7995	3.236	4.570
			0.8053	3.233	4.609
			0.9013	3.145	5.727

	Position
Effluent (250-1180um)(Controlled)	5
	NLI
	4
Effluent (250-1180um)(Initial 20)	8
	NLI
	7
Effluent (250-1180um)(Current 30)	12
	NLI
	11

Kruskal-Wallis: Conclusions

The following groups showed significant differences (adjusted for ties):

Groups
Effluent (250-1180um)(Controlled) vs. Effluent (250-1180um)(Current 30)
Effluent (250-1180um)(Controlled) vs. Effluent (250-1180um)(Initial 20)

Appendix C.9: Kruskal-Wallis Multiple Comparison between Controlled Sediment Test and Actual Storms Monitoring for Effluent >1180 μm Solids

Kruskal-Wallis: Multiple Comparisons

Kruskal-Wallis Test on the data

Group	N	Median	Ave Rank	Z
Effluent (>1180um)(Controlled)	12	0.000000000	17.0	-3.10
Effluent (>1180um)(Initial 20)	20	0.000000000	17.0	-4.37
Effluent (>1180um)(Current 30)	30	1.696711874	47.0	6.54
Overall	62		31.5	

H = 42.72 DF = 2 P = 0.000
H = 50.30 DF = 2 P = 0.000 (adjusted for ties)

Kruskal-Wallis: All Pairwise Comparisons

Comparisons:	3
Ties:	32
Family Alpha:	0.2
Bonferroni Individual Alpha:	0.067
Bonferroni Z-value (2-sided):	1.834

Standardized Absolute Mean Rank Differences
|Rbar(i)-Rbar(j)| / Stdev

Rows: Group i = 1,...,n
Columns: Group j = 1,...,n

1. Table of Z-values

Effluent (>1180um)(Controlled)	0.00000	*	*
Effluent (>1180um)(Initial 20)	0.00000	0.00000	*
Effluent (>1180um)(Current 30)	4.86284	5.75378	0

Adjusted for Ties in the Data

1. Table of Z-values

Effluent (>1180um)(Controlled)	0.00000	*	*
Effluent (>1180um)(Initial 20)	0.00000	0.00000	*
Effluent (>1180um)(Current 30)	5.27662	6.24339	0

2. Table of P-values

Effluent (>1180um)(Controlled)	1.00000	*	*
Effluent (>1180um)(Initial 20)	1.00000	1.00000	*
Effluent (>1180um)(Current 30)	0.00000	0.00000	1

Sign Confidence Intervals controlled at a family error rate of 0.2

Desired Confidence: 80.529

Sign confidence interval for median

	N	Median	Achieved Confidence	Confidence Interval Lower	Confidence Interval Upper
Effluent (>1180um)(Controlled)	12	0.00000	0.6123	0.00000	0.00000
			0.8053	0.00000	0.00000
			0.8540	0.00000	0.00000
Effluent (>1180um)(Initial 20)	20	0.00000	0.7368	0.00000	0.00000
			0.8053	0.00000	0.00000
			0.8847	0.00000	0.00000
Effluent (>1180um)(Current 30)	30	1.697	0.7995	1.380	1.888
			0.8053	1.375	1.900
			0.9013	1.245	2.257

	Position
Effluent (>1180um)(Controlled)	5
	NLI
	4
Effluent (>1180um)(Initial 20)	8
	NLI
	7
Effluent (>1180um)(Current 30)	12
	NLI
	11

Kruskal-Wallis: Conclusions

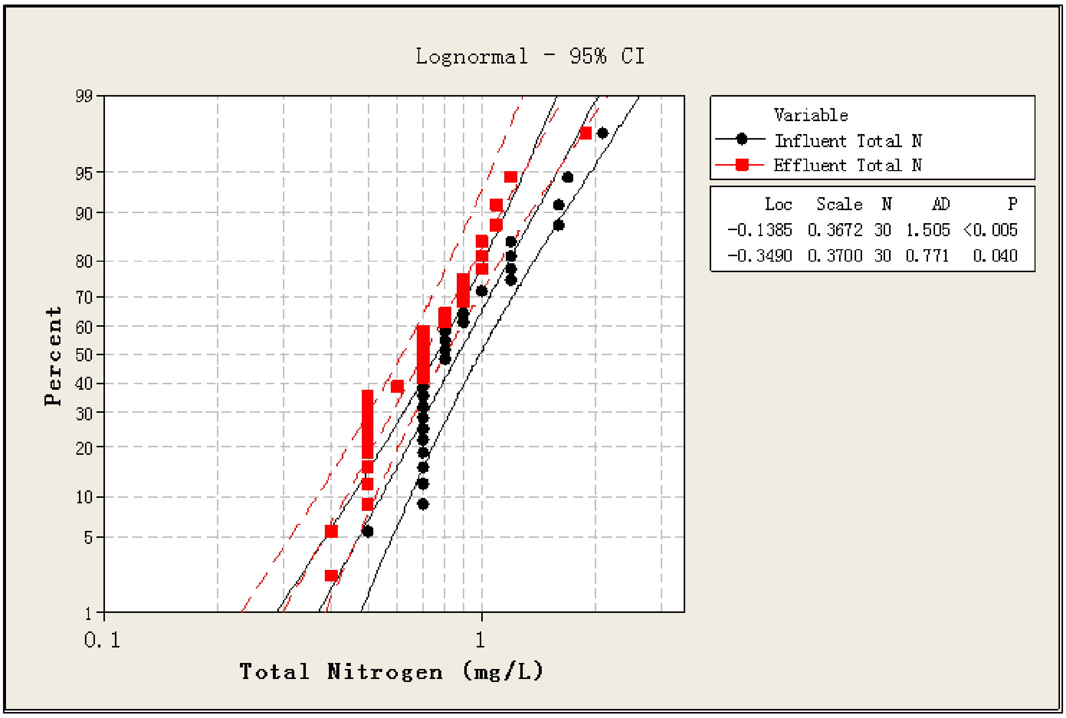
The following groups showed significant differences (adjusted for ties):

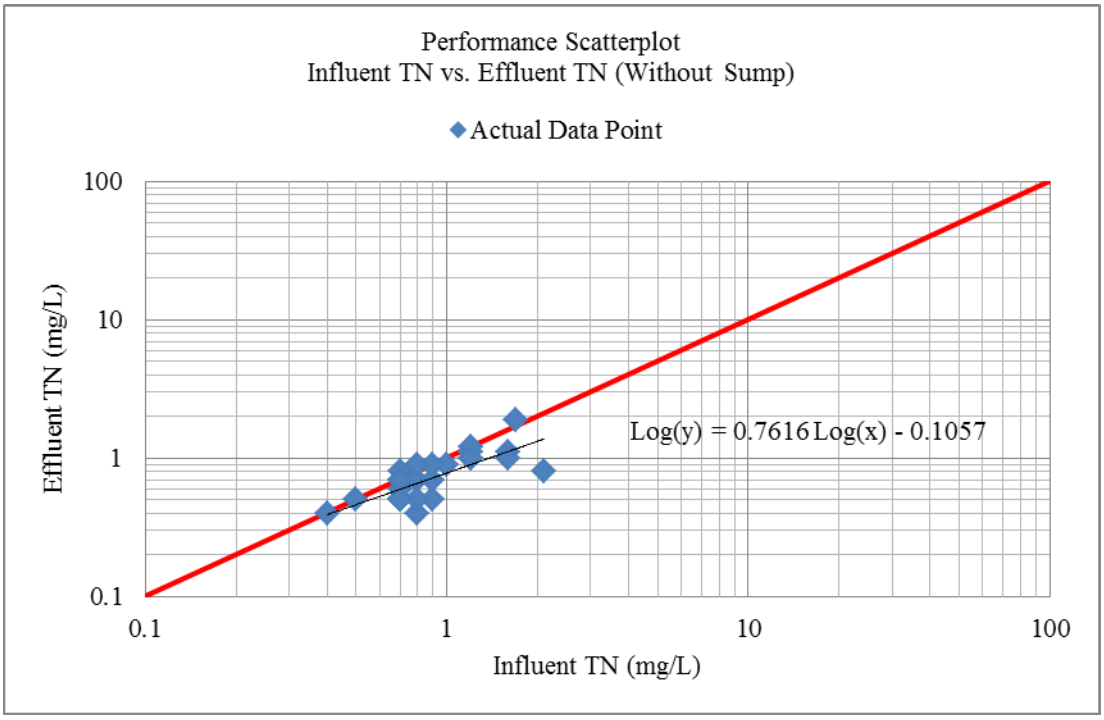
Groups
Effluent (>1180um)(Initial 20) vs. Effluent (>1180um)(Current 30)
Effluent (>1180um)(Controlled) vs. Effluent (>1180um)(Current 30)

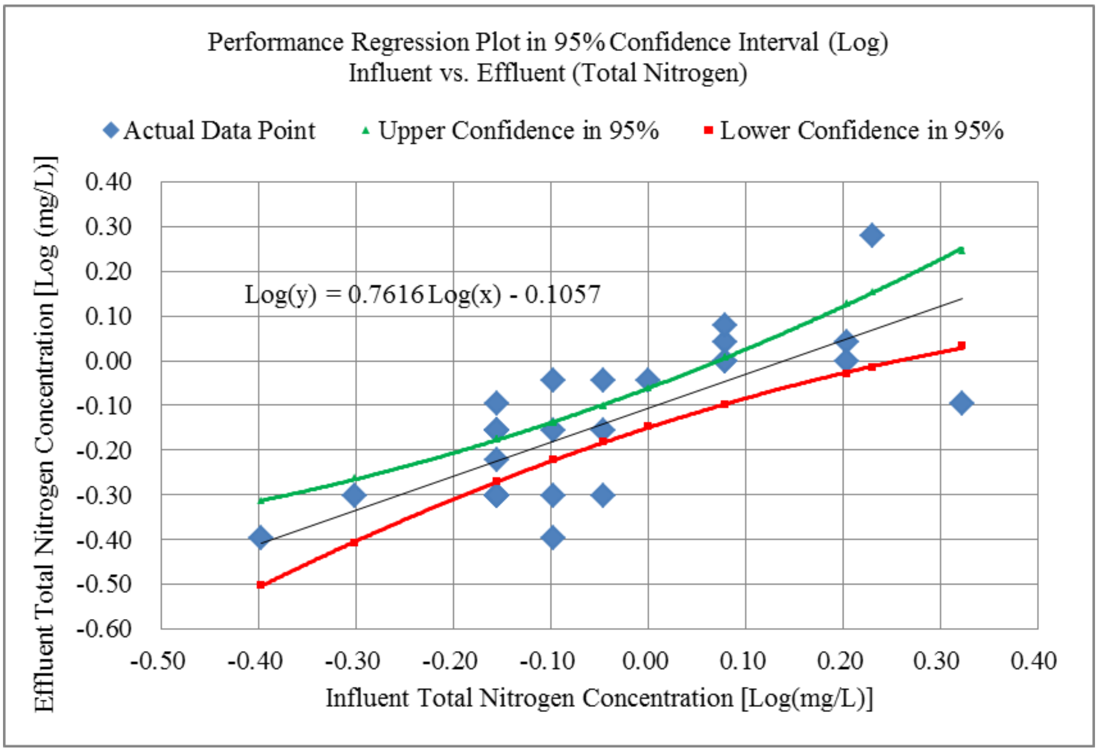
Z vs. Critical value	P-value
6.24339 >= 1.834	0
5.27662 >= 1.834	0

Z vs. Critical value	P-value
5.27144 >= 1.834	0
4.41046 >= 1.834	0

Appendix D.1: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Nitrogen (30 Sampled Storms)







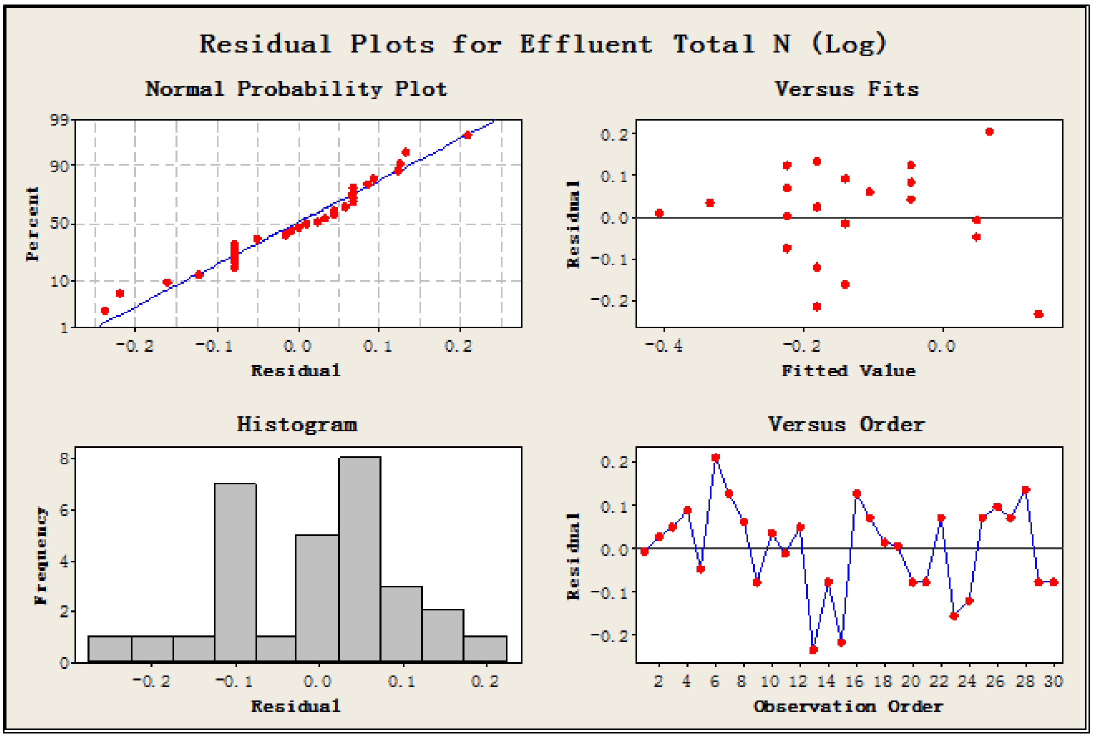
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.76
R Square	0.57
Adjusted R Square	0.56
Standard Error	0.11
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.43	0.43	37.31	0.00
Residual	28.00	0.32	0.01		
Total	29.00	0.75			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.11	0.02	-5.05	0.00	-0.15	-0.06	-0.15	-0.06
X Variable 1	0.76	0.12	6.11	0.00	0.51	1.02	0.51	1.02



Wilcoxon Signed Rank Test

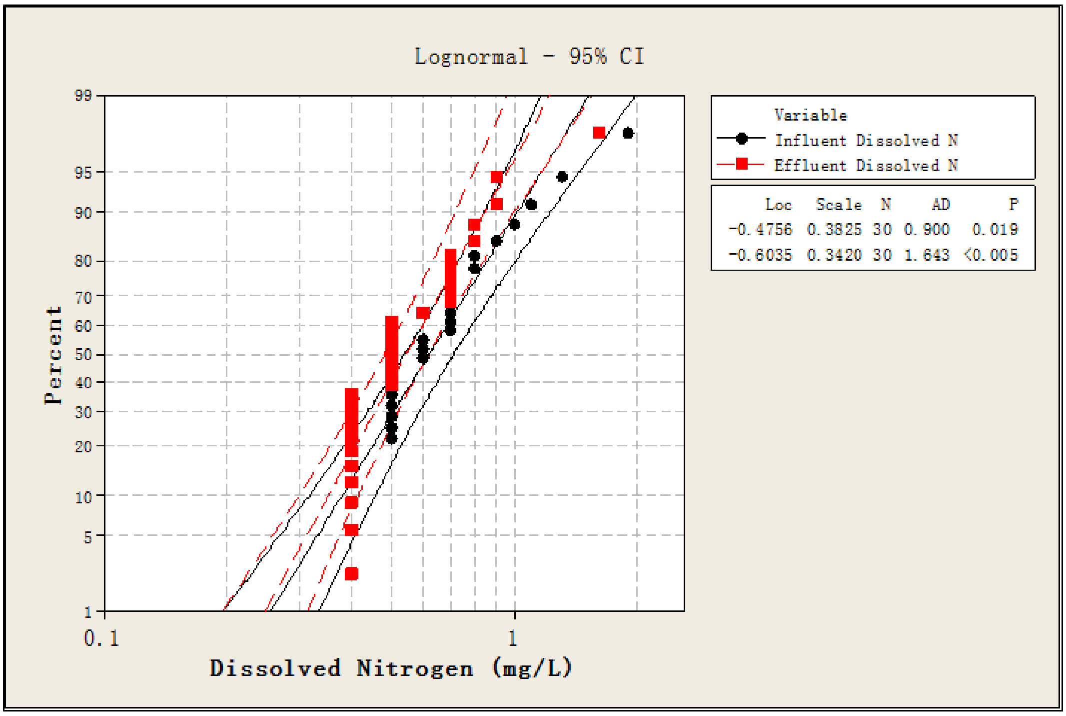
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

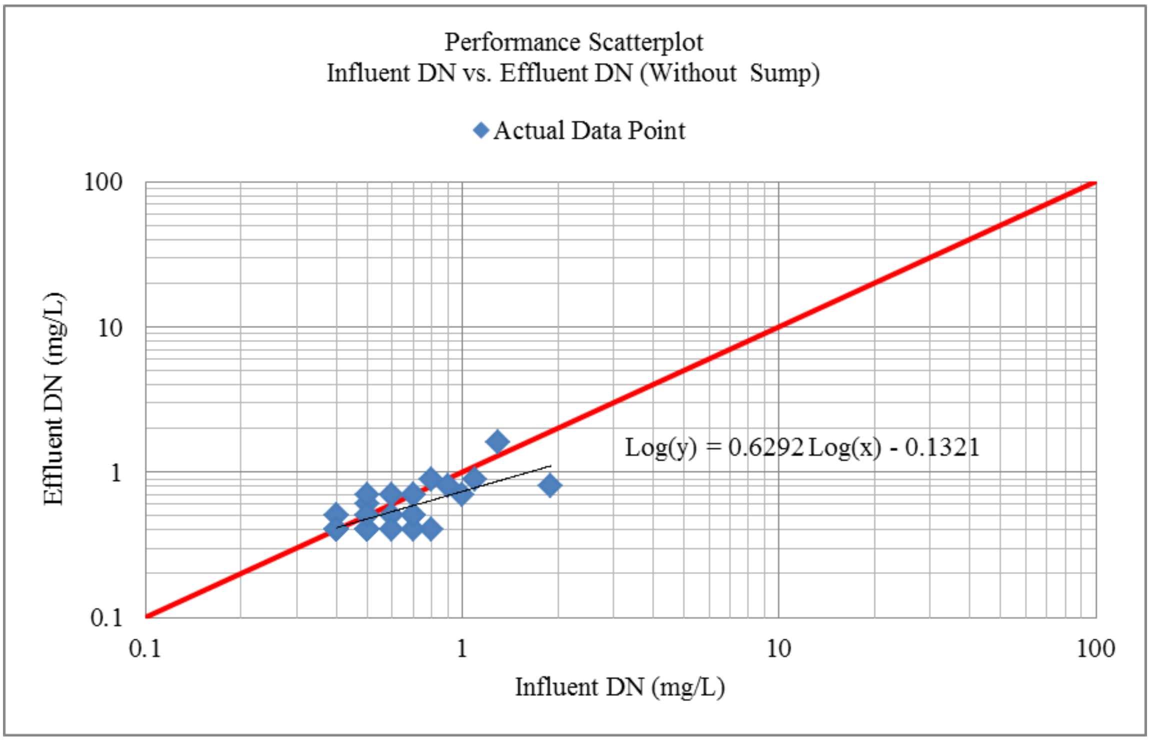
Group	N	Missing	Median	0.25	0.75
Influent TN	30.00	0.00	0.80	0.70	1.20
Effluent TN	30.00	0.00	0.70	0.50	0.93

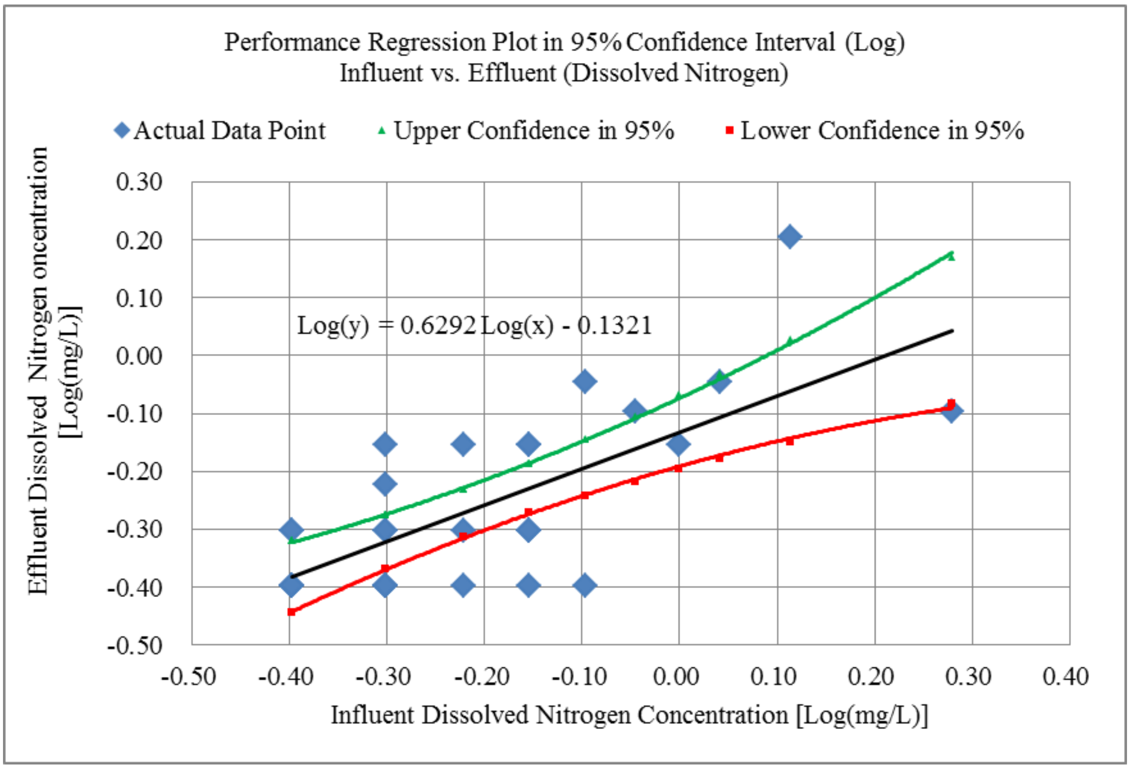
W= -214.000 T+ = 19.500 T-= -233.500
Z-Statistic (based on positive ranks) = -3.503
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix D.2: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Nitrogen (30 Sampled Storms)







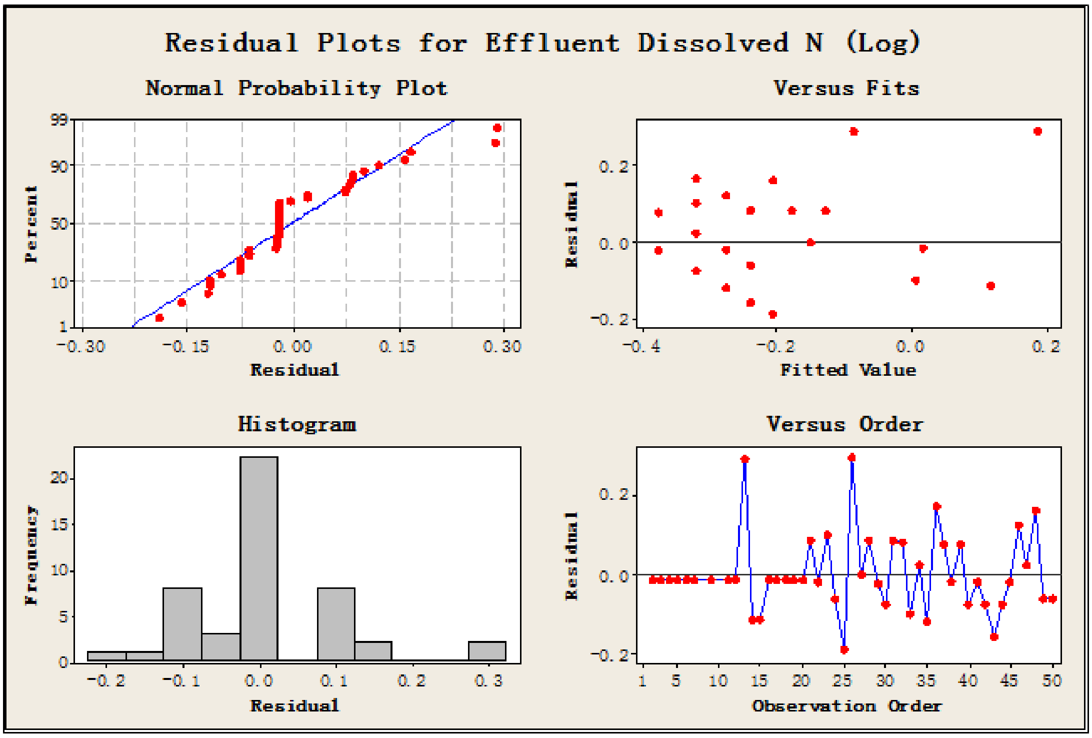
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.70
R Square	0.50
Adjusted R Square	0.48
Standard Error	0.11
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.32	0.32	27.47	0.00
Residual	28.00	0.32	0.01		
Total	29.00	0.64			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.13	0.03	-4.18	0.00	-0.20	-0.07	-0.20	-0.07
X Variable 1	0.63	0.12	5.24	0.00	0.38	0.88	0.38	0.88



Wilcoxon Signed Rank Test

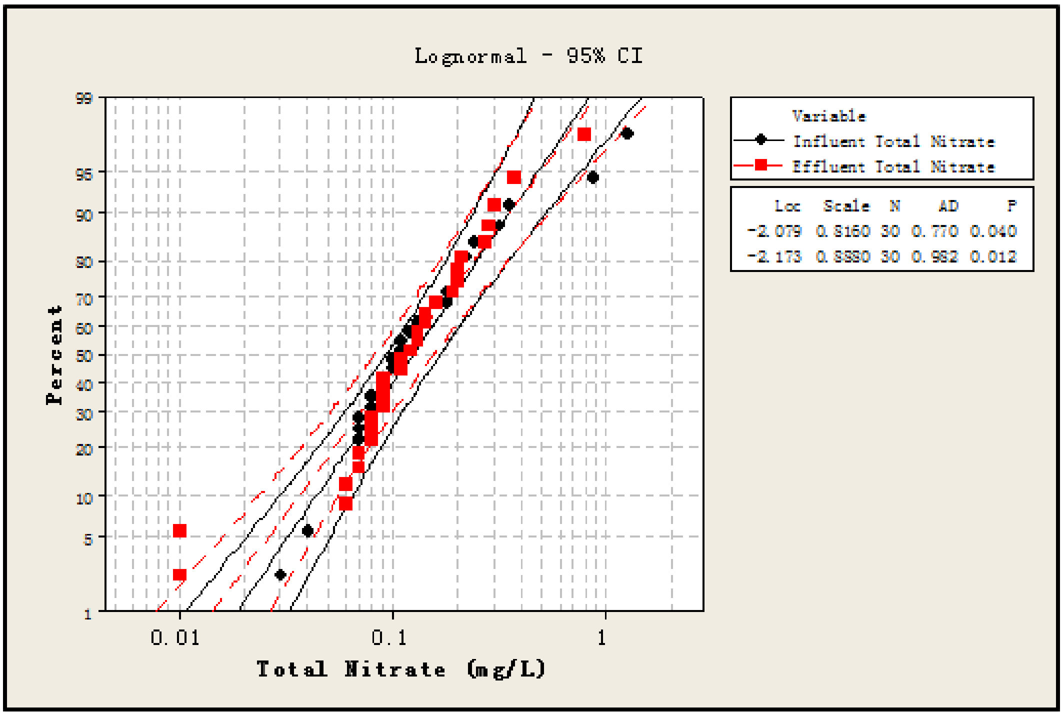
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

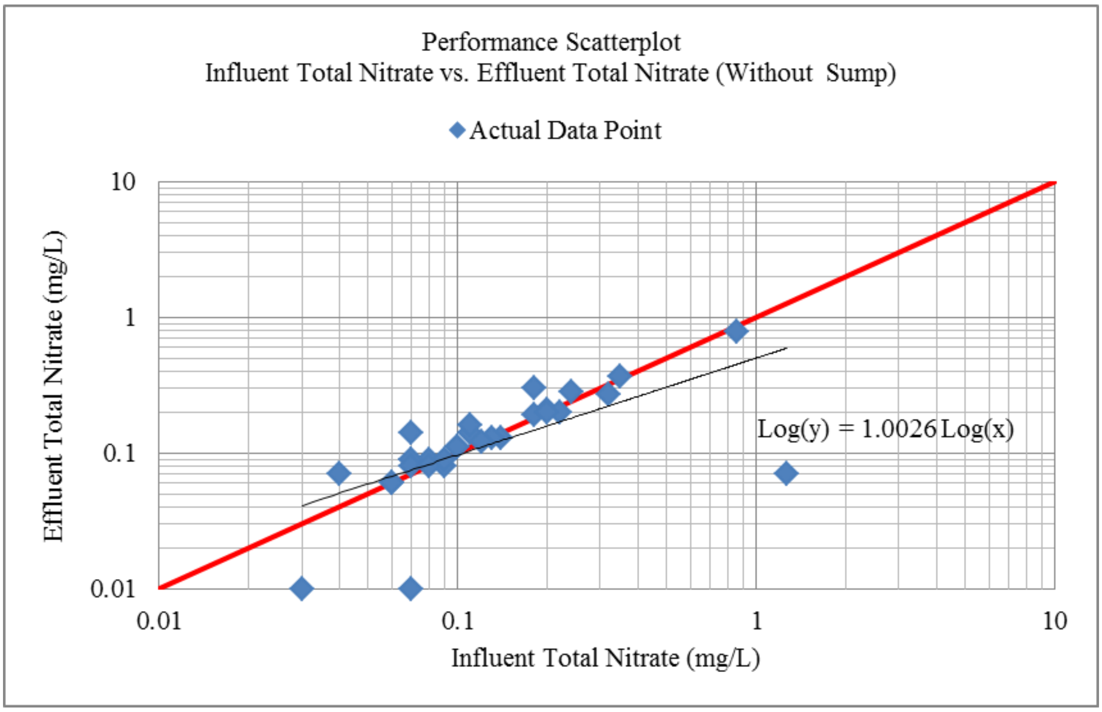
Group	N	Missing	Median	0.25	0.75
Influent DN	30.00	0.00	0.60	0.50	0.73
Effluent DN	30.00	0.00	0.50	0.40	0.70

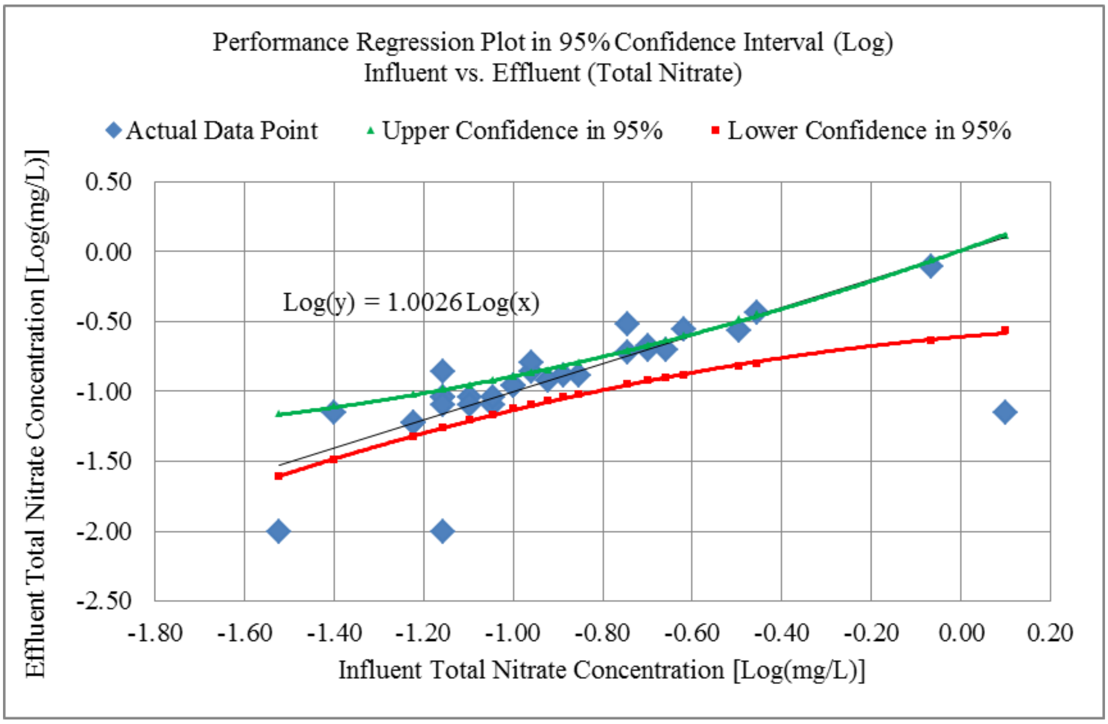
W= -126.000 T+ = 63.500 T-= -189.500
Z-Statistic (based on positive ranks) = -2.079
(P = 0.039)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.039).

Appendix D.3: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Nitrate (30 Sampled Storms)







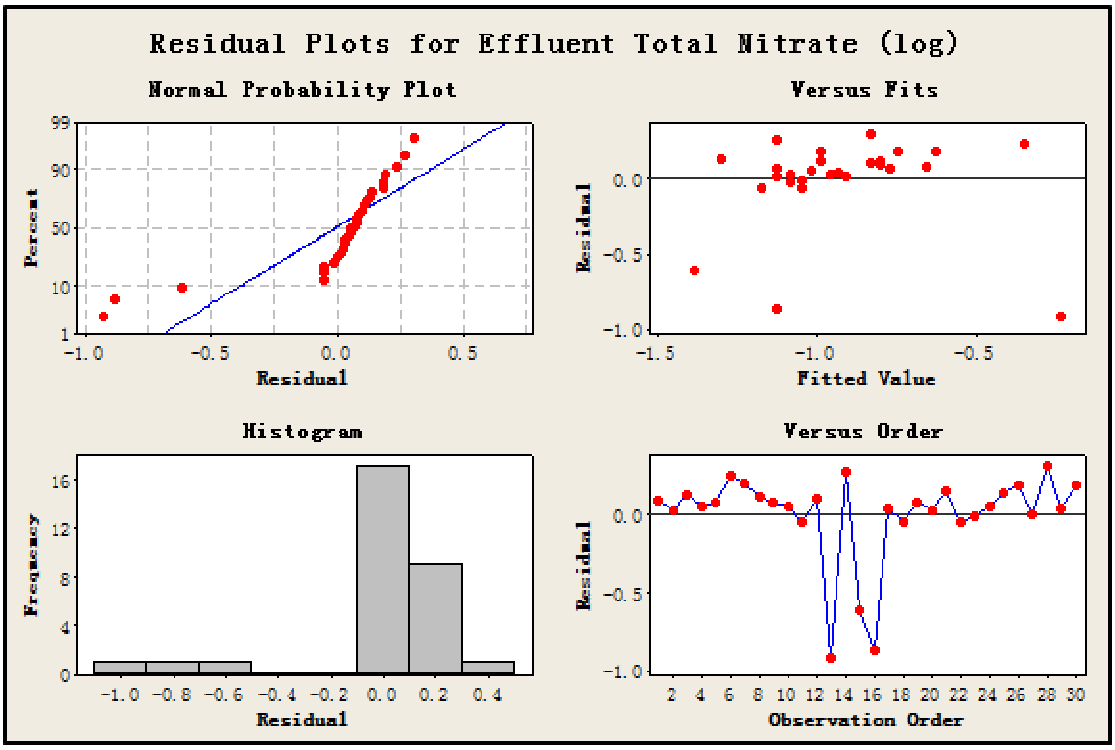
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.95
R Square	0.91
Adjusted R Square	0.88
Standard Error	0.31
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	28.24	28.24	291.90	0.00
Residual	29.00	2.81	0.10		
Total	30.00	31.04			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.00	0.06	17.09	0.00	0.88	1.12	0.88	1.12



Wilcoxon Signed Rank Test

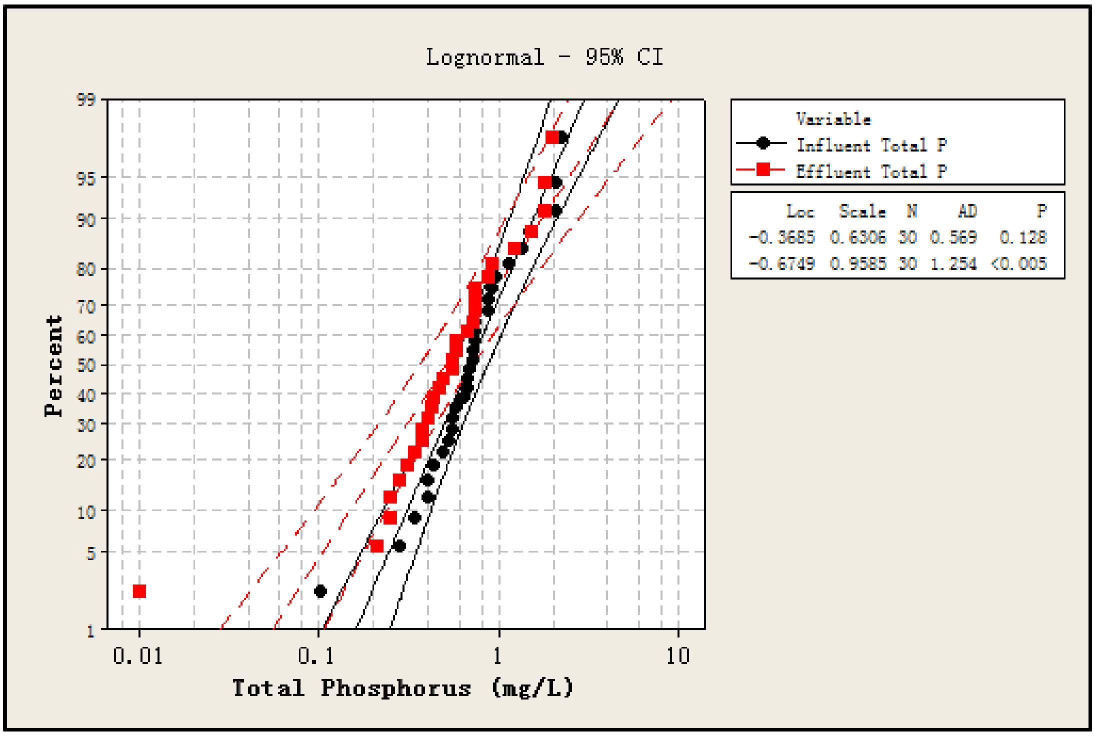
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

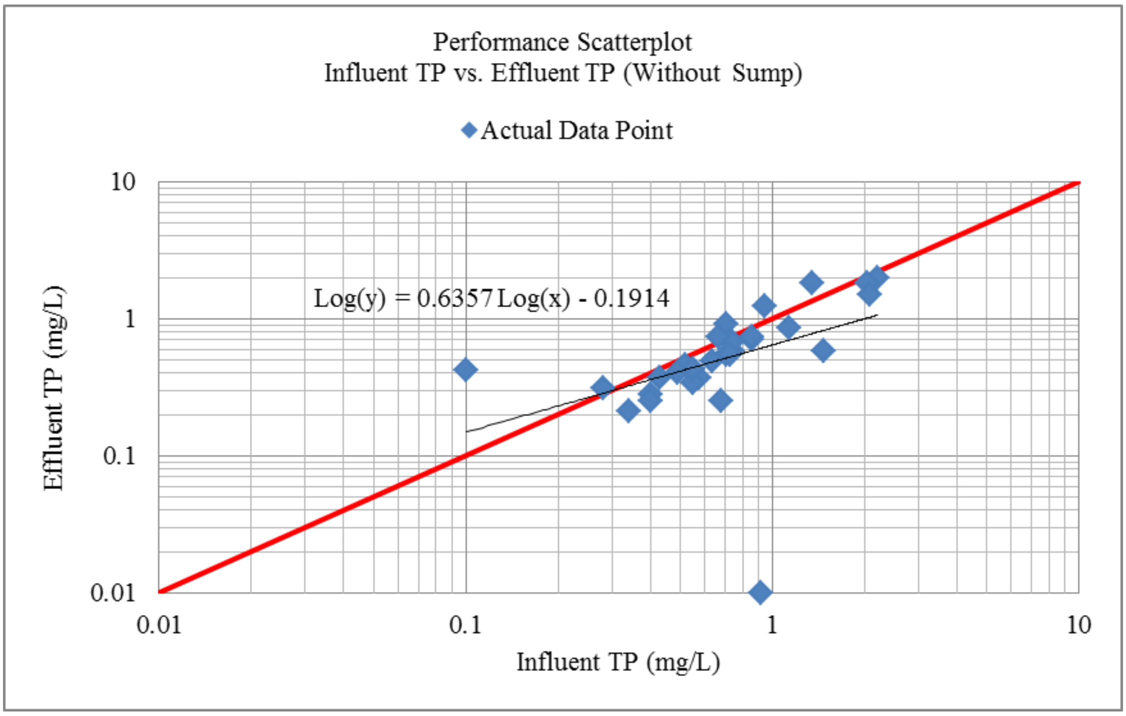
Group	N	Missing	Median	0.25	0.75
Influent Nitrate	30.00	0.00	0.11	0.07	0.20
Effluent Nitrate	30.00	2.00	0.13	0.08	0.20

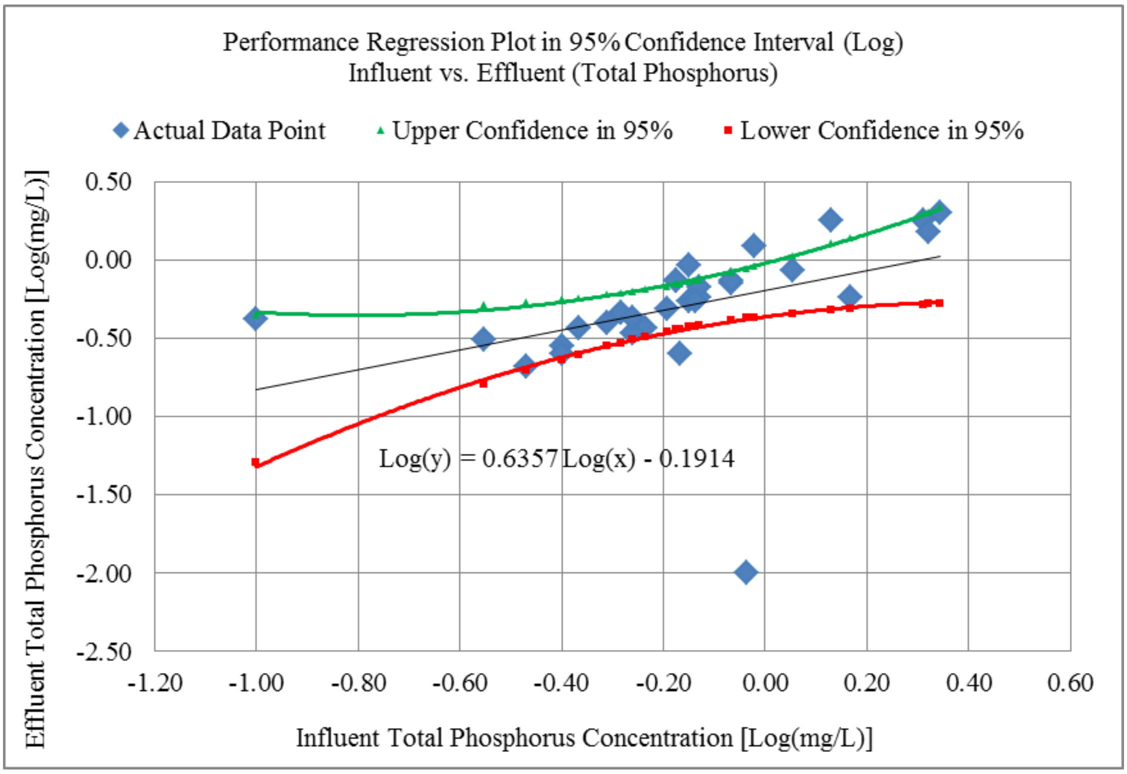
W= 78.000 T+ = 154.500 T-= -76.500
Z-Statistic (based on positive ranks) = 1.358
($P = 0.180$)

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance ($P = 0.180$).

Appendix D.4: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Phosphorus (30 Sampled Storms)







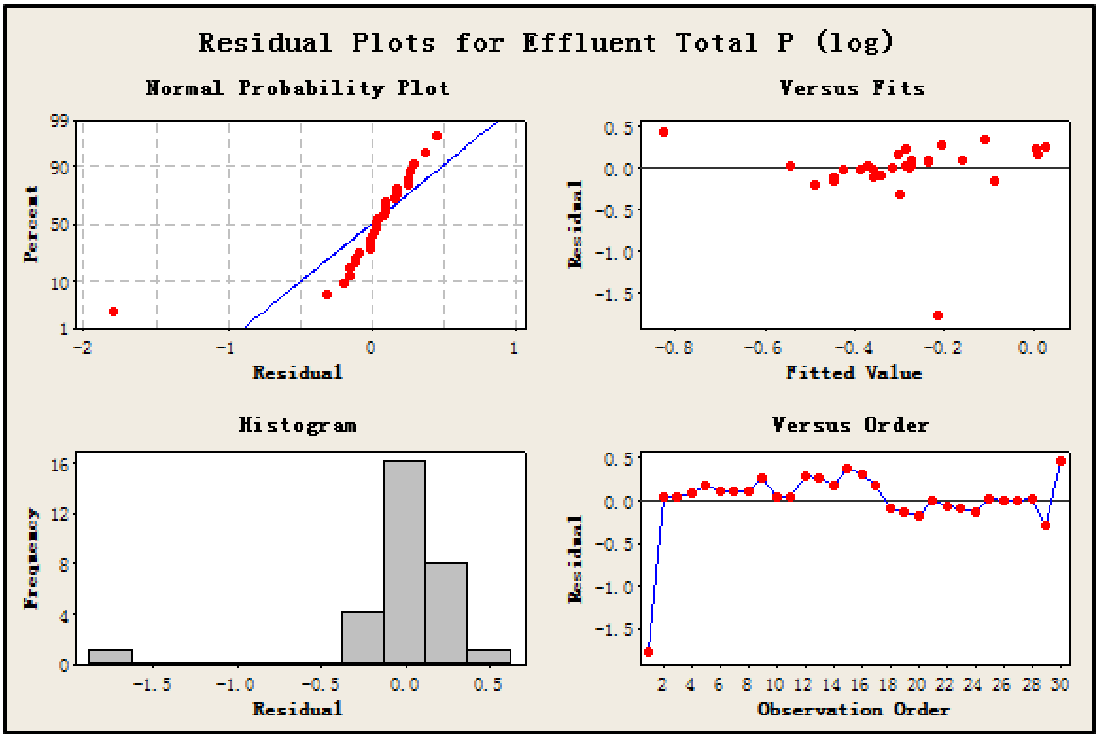
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.42
R Square	0.17
Adjusted R Square	0.15
Standard Error	0.38
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.88	0.88	5.94	0.02
Residual	28.00	4.15	0.15		
Total	29.00	5.03			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.19	0.08	-2.34	0.03	-0.36	-0.02	-0.36	-0.02
X Variable 1	0.64	0.26	2.44	0.02	0.10	1.17	0.10	1.17



Note: consistent high level of phosphorus concentrations were found from October, November, and December, 2012. Reason was unknown.

Wilcoxon Signed Rank Test

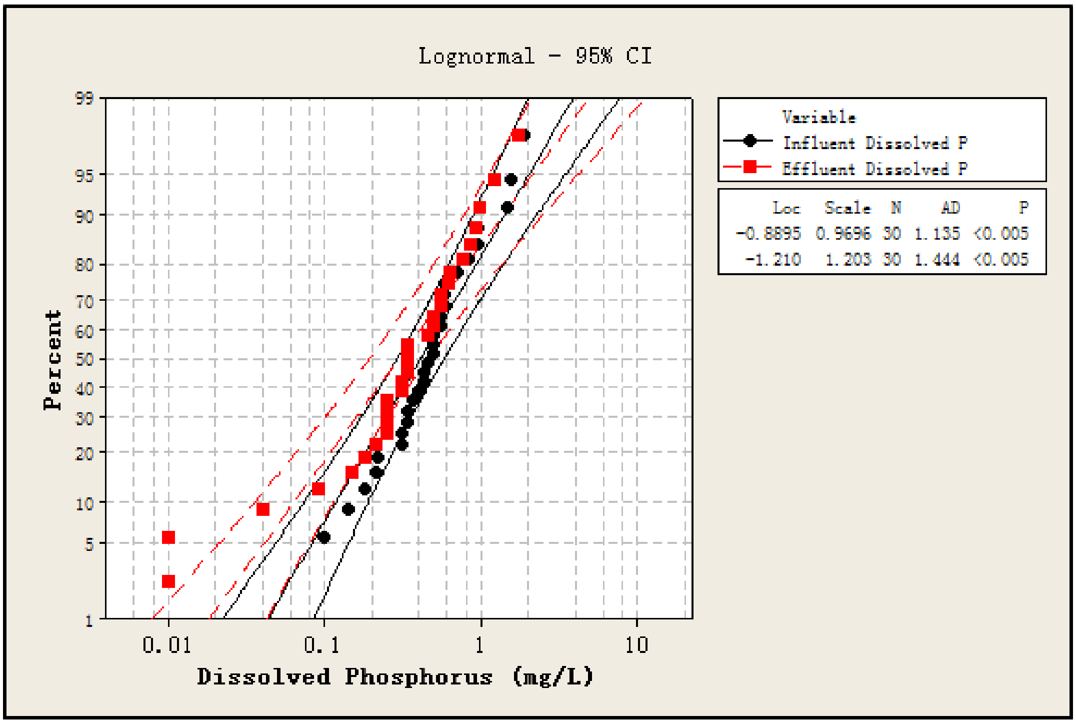
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

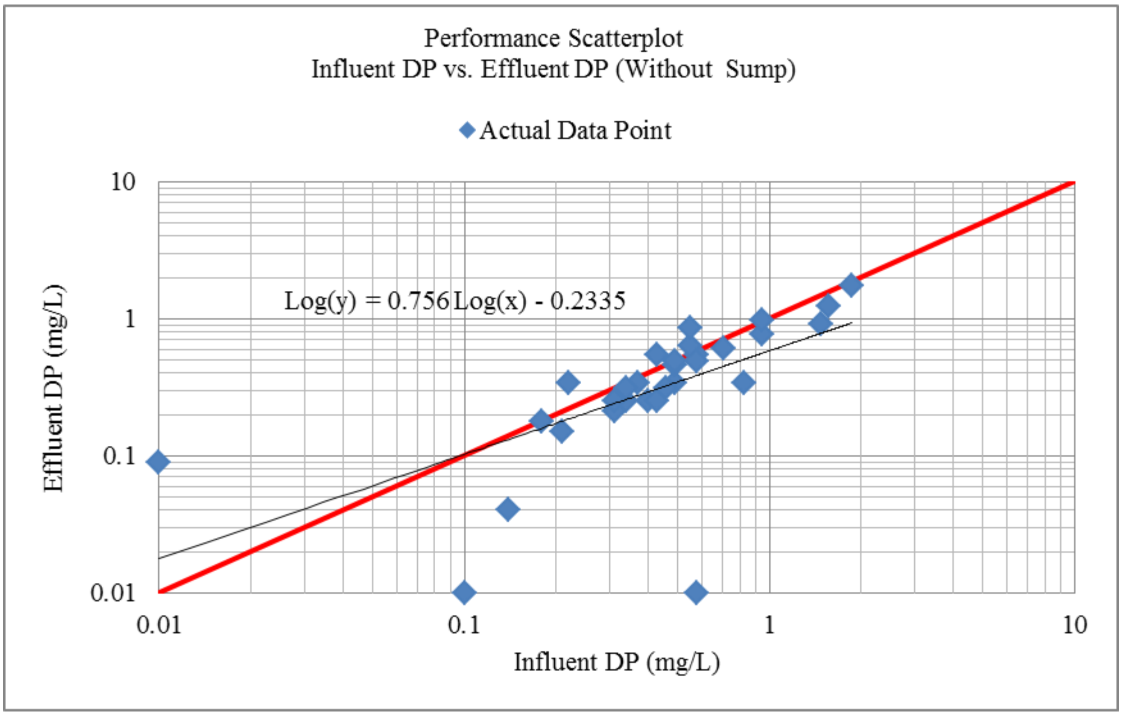
Group	N	Missing	Median	0.25	0.75
Influent TP	30.00	0.00	0.70	0.51	0.93
Effluent TP	30.00	1.00	0.55	0.37	0.80

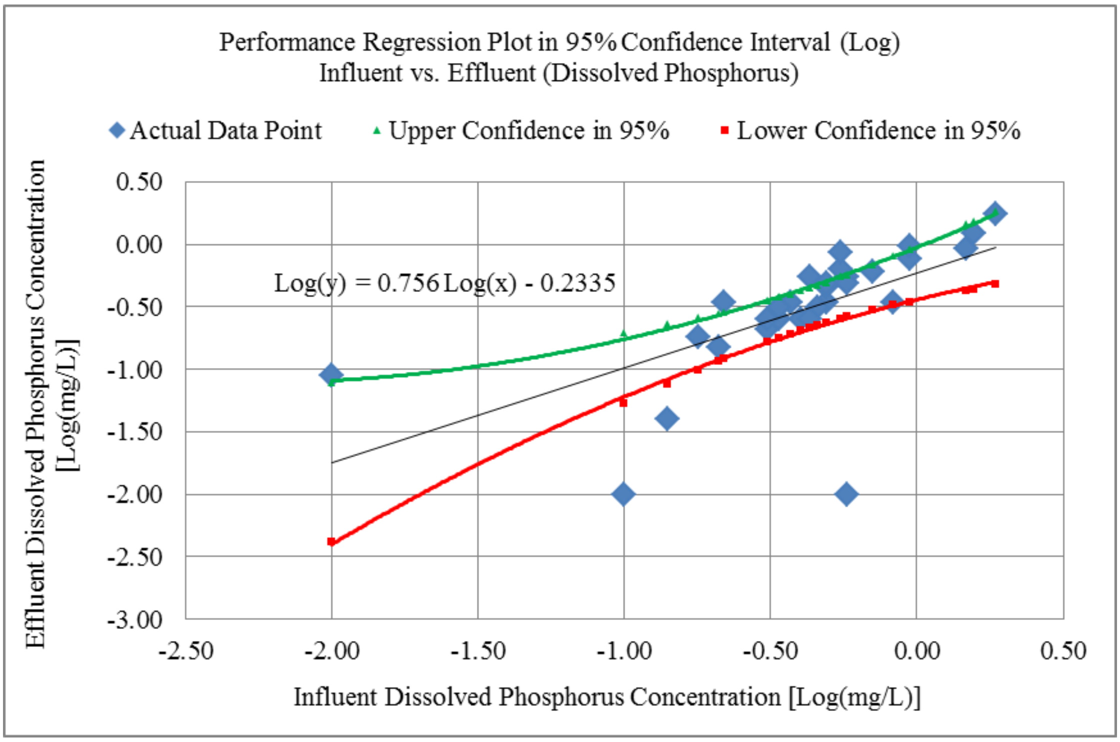
W= -221.000 T+ = 107.000 T-= -328.000
Z-Statistic (based on positive ranks) = -2.390
($P = 0.017$)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference ($P = 0.017$).

Appendix D.5: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Phosphorus (30 Sampled Storms)







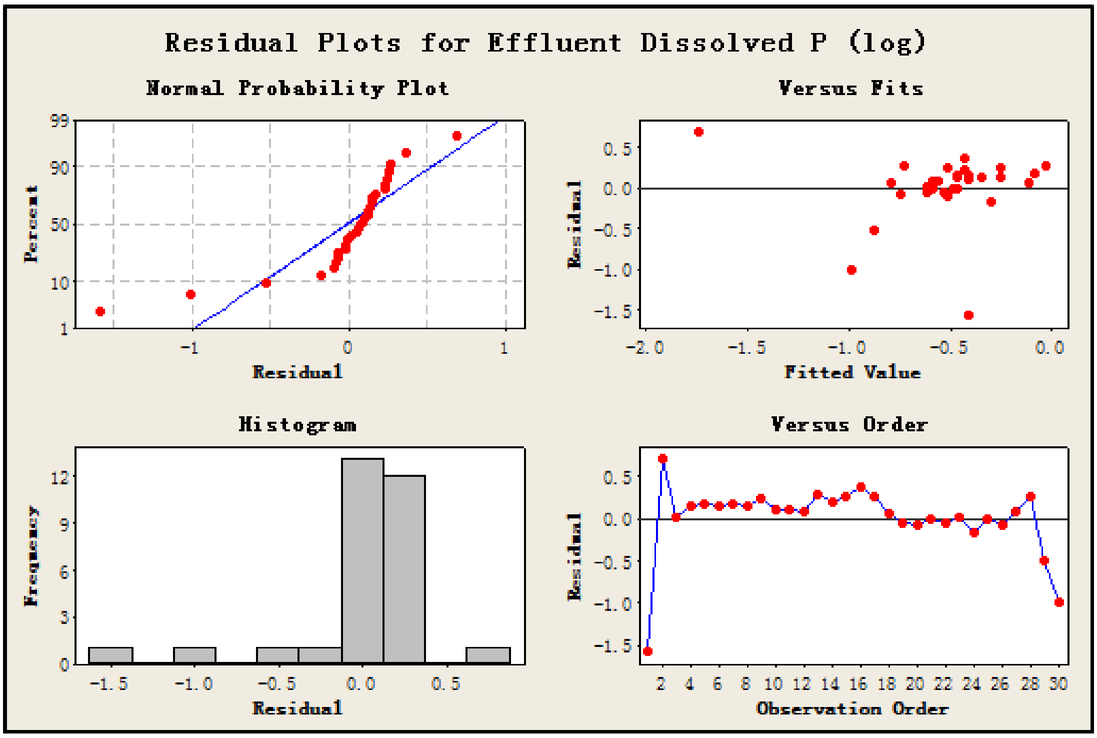
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.61
R Square	0.37
Adjusted R Square	0.35
Standard Error	0.42
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	2.94	2.94	16.55	0.00
Residual	28.00	4.97	0.18		
Total	29.00	7.91			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.23	0.11	-2.22	0.03	-0.45	-0.02	-0.45	-0.02
X Variable 1	0.76	0.19	4.07	0.00	0.38	1.14	0.38	1.14



Note: consistent high level of phosphorus concentrations were found from October, November, and December, 2012. Reason was unknown.

Wilcoxon Signed Rank Test

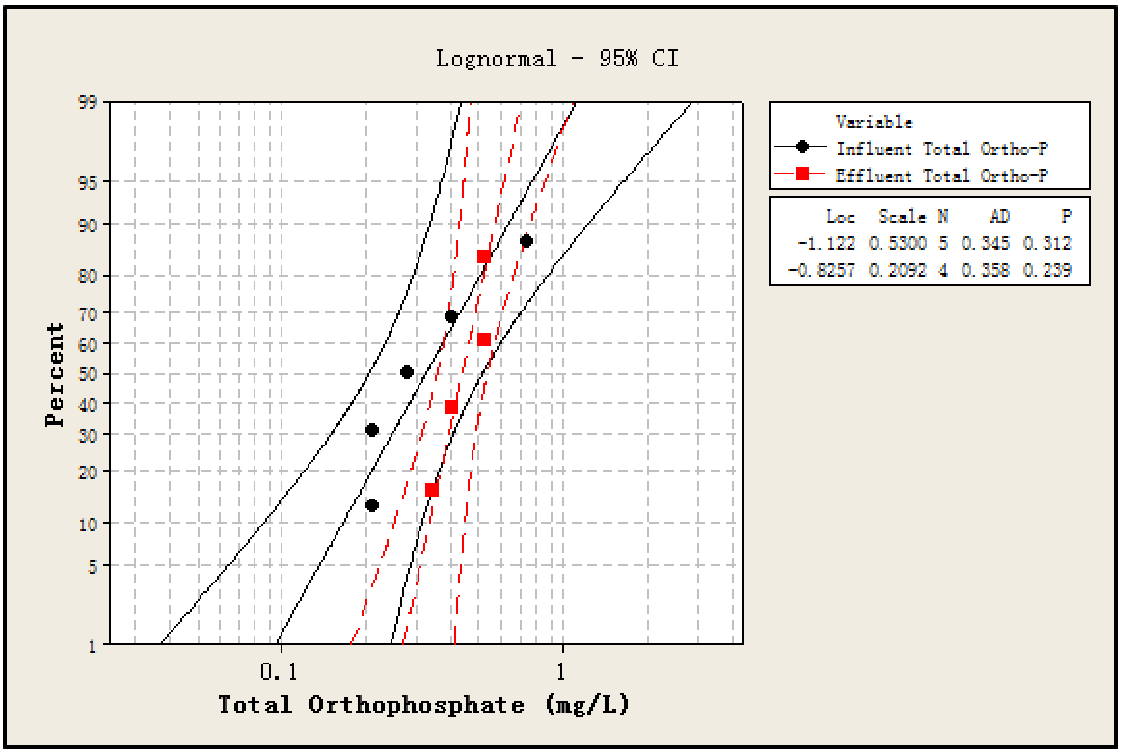
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

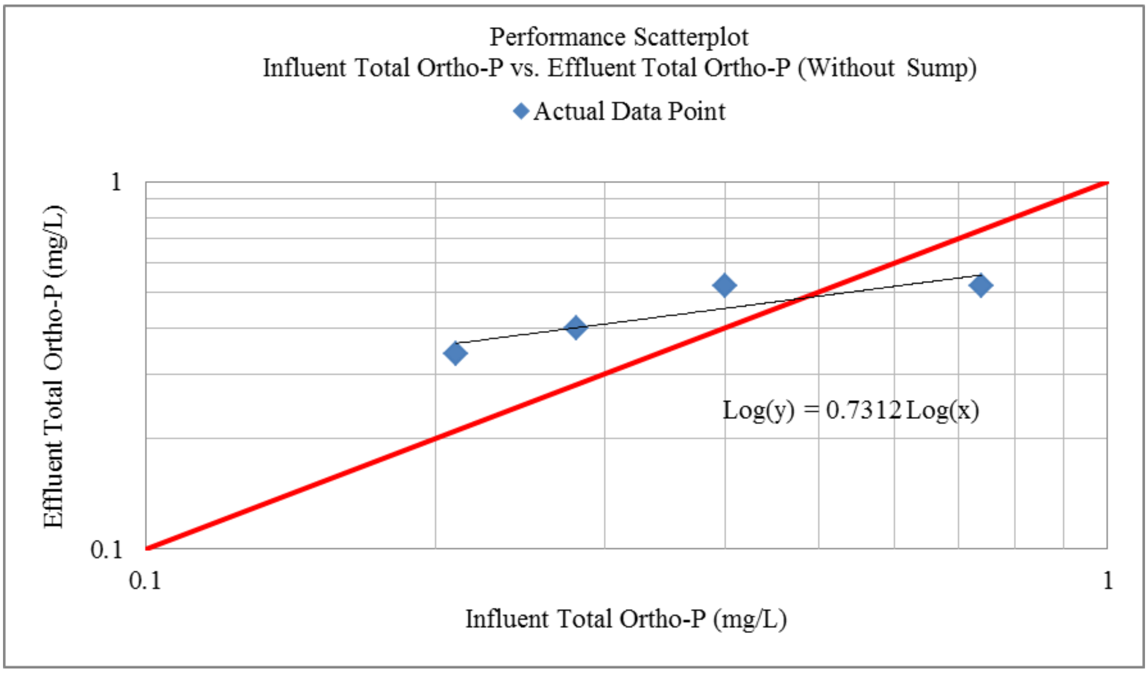
Group	N	Missing	Median	0.25	0.75
Influent DP	30.00	1.00	0.48	0.31	0.61
Effluent DP	30.00	2.00	0.34	0.24	0.62

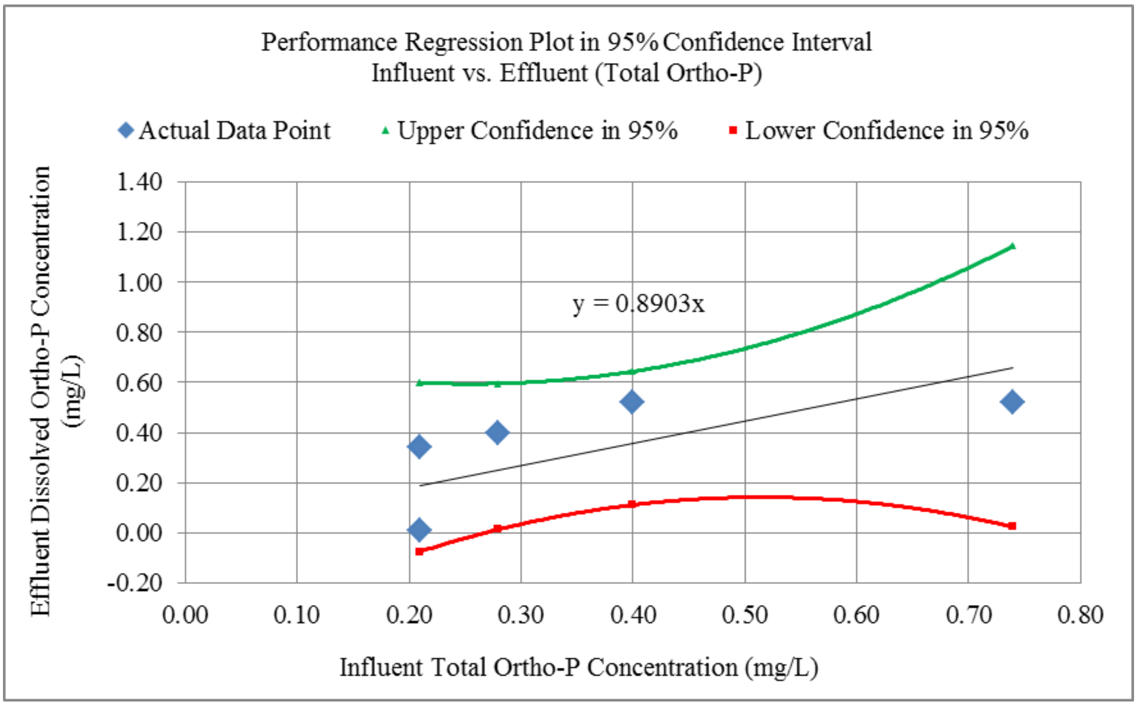
W= -248.000 T+ = 79.000 T-= -327.000
Z-Statistic (based on positive ranks) = -2.824
(P = 0.005)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.005).

Appendix D.6: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Orthophosphate (30 Sampled Storms)







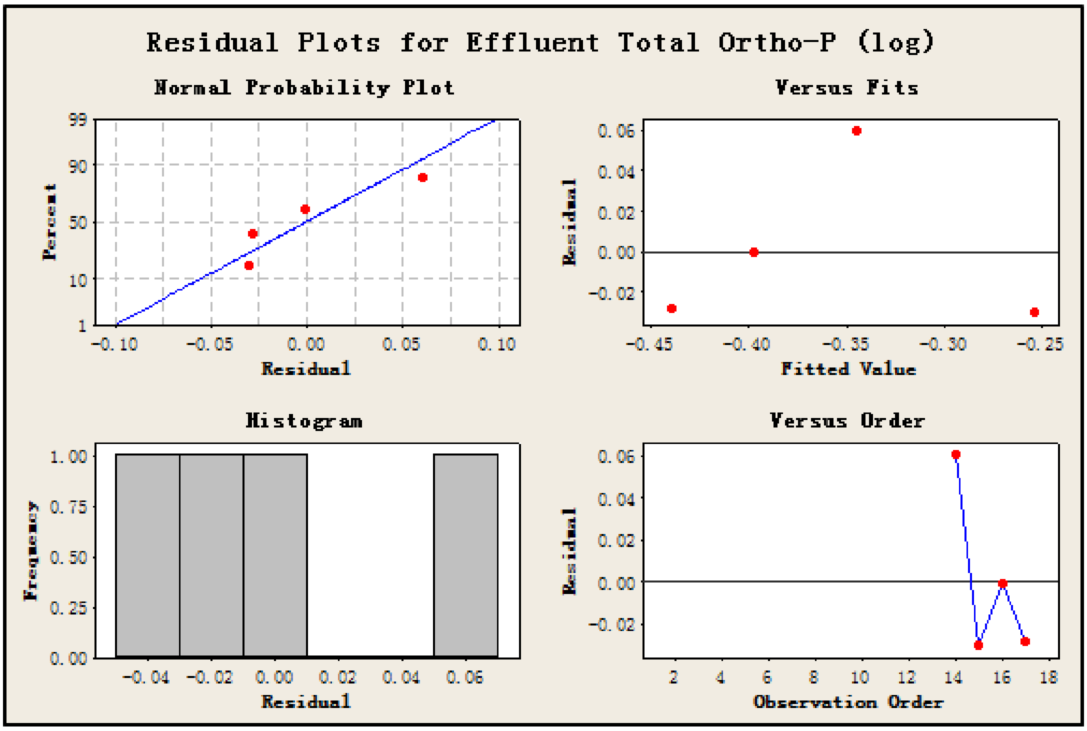
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.92
R Square	0.85
Adjusted R Square	0.60
Standard Error	0.18
Observations	5.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.69	0.69	22.43	0.02
Residual	4.00	0.12	0.03		
Total	5.00	0.82			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.89	0.19	4.74	0.01	0.37	1.41	0.37	1.41



Wilcoxon Signed Rank Test

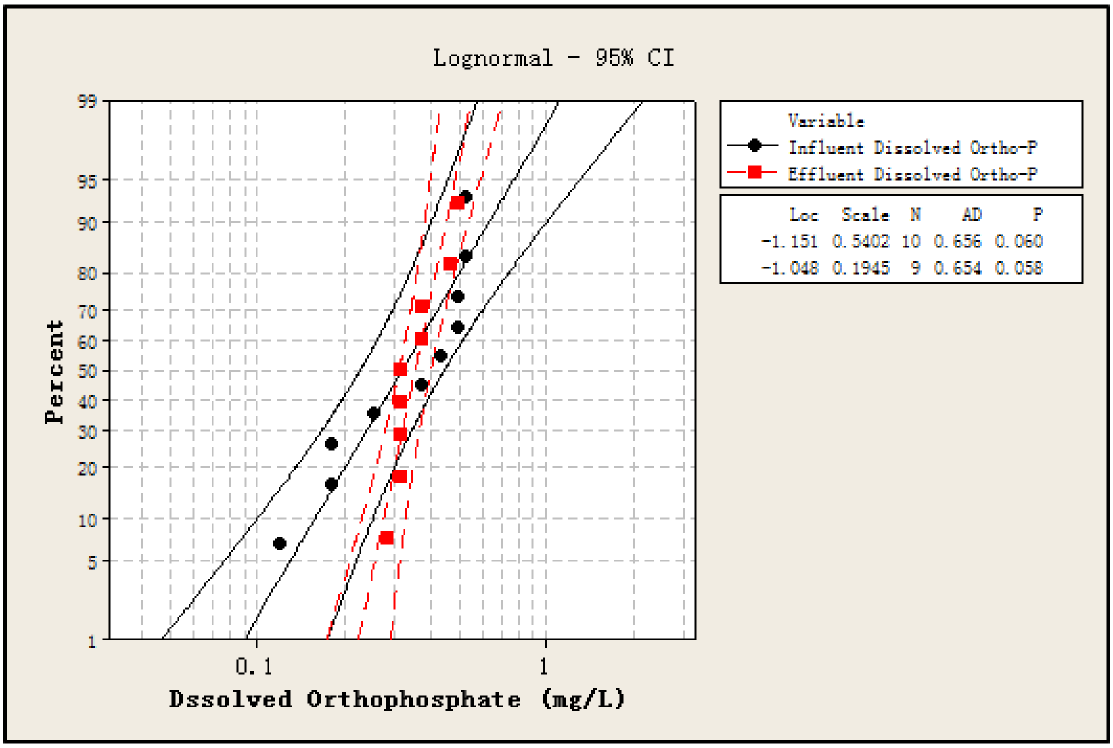
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

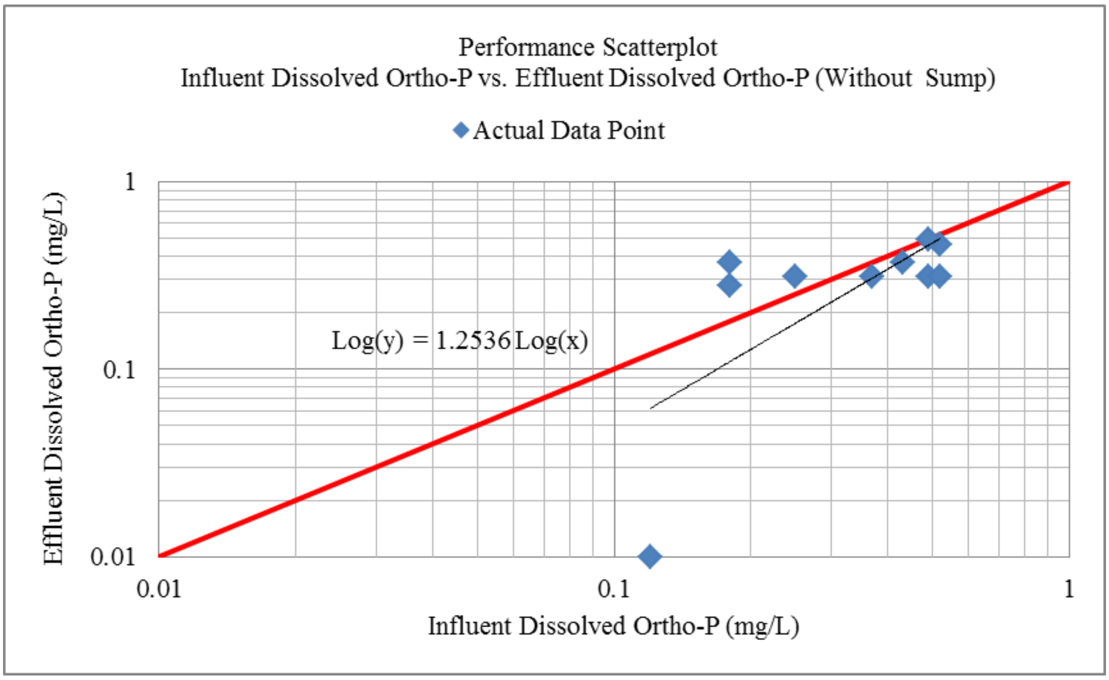
Group	N	Missing	Median	0.25	0.75
Influent Total Ortho-P	18.00	13.00	0.28	0.21	0.57
Effluent Total Ortho-P	18.00	14.00	0.46	0.36	0.52

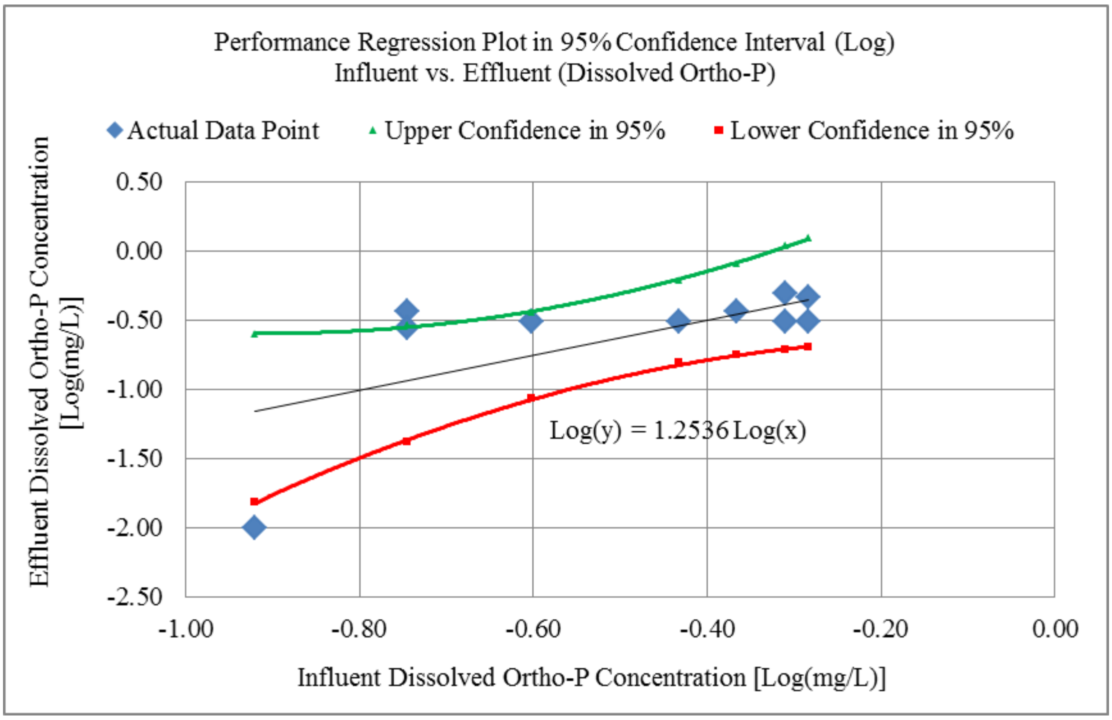
W= 2.000 T+ = 6.000 T-= -4.000
Z-Statistic (based on positive ranks) = 0.368
P(est.)= 0.854 P(exact)= 0.875

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.875).

Appendix D.7: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Orthophosphate (30 Sampled Storms)







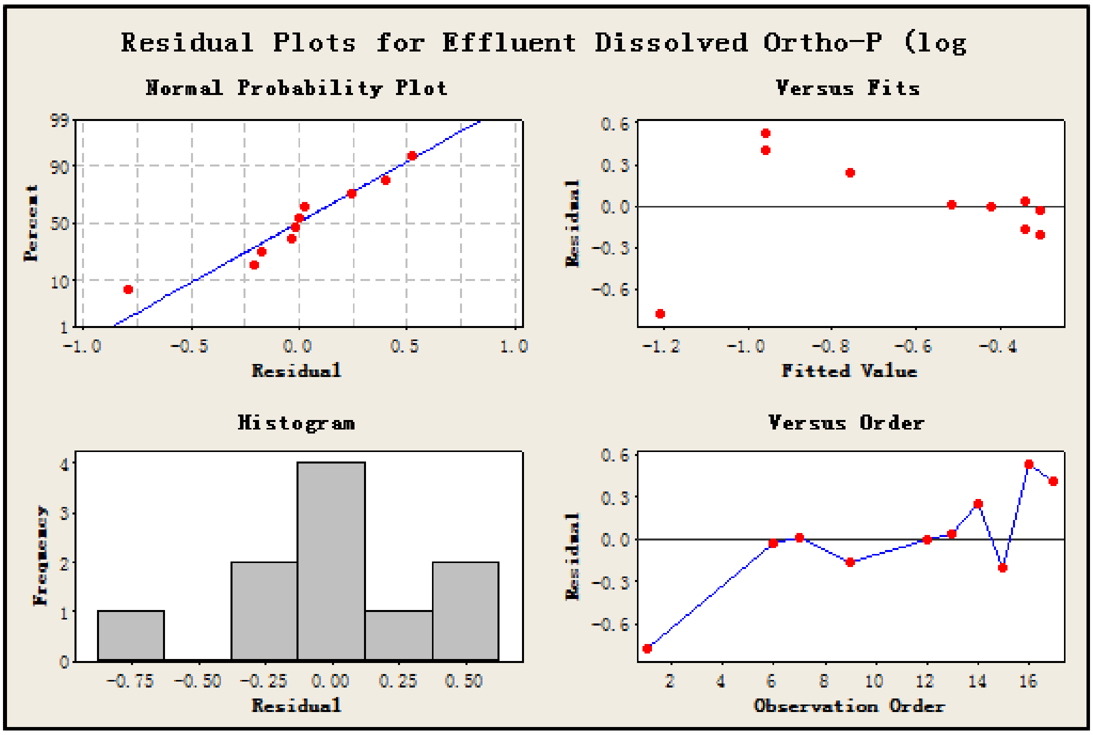
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.89
R Square	0.79
Adjusted R Square	0.68
Standard Error	0.37
Observations	10.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	4.70	4.70	34.75	0.00
Residual	9.00	1.22	0.14		
Total	10.00	5.92			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.25	0.21	5.89	0.00	0.77	1.73	0.77	1.73

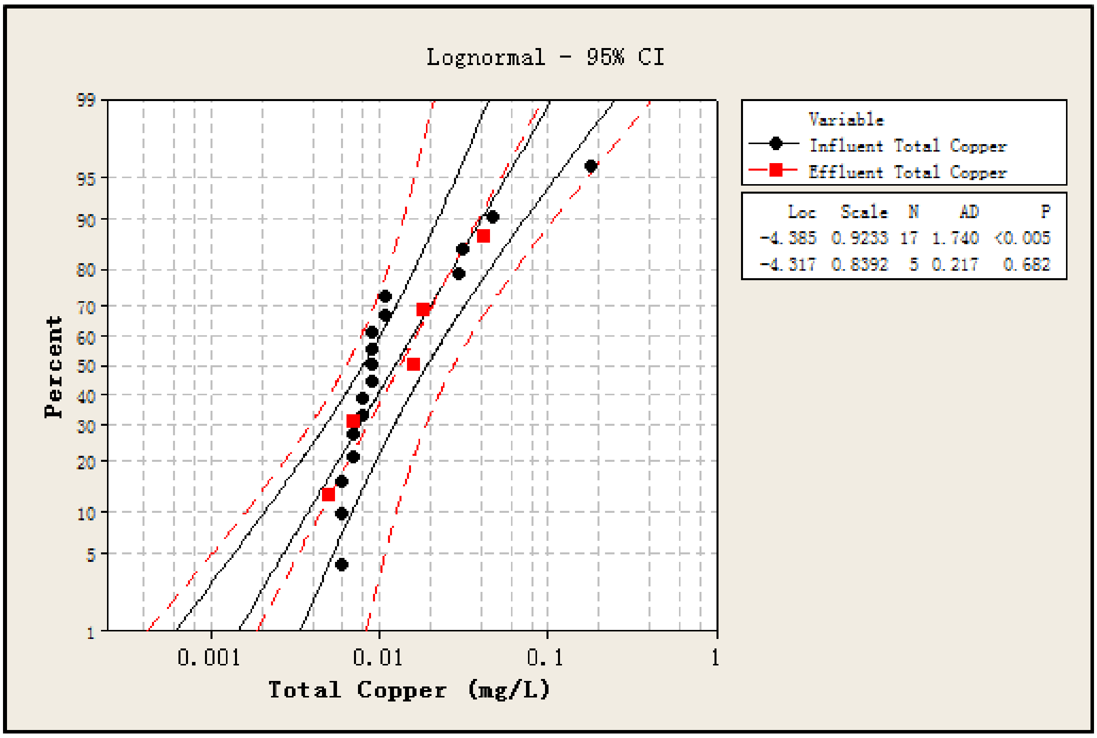


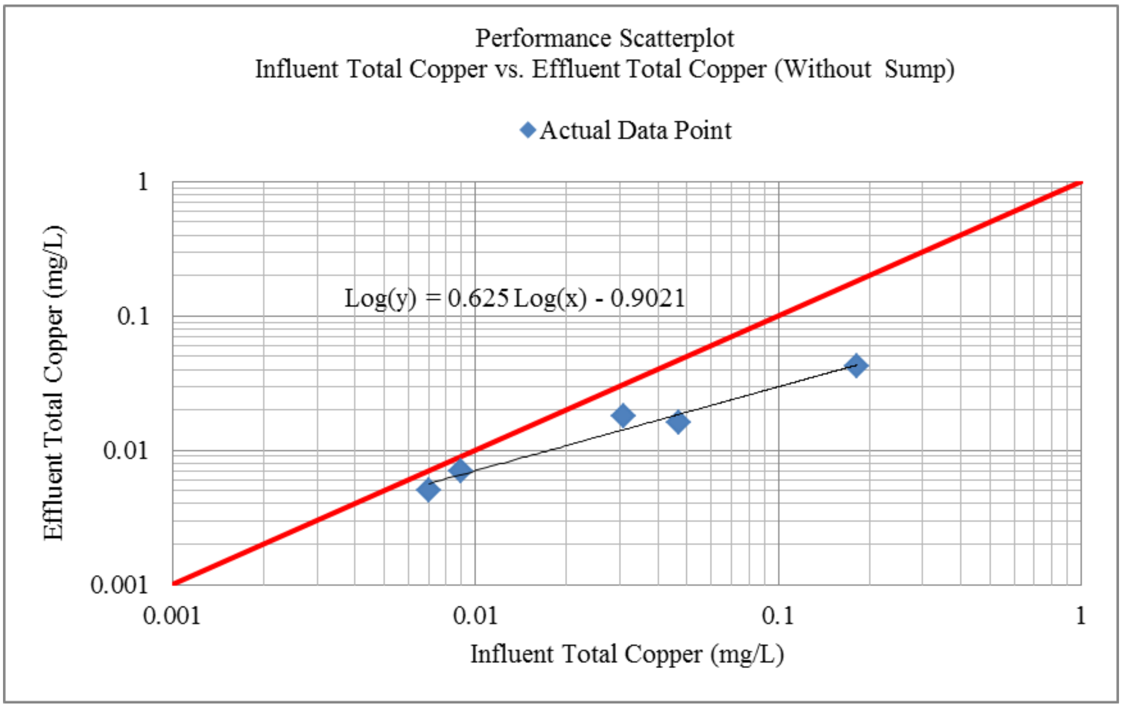
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Passed	(P = 0.814)			
Group	N	Missing	Median	0.25	0.75
Influent Dissolved Ortho-P	17.00	7.00	0.40	0.18	0.50
Effluent Dissolved Ortho-P	17.00	8.00	0.31	0.31	0.42

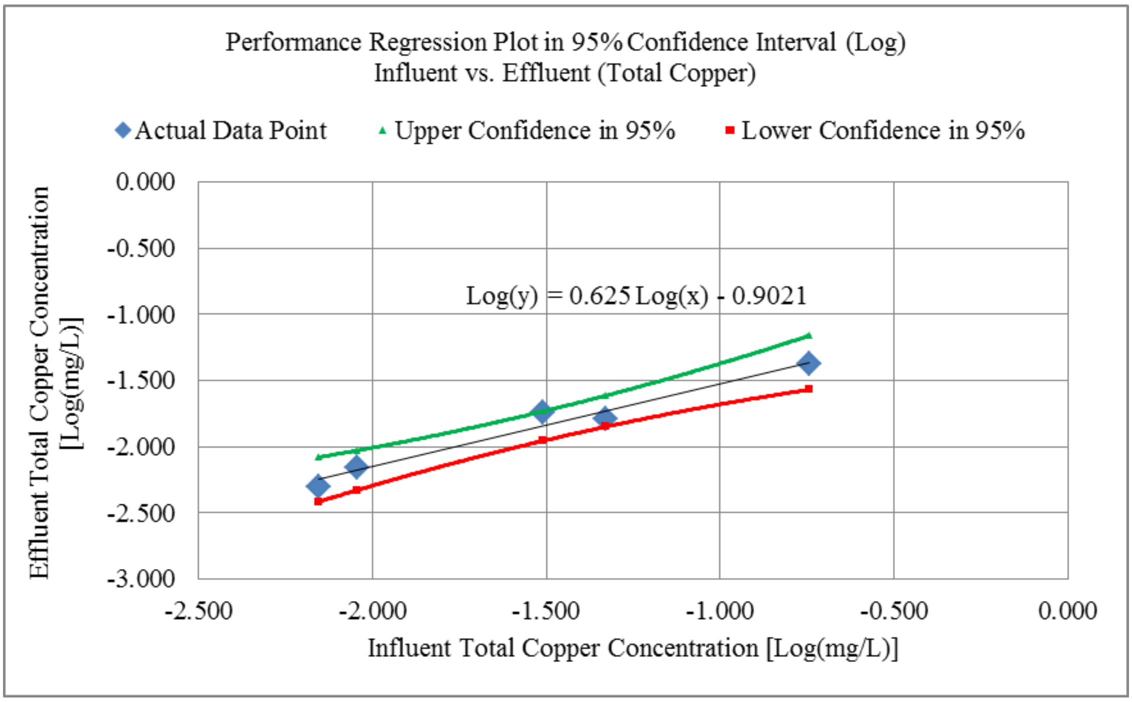
W= -7.000 T+ = 14.500 T-= -21.500
Z-Statistic (based on positive ranks) = -0.496
P(est.)= 0.671 P(exact)= 0.641

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.641).

Appendix D.8: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Copper (30 Sampled Storms)







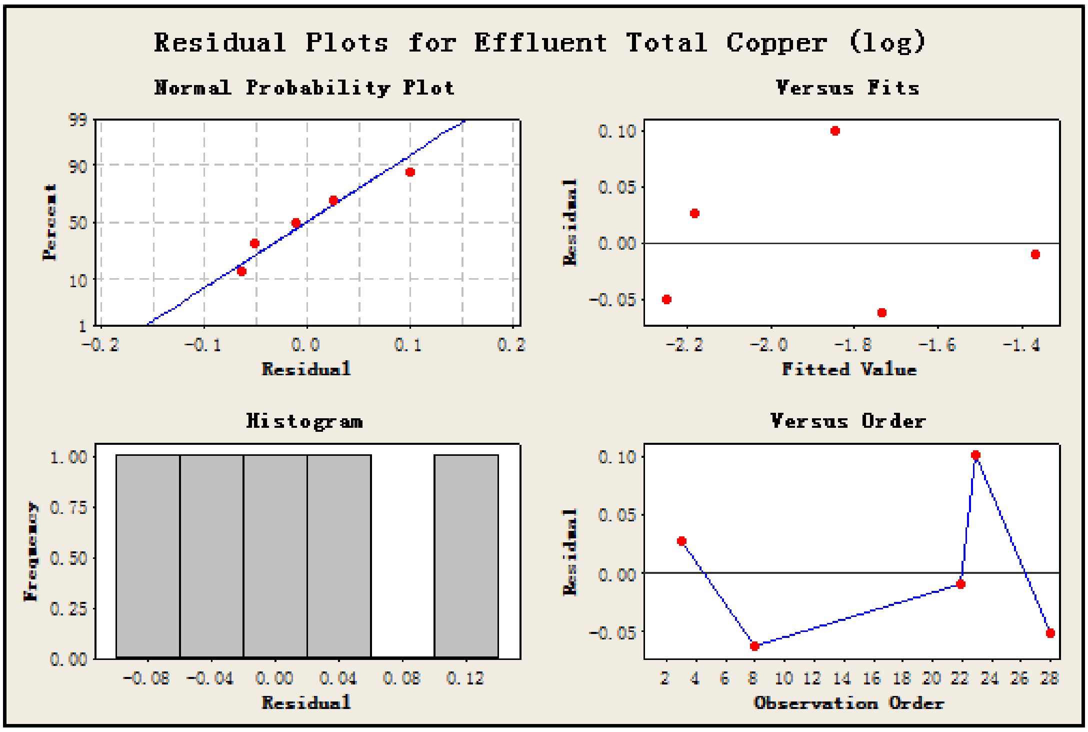
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.98
R Square	0.97
Adjusted R Square	0.96
Standard Error	0.08
Observations	5.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.51	0.51	87.43	0.00
Residual	3.00	0.02	0.01		
Total	4.00	0.53			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.90	0.11	-8.24	0.00	-1.25	-0.55	-1.25	-0.55
X Variable 1	0.63	0.07	9.35	0.00	0.41	0.84	0.41	0.84

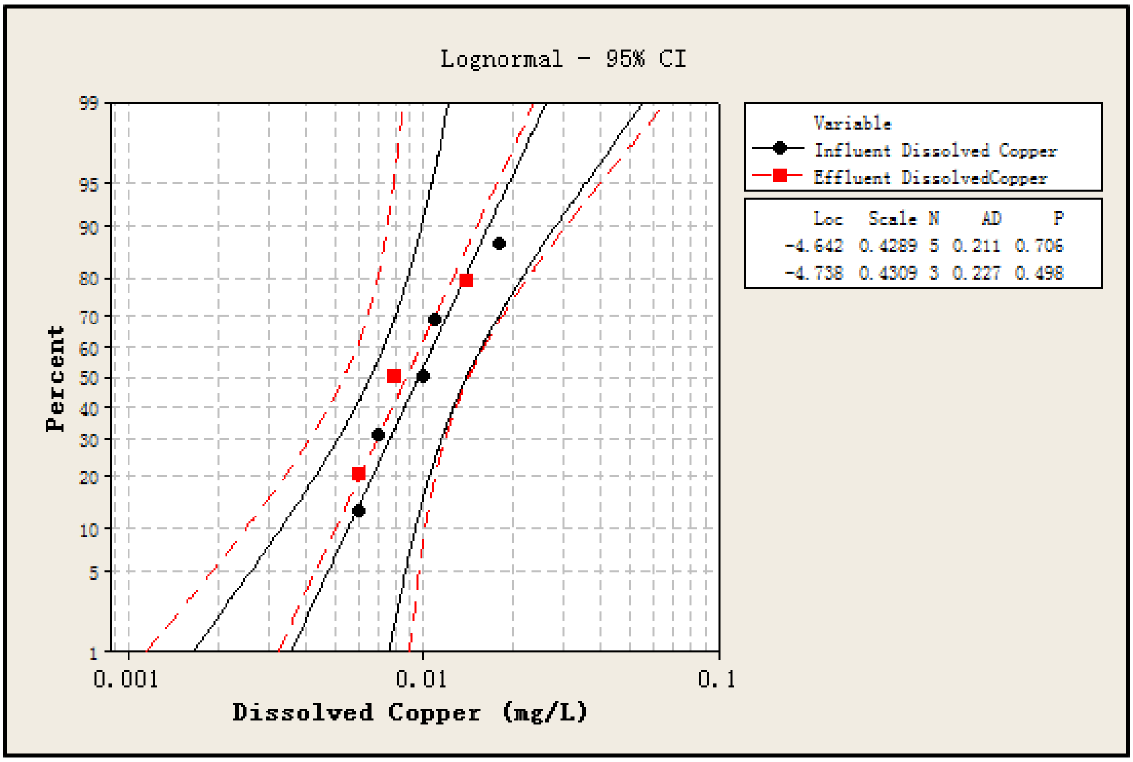


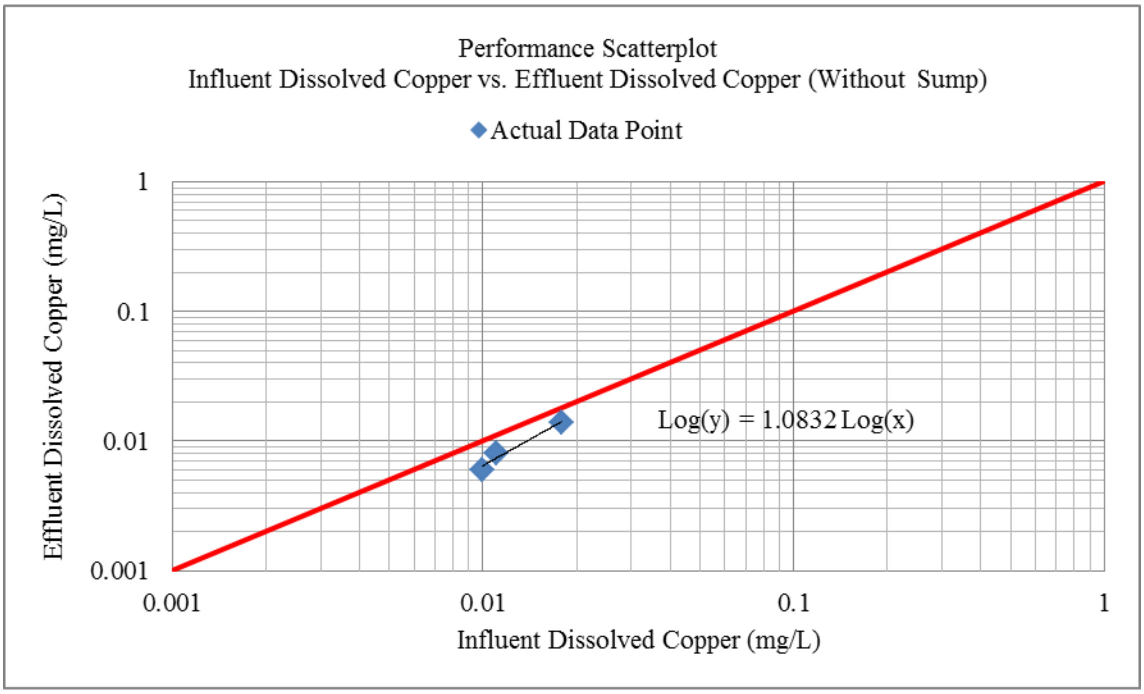
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent Total Copper	30.00	13.00	0.01	0.01	0.02
Effluent Total Copper	30.00	25.00	0.02	0.01	0.03

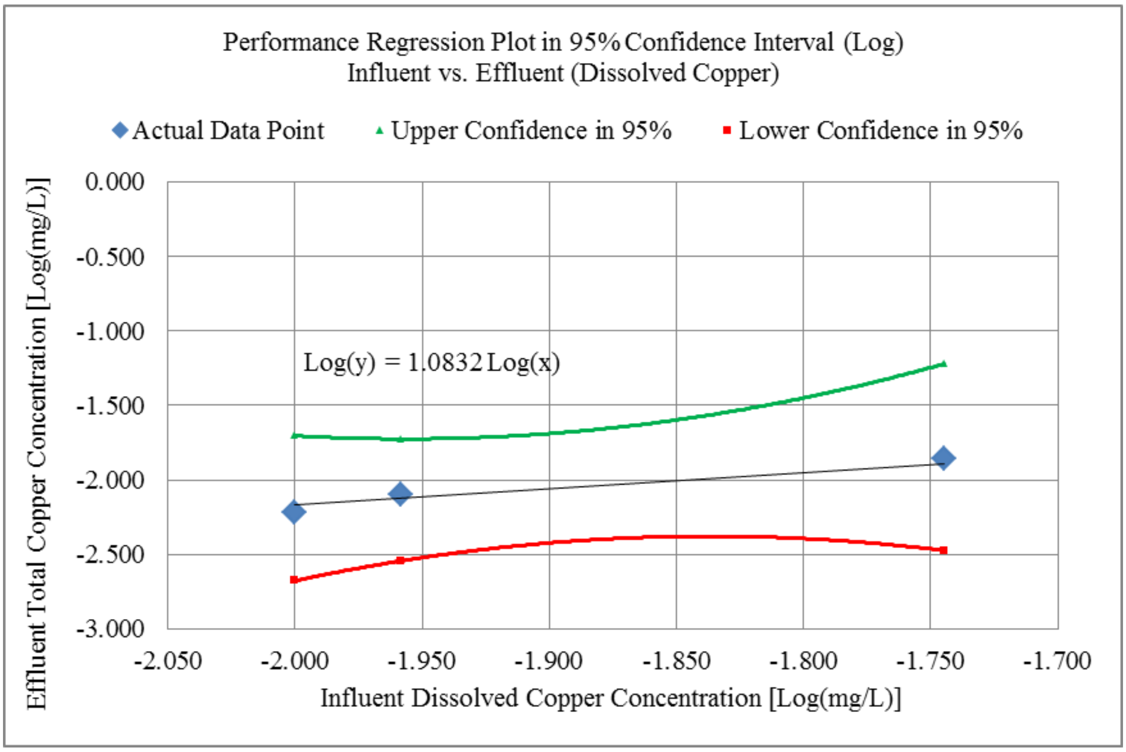
W= -15.000 T+ = 0.000 T-= -15.000
Z-Statistic (based on positive ranks) = -2.023
P(est.)= 0.059 P(exact)= 0.063

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.063).

Appendix D.9: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Copper (30 Sampled Storms)







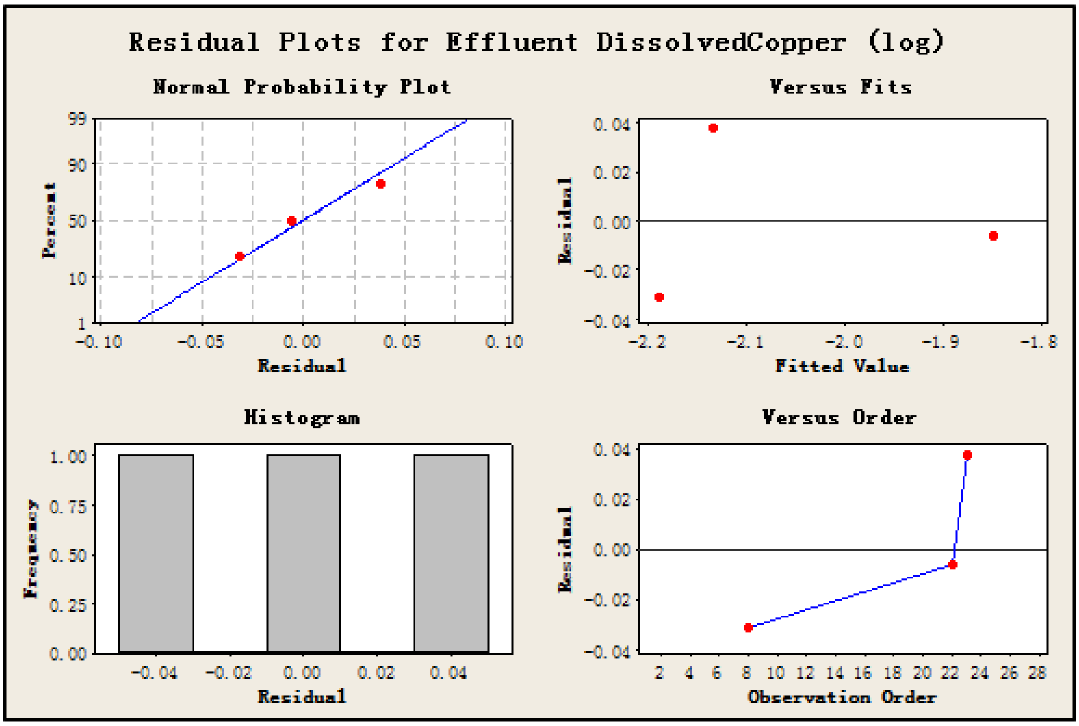
SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	1.00
Adjusted R Square	0.50
Standard Error	0.05
Observations	3.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	12.77	12.77	5127.16	0.01
Residual	2.00	0.00	0.00		
Total	3.00	12.77			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.08	0.02	71.60	0.00	1.02	1.15	1.02	1.15



Wilcoxon Signed Rank Test

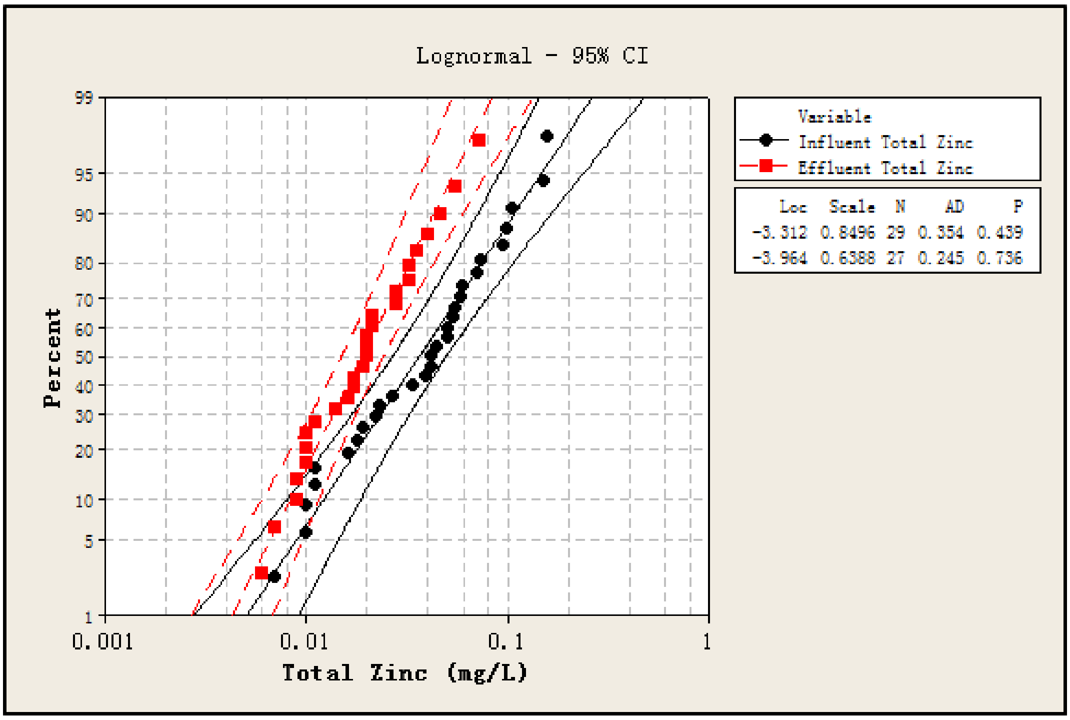
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

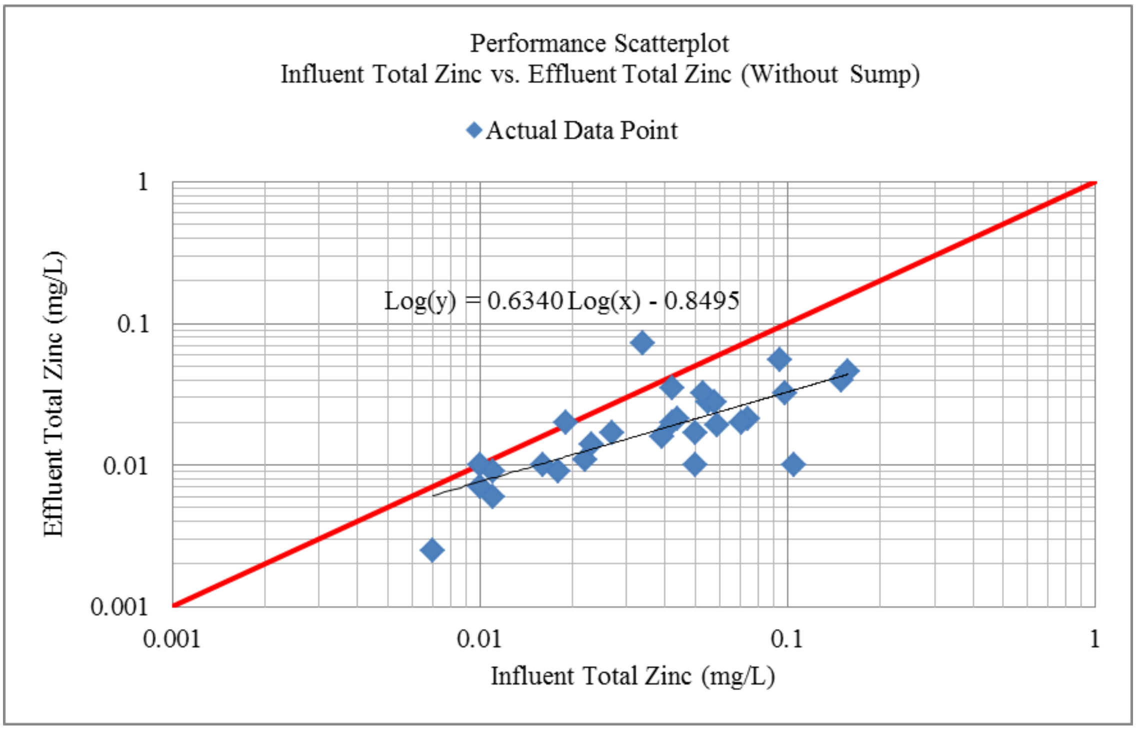
Group	N	Missing	Median	0.25	0.75
Influent Dissolved Copper	28.00	23.00	0.01	0.01	0.01
Effluent Dissolved Copper	28.00	25.00	0.01	0.01	0.01

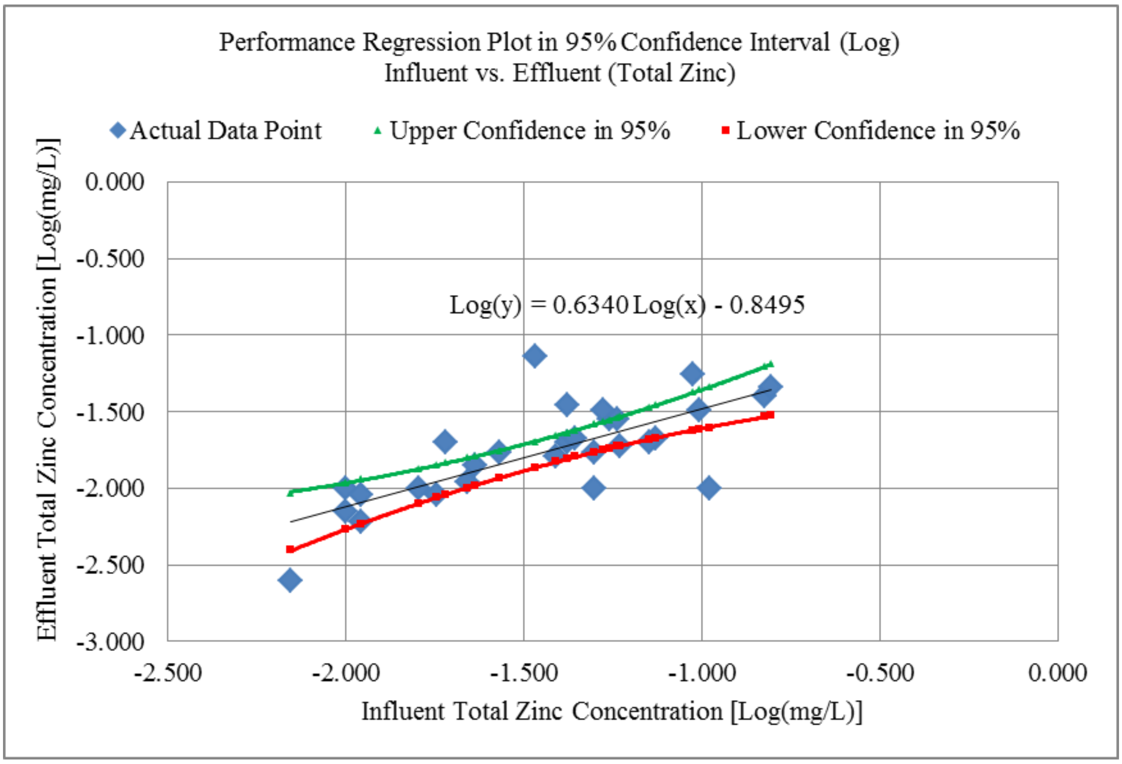
W= -6.000 T+ = 0.000 T-= -6.000
Z-Statistic (based on positive ranks) = -1.604
P(est.)= 0.181 P(exact)= 0.250

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.250).

Appendix D.10: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Zinc (30 Sampled Storms)







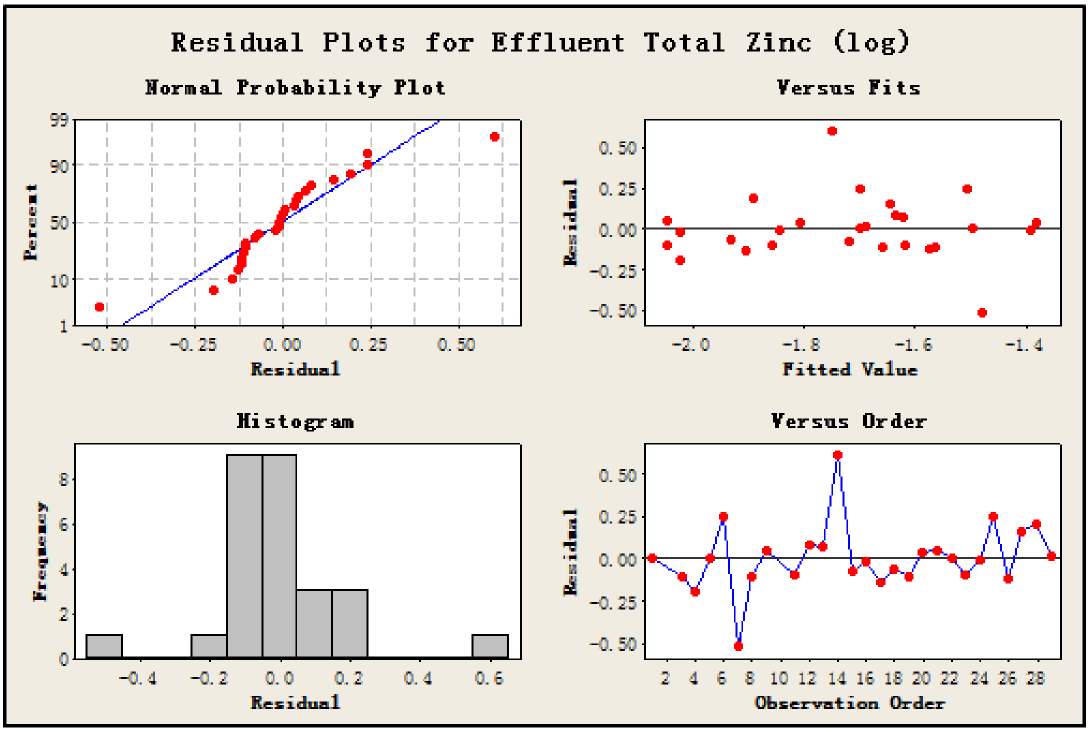
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.74
R Square	0.55
Adjusted R Square	0.53
Standard Error	0.22
Observations	29.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.53	1.53	32.43	0.00
Residual	27.00	1.28	0.05		
Total	28.00	2.81			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.8495	0.17	-5.14	0.00	-1.19	-0.51	-1.19	-0.51
X Variable 1	0.6340	0.11	5.69	0.00	0.41	0.86	0.41	0.86



Wilcoxon Signed Rank Test

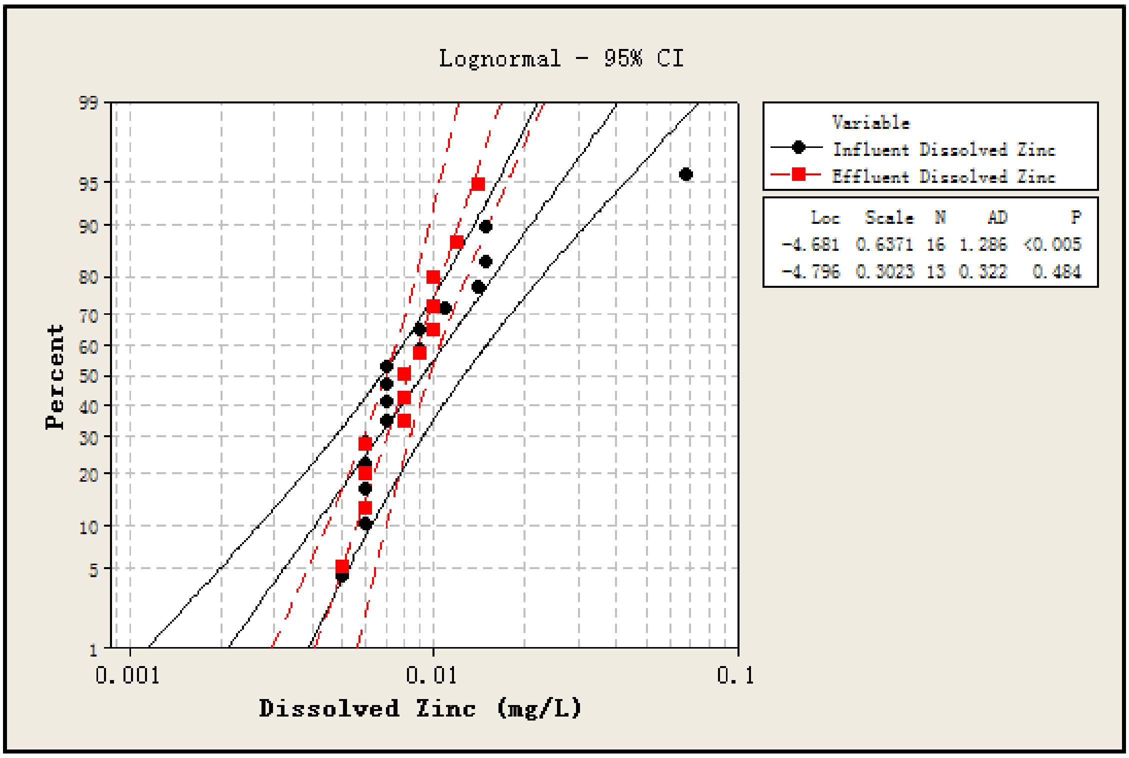
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

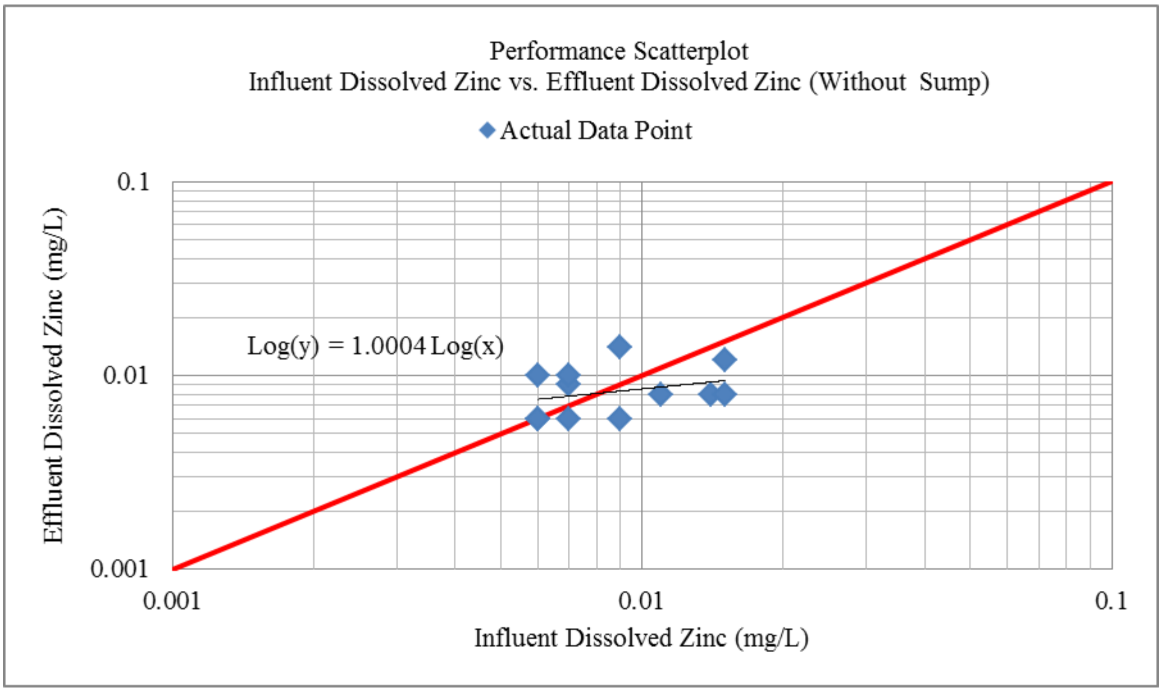
Group	N	Missing	Median	0.25	0.75
Influent Total Zinc	30.00	0.00	0.04	0.02	0.07
Effluent Total Zinc	30.00	2.00	0.02	0.01	0.03

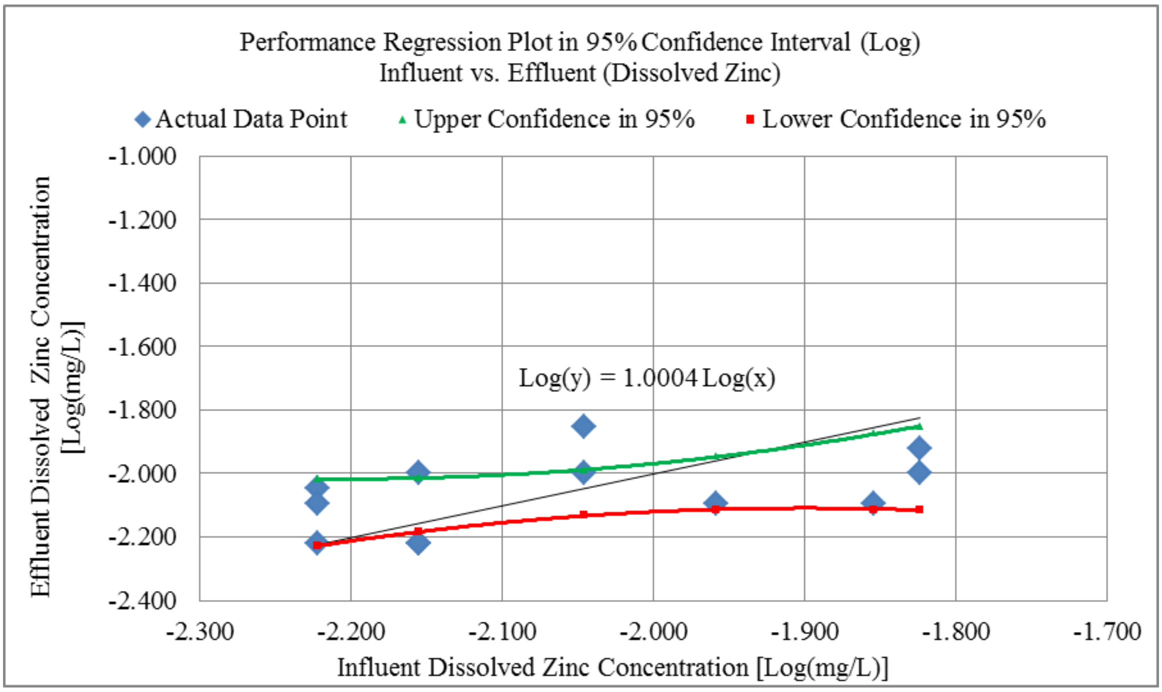
W= -340.000 T+ = 19.000 T-= -359.000
Z-Statistic (based on positive ranks) = -4.084
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix D.11: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Zinc (30 Sampled Storms)







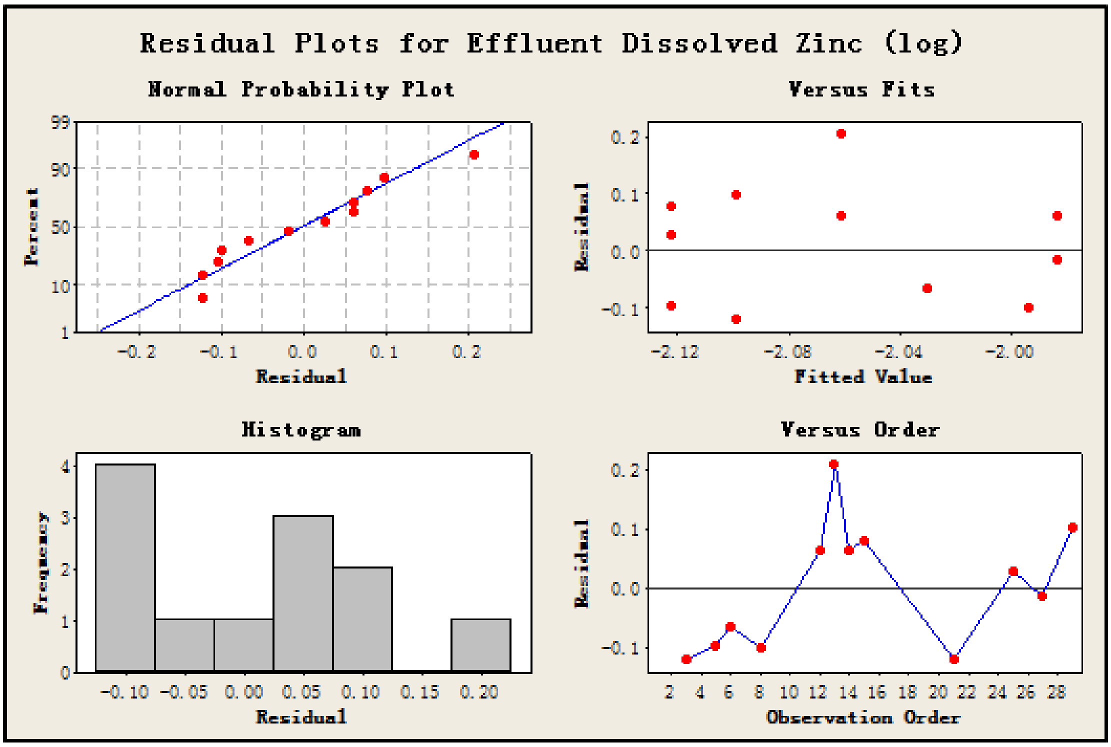
SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	1.00
Adjusted R Square	0.90
Standard Error	0.15
Observations	12.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	51.08	51.08	2369.81	0.00
Residual	11.00	0.24	0.02		
Total	12.00	51.31			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.0000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.0004	0.02	48.68	0.00	0.96	1.05	0.96	1.05



Wilcoxon Signed Rank Test

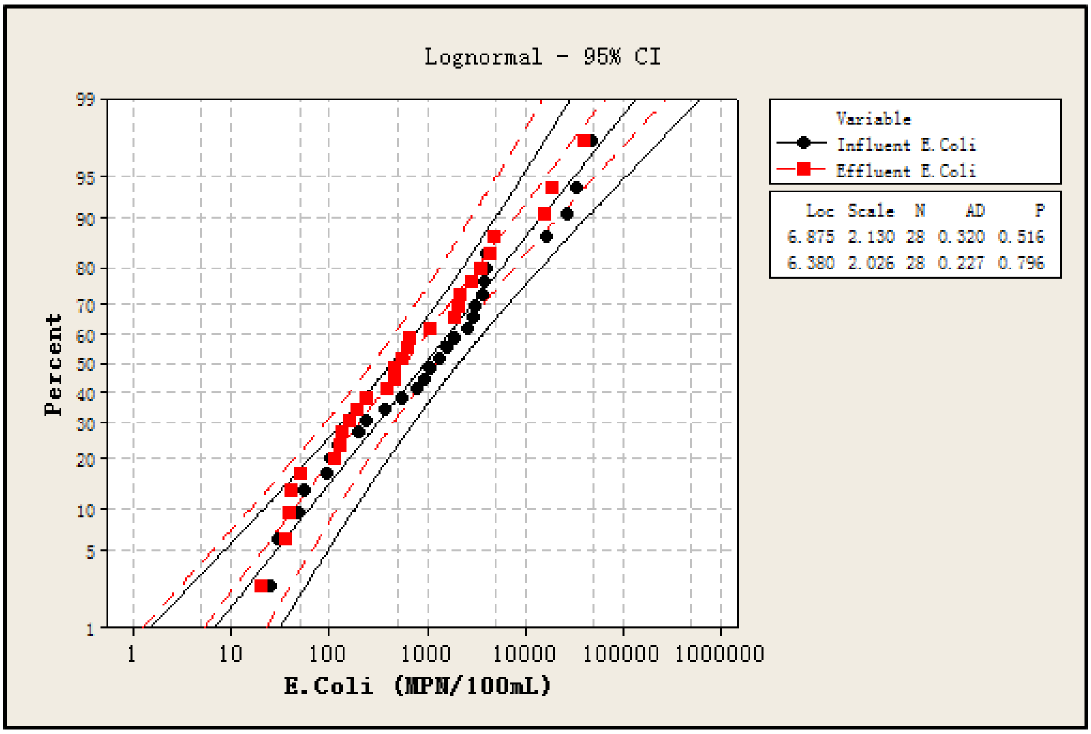
Normality Test (Shapiro-Wilk)   Failed   (P < 0.050)

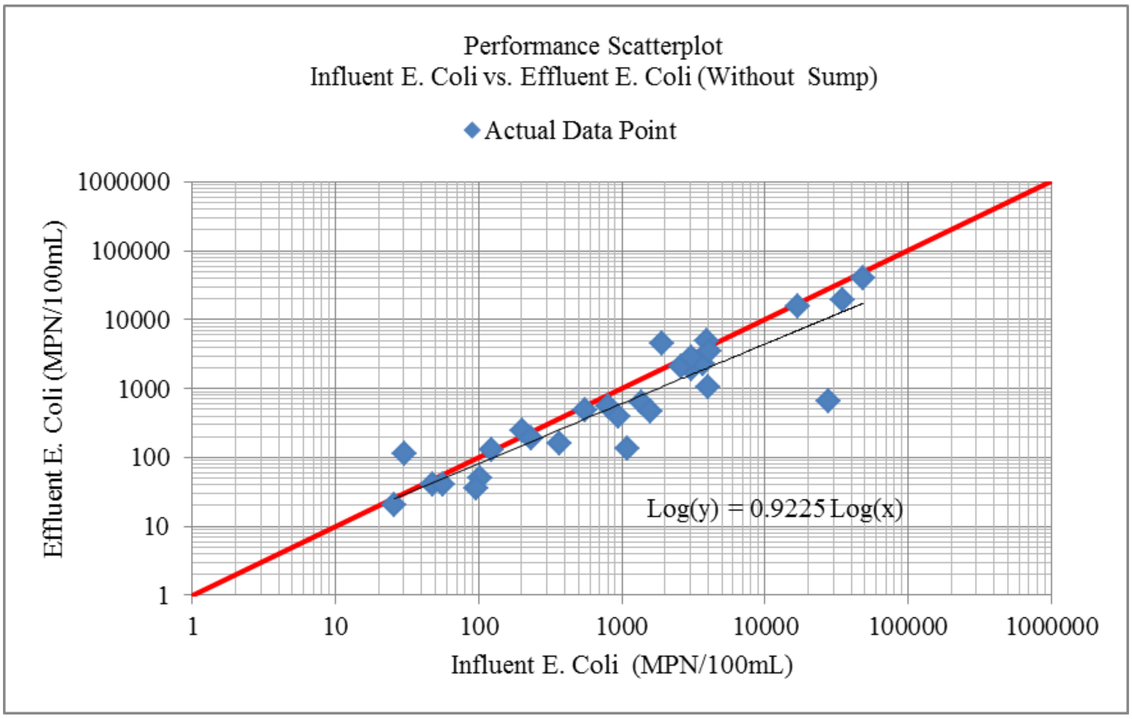
Group	N	Missing	Median	0.25	0.75
Influent Dissolved Zinc	30.00	13.00	0.01	0.01	0.01
Effluent Dissolved Zinc	30.00	16.00	0.01	0.01	0.01

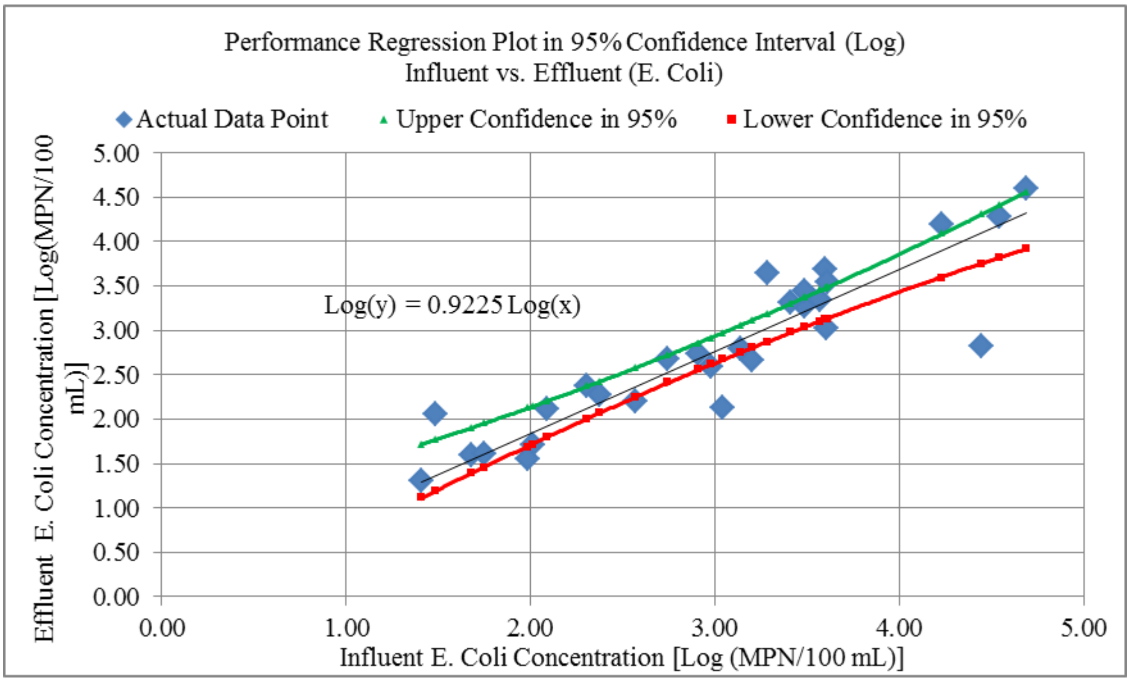
W= -16.000 T+ = 31.000 T-= -47.000
Z-Statistic (based on positive ranks) = -0.629
P(est.)= 0.556 P(exact)= 0.569

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.569).

Appendix D.12: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for *E. Coli* (30 Sampled Storms)







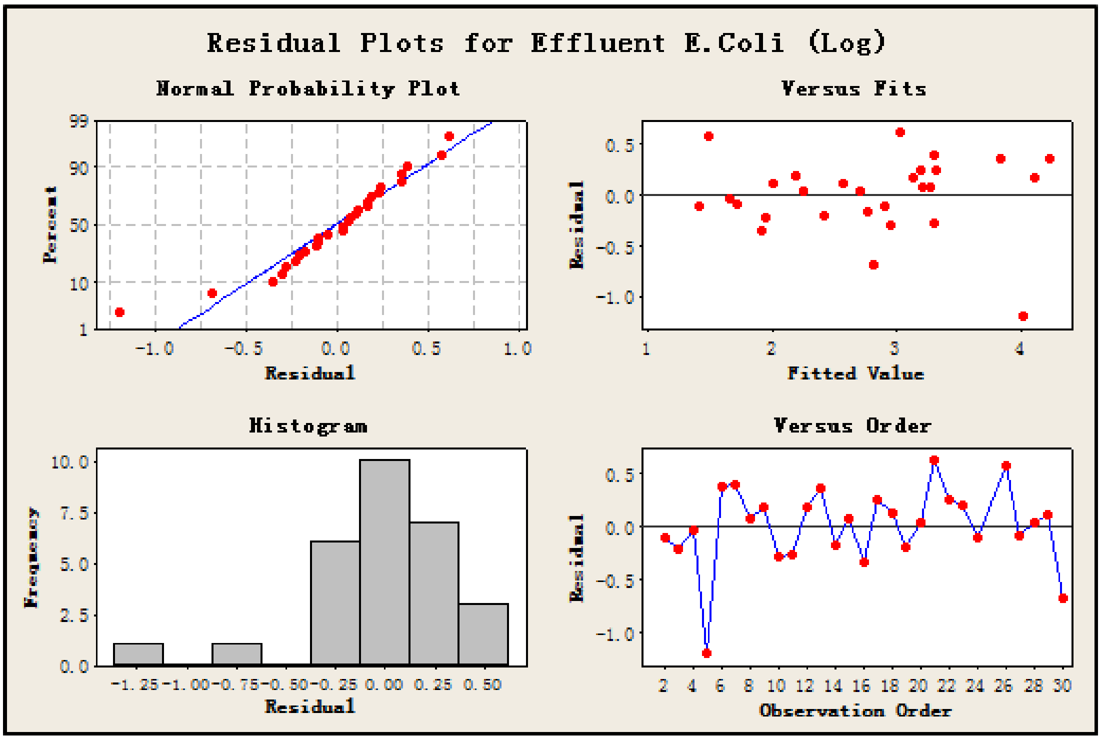
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.98
Adjusted R Square	0.95
Standard Error	0.38
Observations	28.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	232.07	232.07	1633.32	0.00
Residual	27.00	3.84	0.14		
Total	28.00	235.90			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.92	0.02	40.41	0.00	0.88	0.97	0.88	0.97

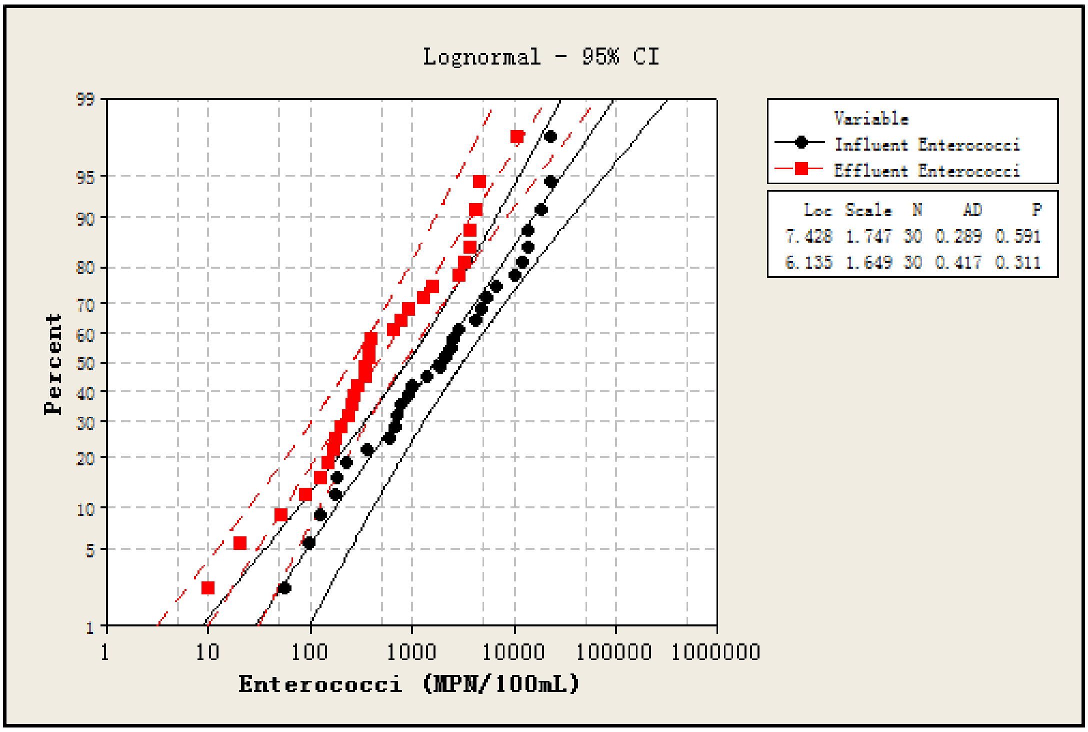


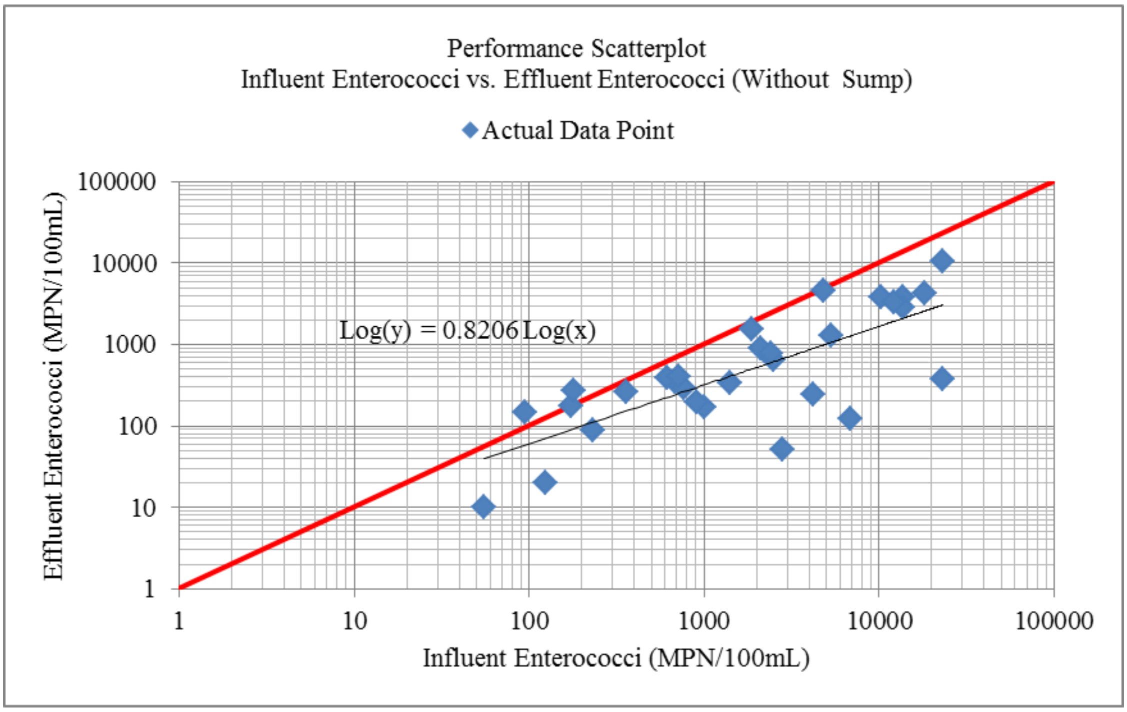
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent E.Coli	30.00	2.00	1233.00	143.25	3882.50
Effluent E.Coli	30.00	2.00	510.50	130.38	2667.25

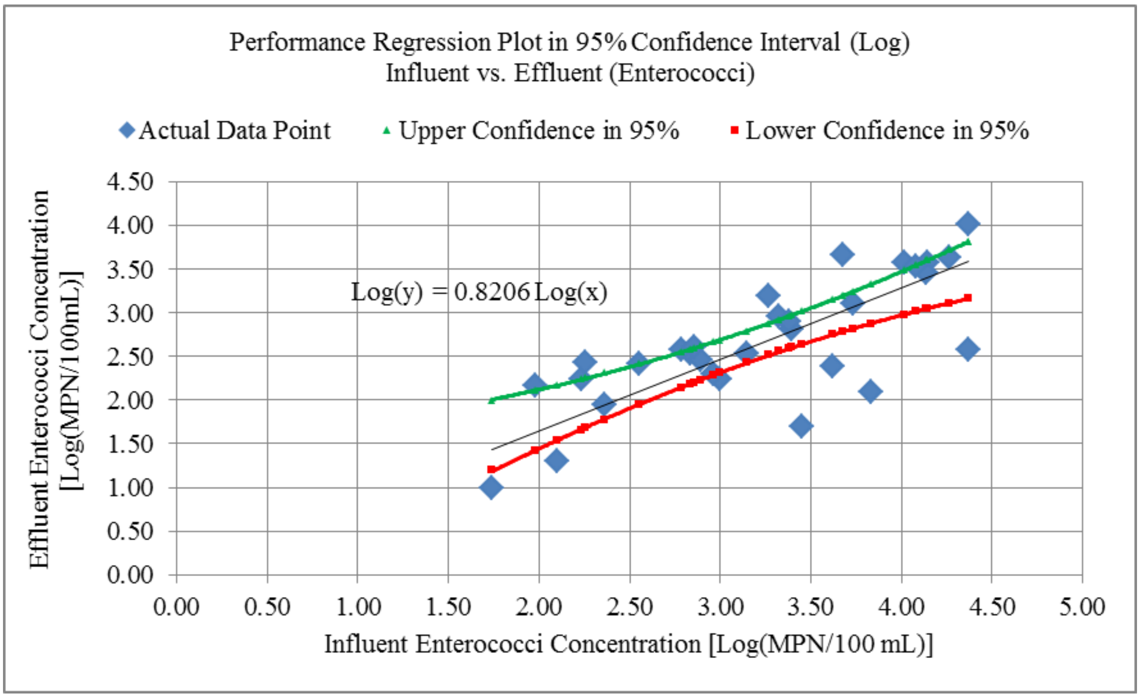
W= -290.000 T+ = 58.000 T-= -348.000
Z-Statistic (based on positive ranks) = -3.302
(P = 0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.001).

Appendix D.13: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Enterococci (30 Sampled Storms)







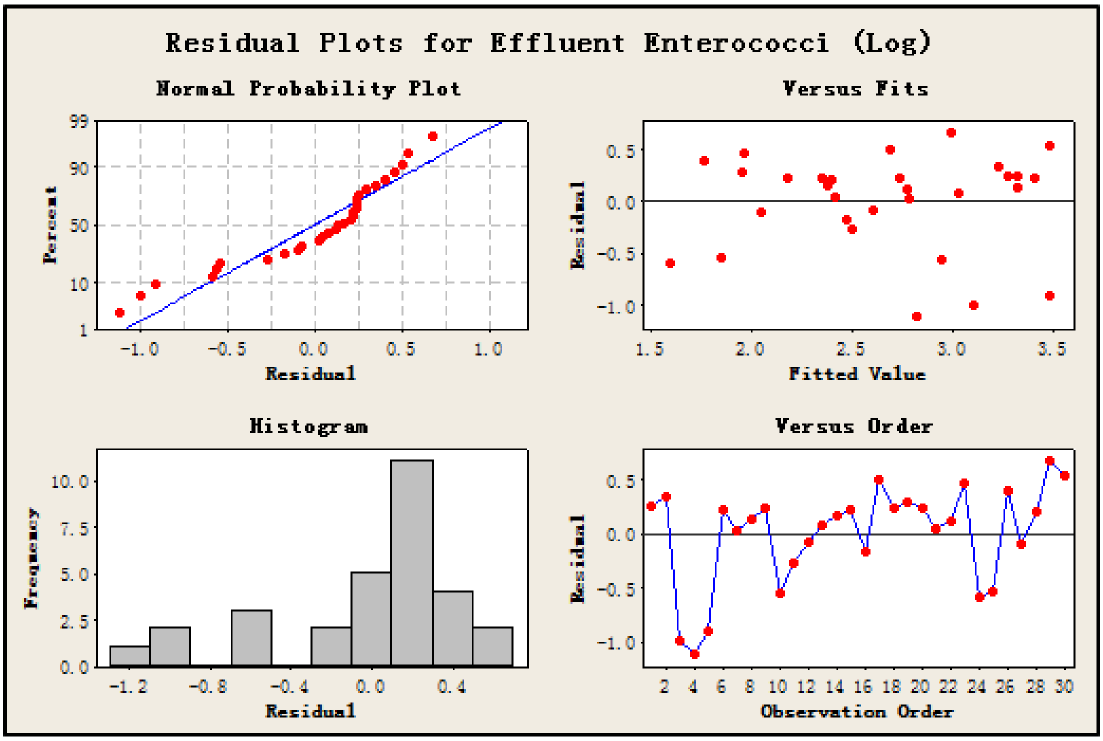
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.97
Adjusted R Square	0.94
Standard Error	0.47
Observations	30.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	221.48	221.48	1002.26	0.00
Residual	29.00	6.41	0.22		
Total	30.00	227.88			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.82	0.03	31.66	0.00	0.77	0.87	0.77	0.87



Wilcoxon Signed Rank Test

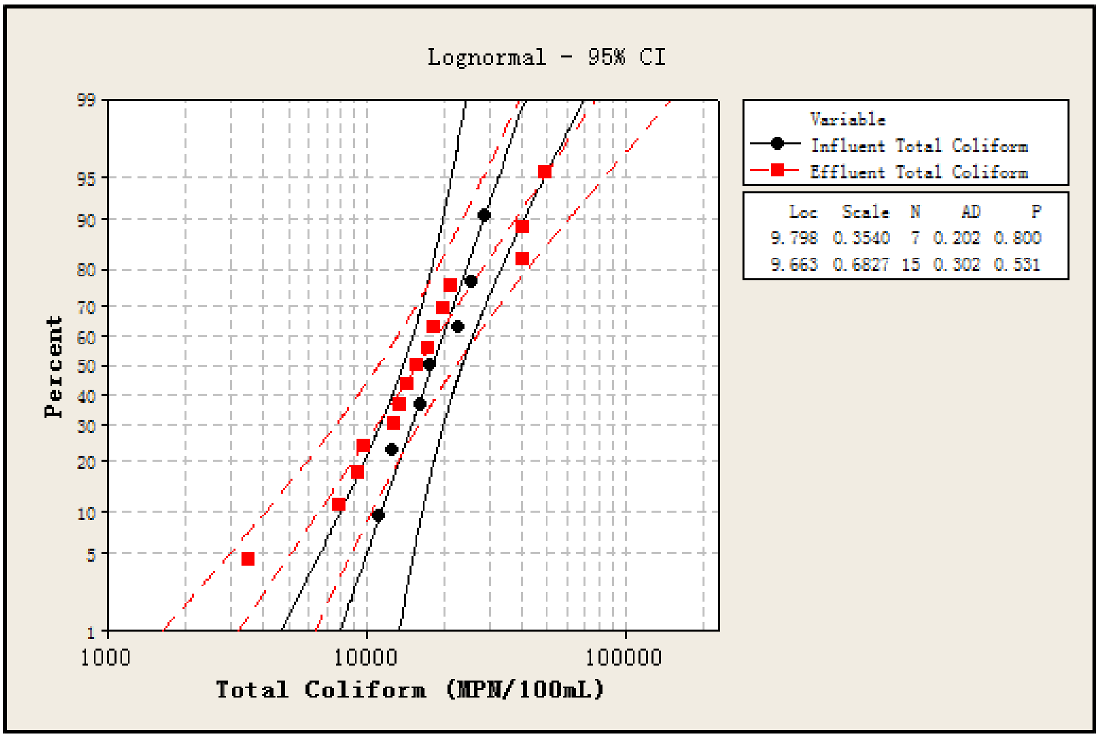
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

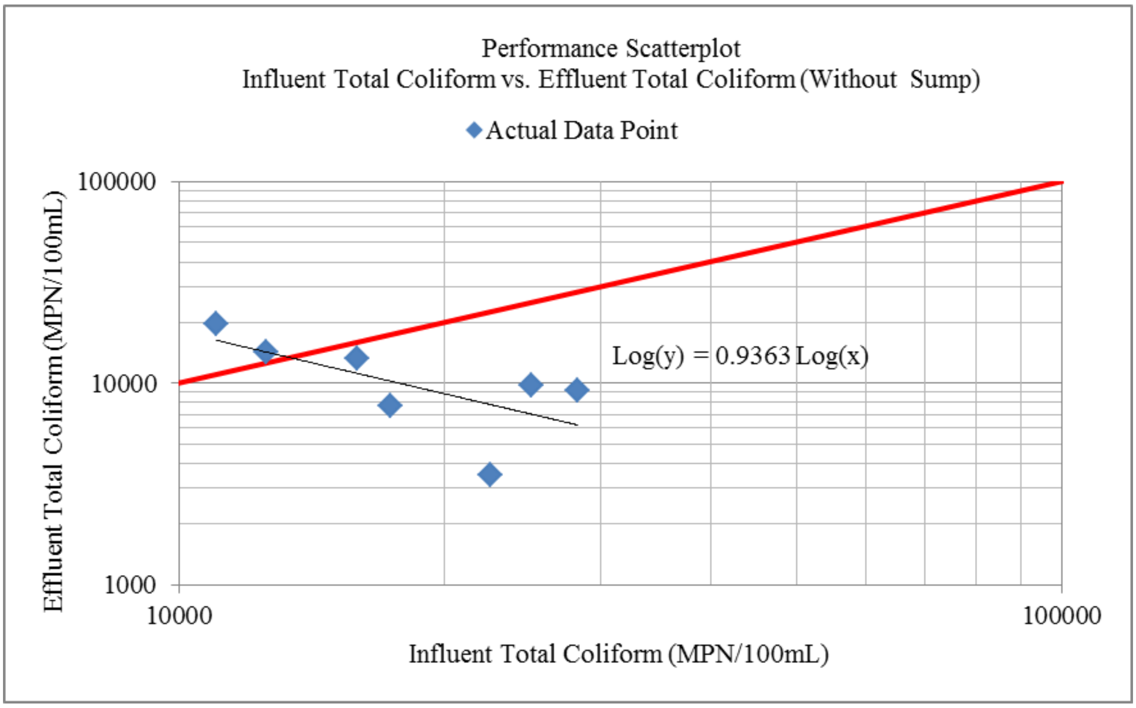
Group	N	Missing	Median	0.25	0.75
Influent Enterococci	30.00	0.00	1991.50	550.00	7735.00
Effluent Enterococci	30.00	0.00	359.00	174.75	1885.50

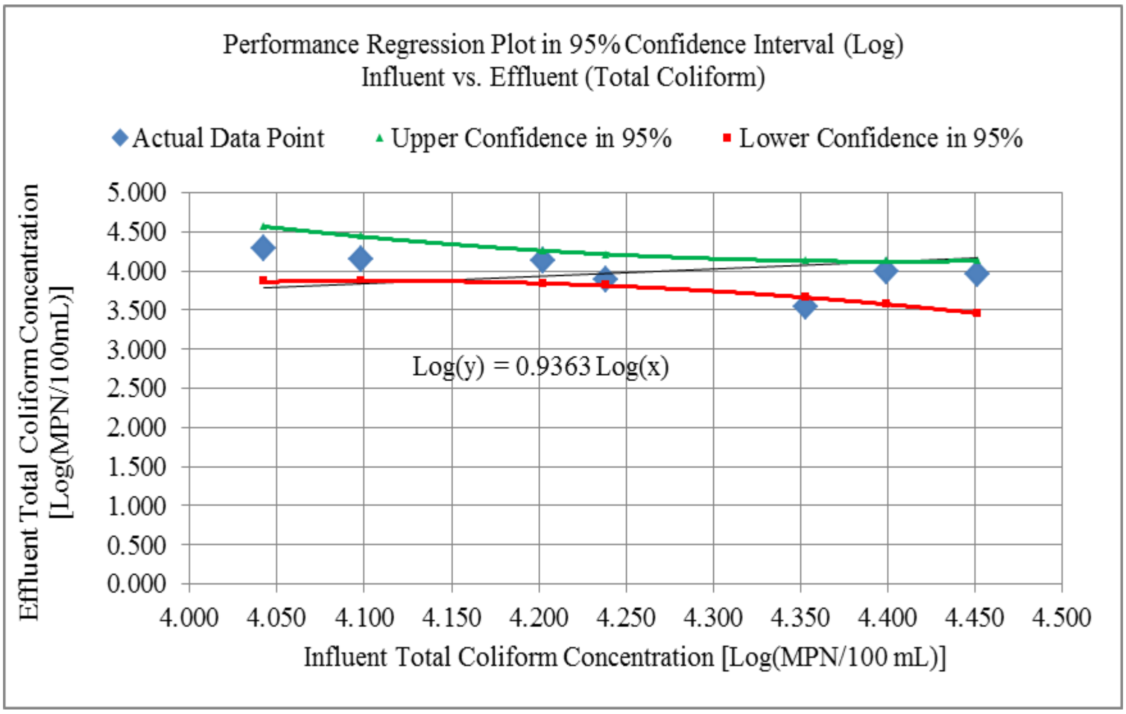
W= -449.000 T+ = 8.000 T-= -457.000
Z-Statistic (based on positive ranks) = -4.618
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix D.14: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Coliform (30 Sampled Storms)







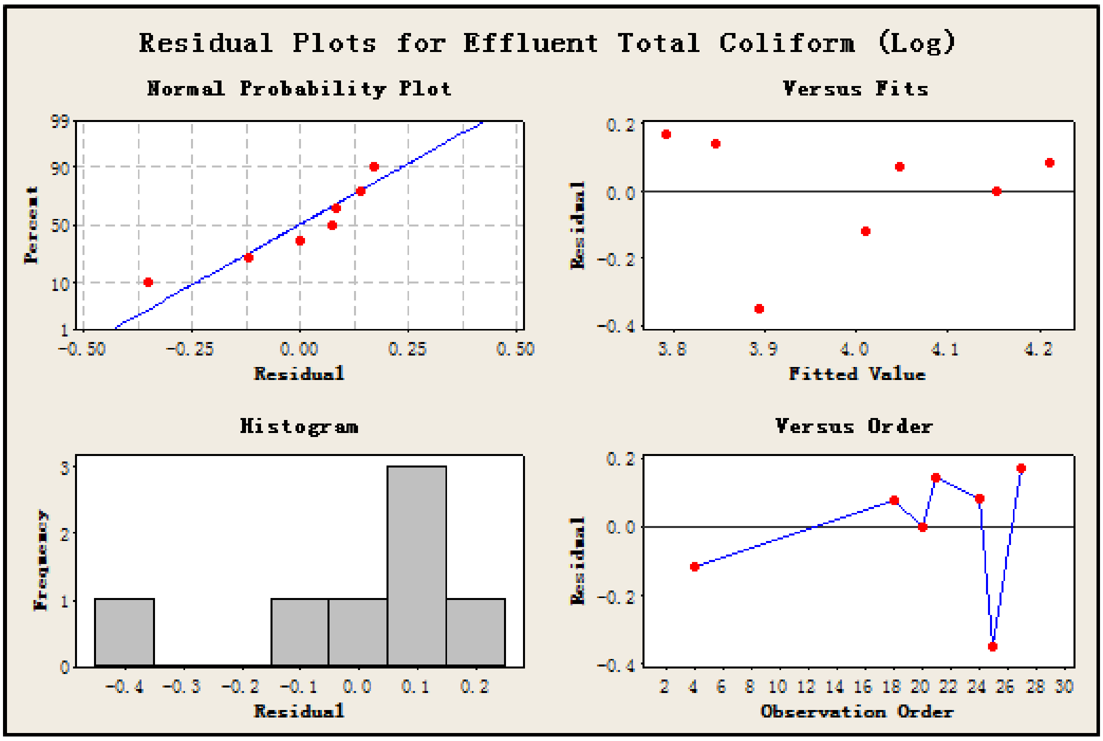
SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	0.99
Adjusted R Square	0.83
Standard Error	0.35
Observations	7.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	111.24	111.24	893.11	0.00
Residual	6.00	0.75	0.12		
Total	7.00	111.99			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.94	0.03	29.88	0.00	0.86	1.01	0.86	1.01



Wilcoxon Signed Rank Test

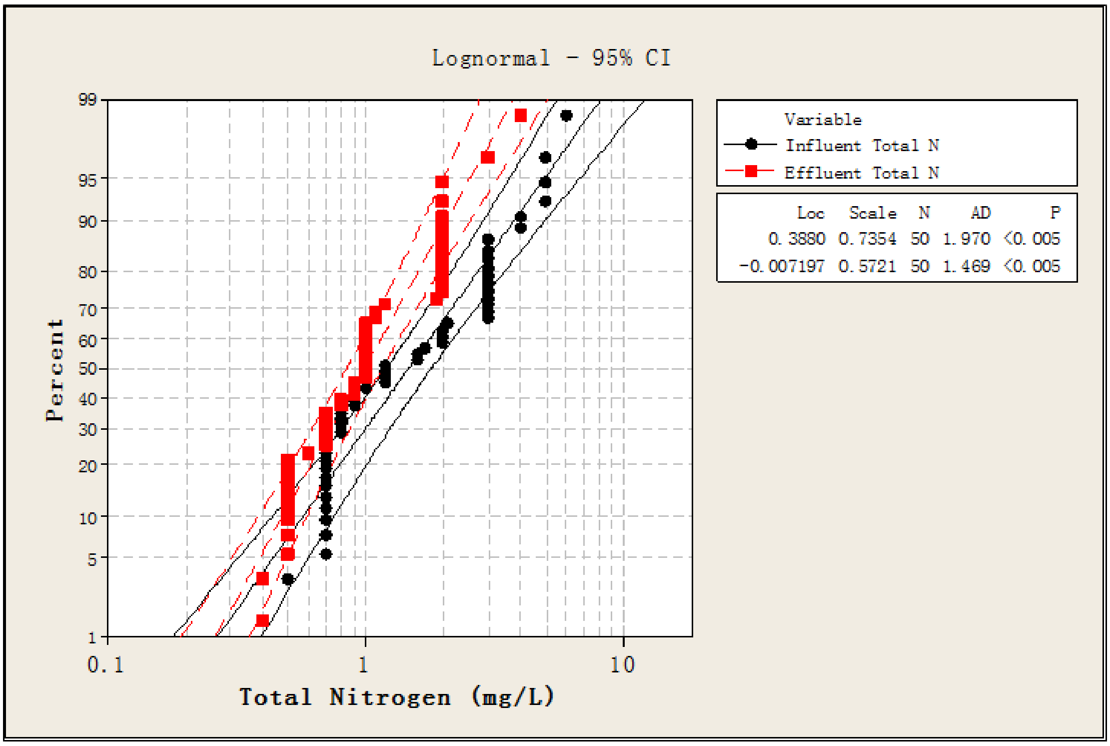
Normality Test (Shapiro-Wilk) Passed (P = 0.444)

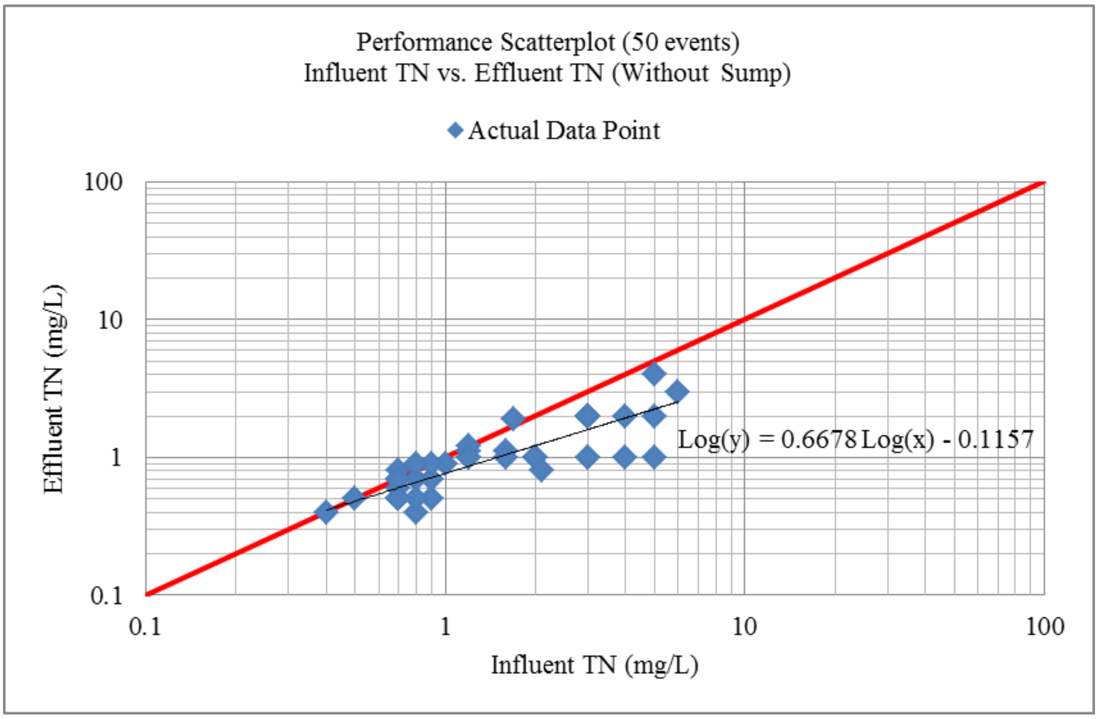
Group	N	Missing	Median	0.25	0.75
Influent Total Coliform	30.00	23.00	17329.00	12543.00	25095.00
Effluent Total Coliform	30.00	15.00	15531.50	9705.50	20924.00

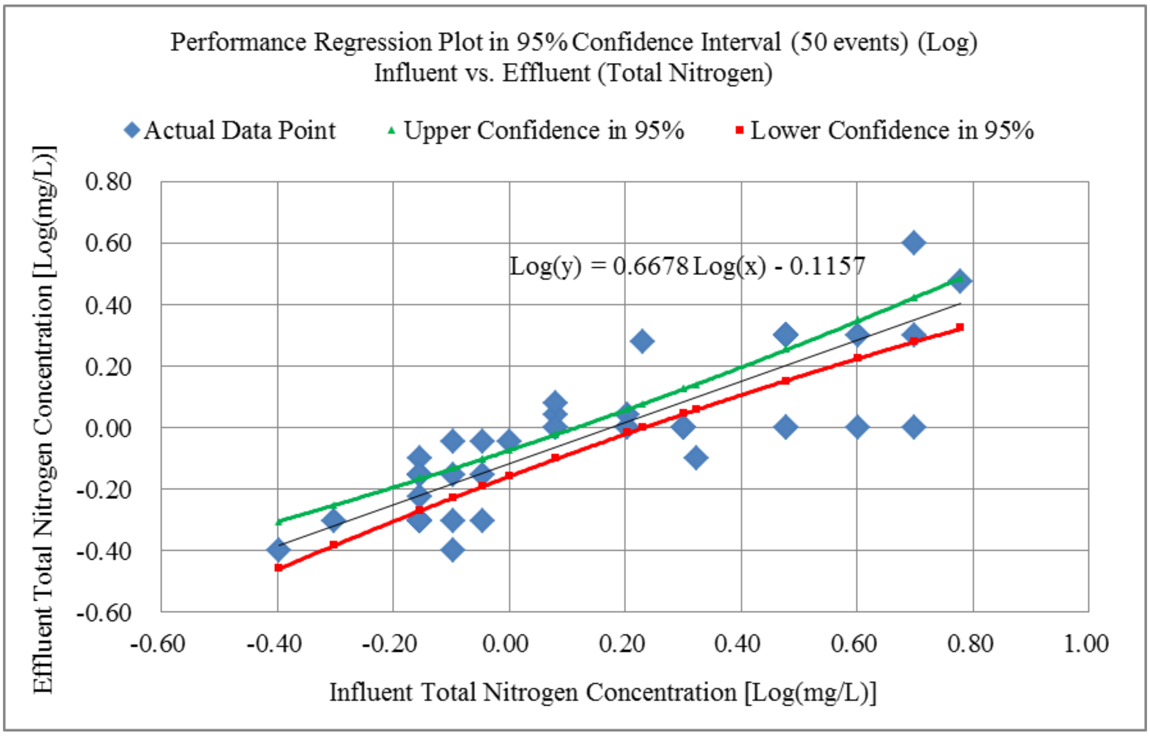
W= -20.000 T+ = 4.000 T-= -24.000
Z-Statistic (based on positive ranks) = -1.690
P(est.)= 0.108 P(exact)= 0.109

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.109).

Appendix E.1: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Nitrogen (50 Sampled Storms)







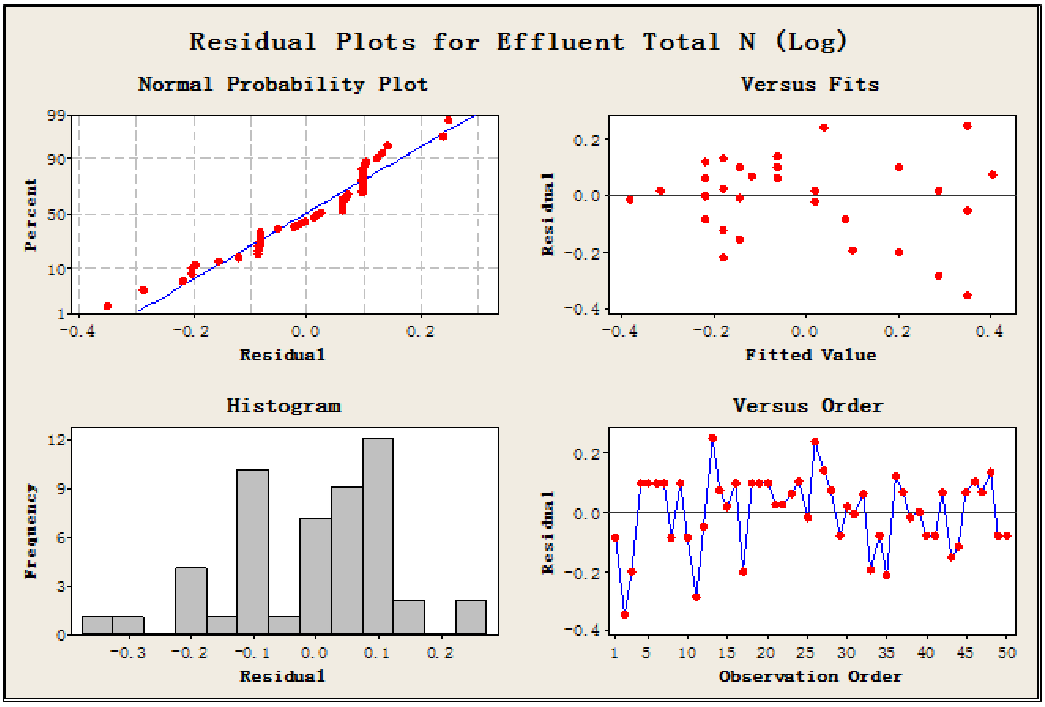
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.86
R Square	0.74
Adjusted R Square	0.73
Standard Error	0.13
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	2.23	2.23	134.55	0.00
Residual	48.00	0.80	0.02		
Total	49.00	3.02			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.12	0.02	-5.61	0.00	-0.16	-0.07	-0.16	-0.07
X Variable 1	0.67	0.06	11.60	0.00	0.55	0.78	0.55	0.78



Wilcoxon Signed Rank Test

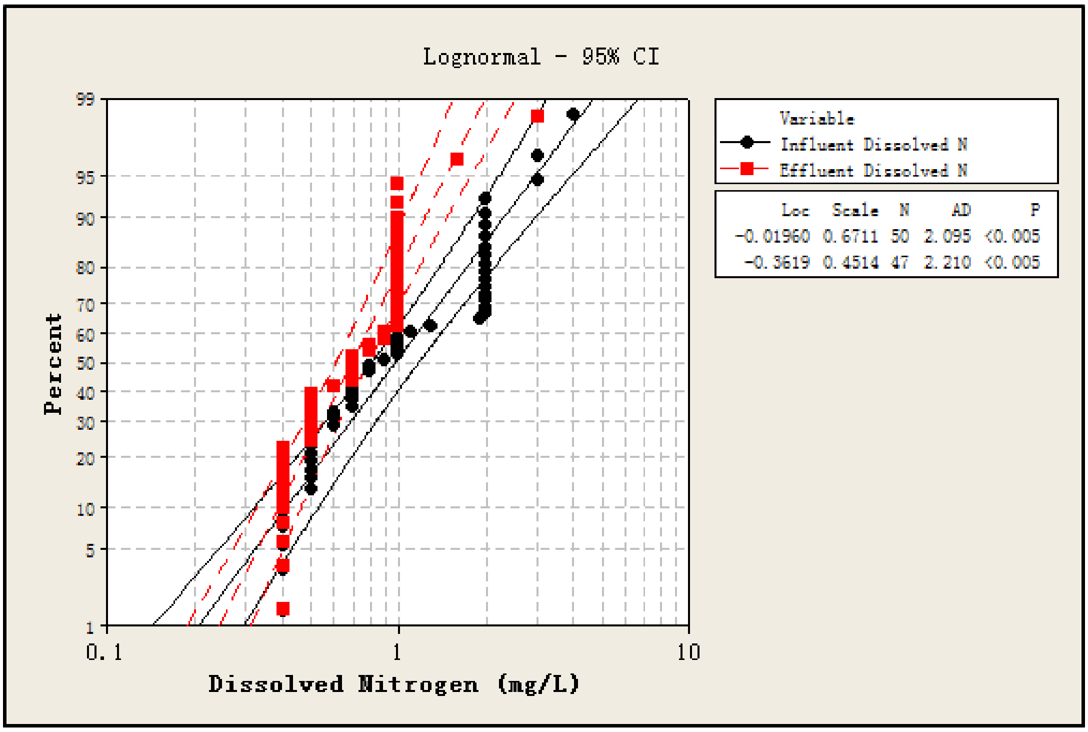
Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

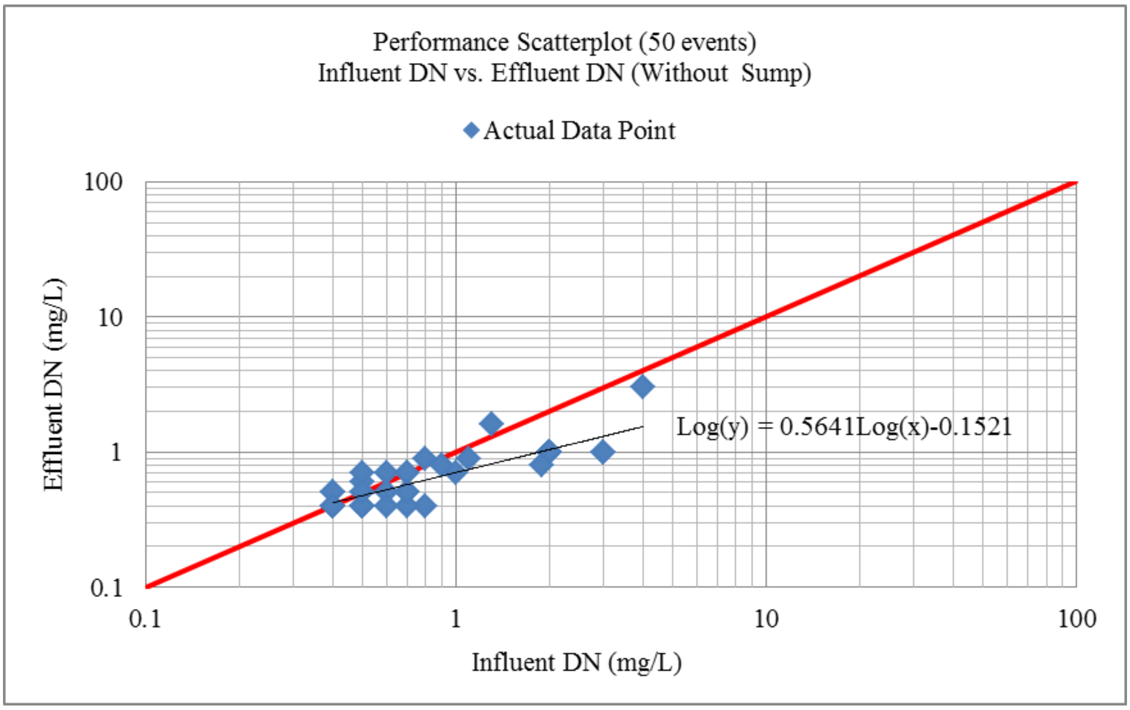
Group	N	Missing	Median	0.25	0.75
Influent TN	50.00	0.00	1.20	0.70	3.00
Effluent TN	50.00	0.00	1.00	0.68	2.00

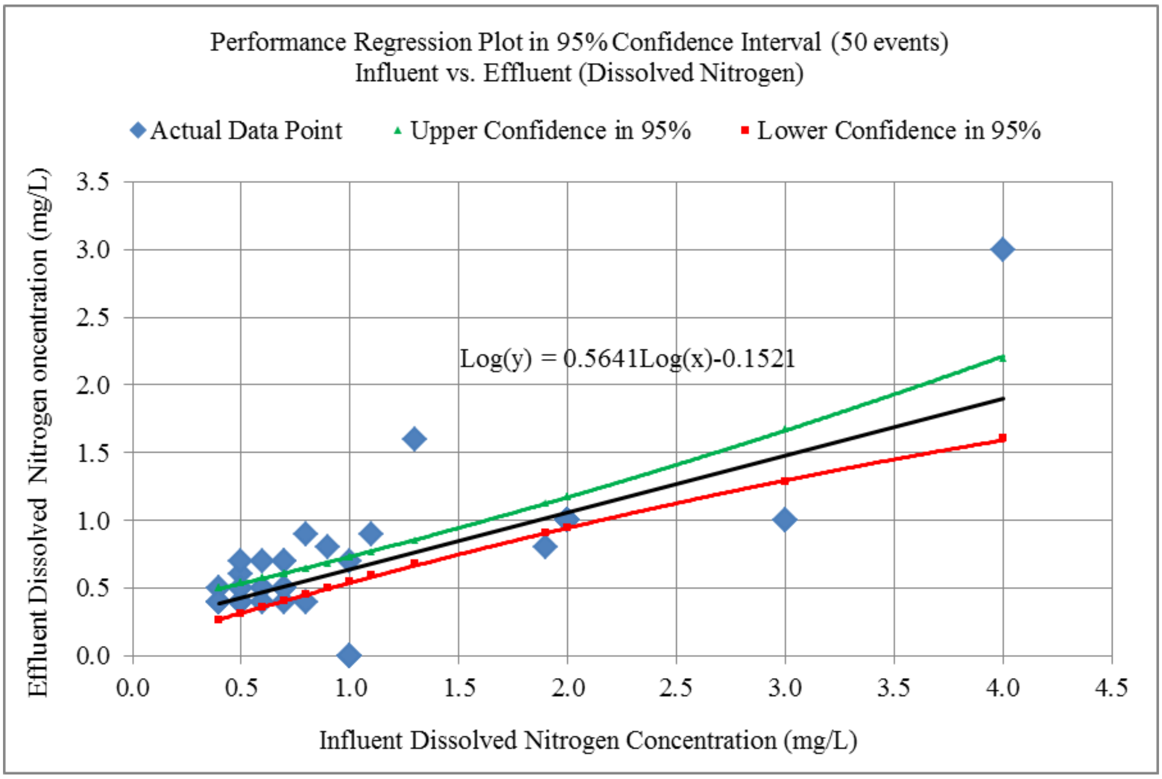
W= -864.000 T+ = 19.500 T-= -883.500
Z-Statistic (based on positive ranks) = -5.428
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.2: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Nitrogen (50 Sampled Storms)







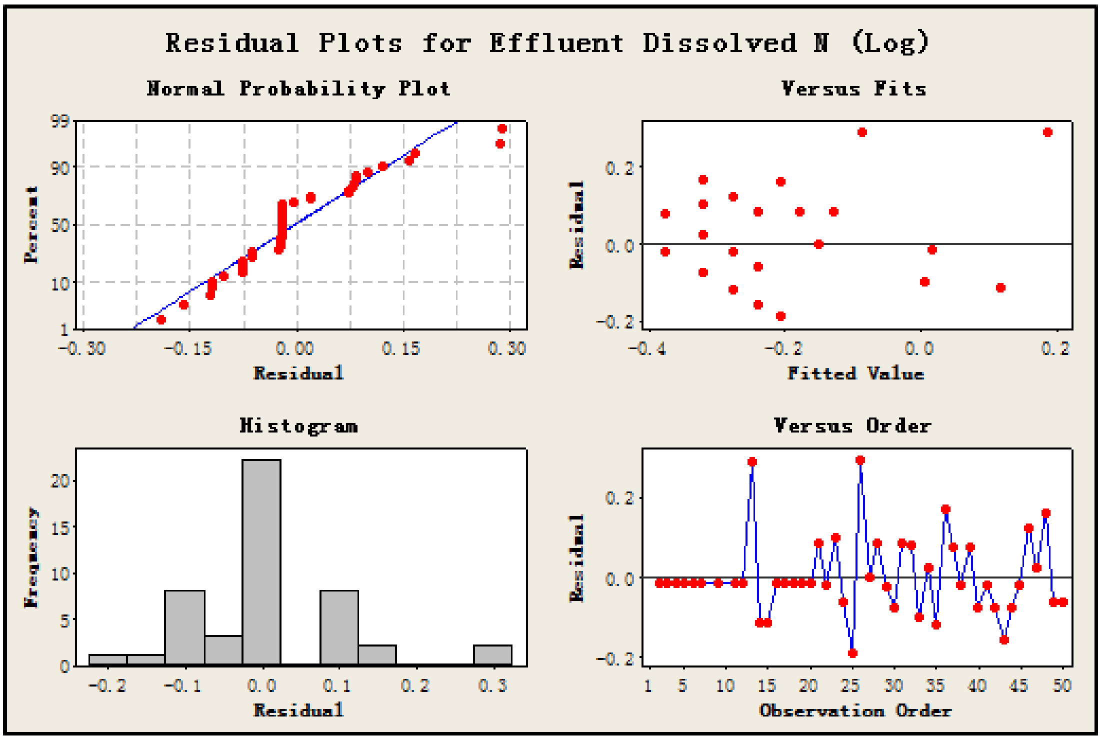
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.87
R Square	0.75
Adjusted R Square	0.74
Standard Error	0.10
Observations	47.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.32	1.32	134.45	0.00
Residual	45.00	0.44	0.01		
Total	46.00	1.77			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.15	0.01	-10.50	0.00	-0.18	-0.12	-0.18	-0.12
X Variable 1	0.56	0.05	11.60	0.00	0.47	0.66	0.47	0.66



Wilcoxon Signed Rank Test

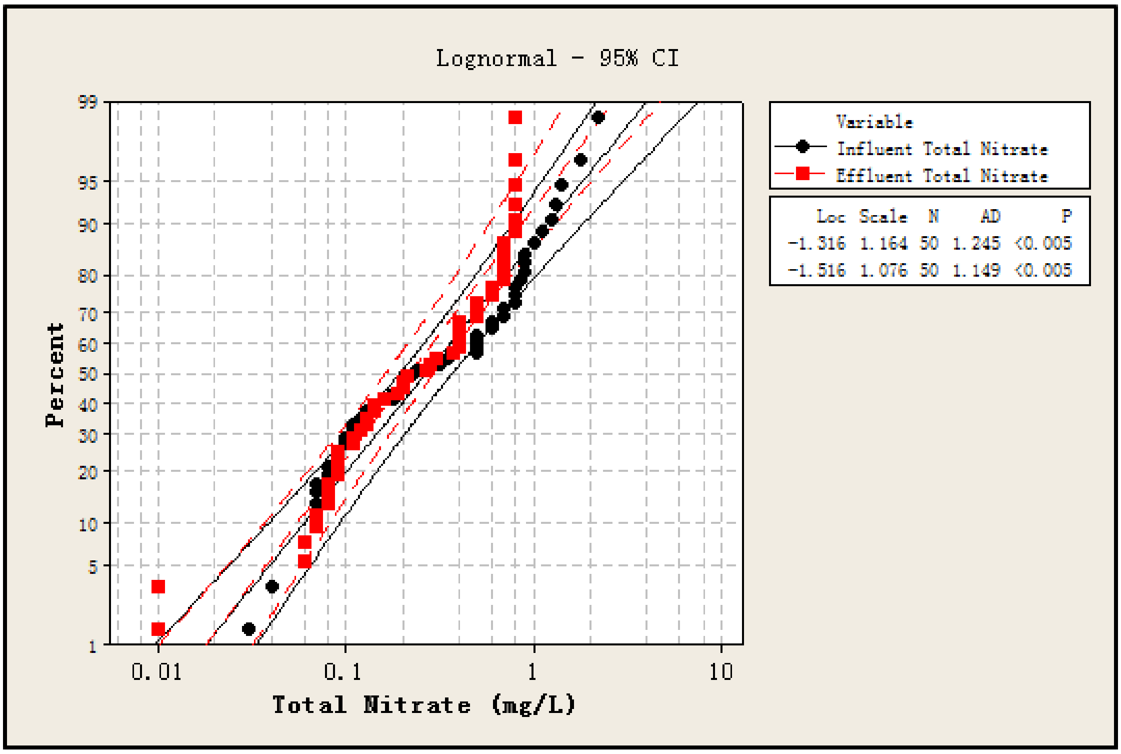
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

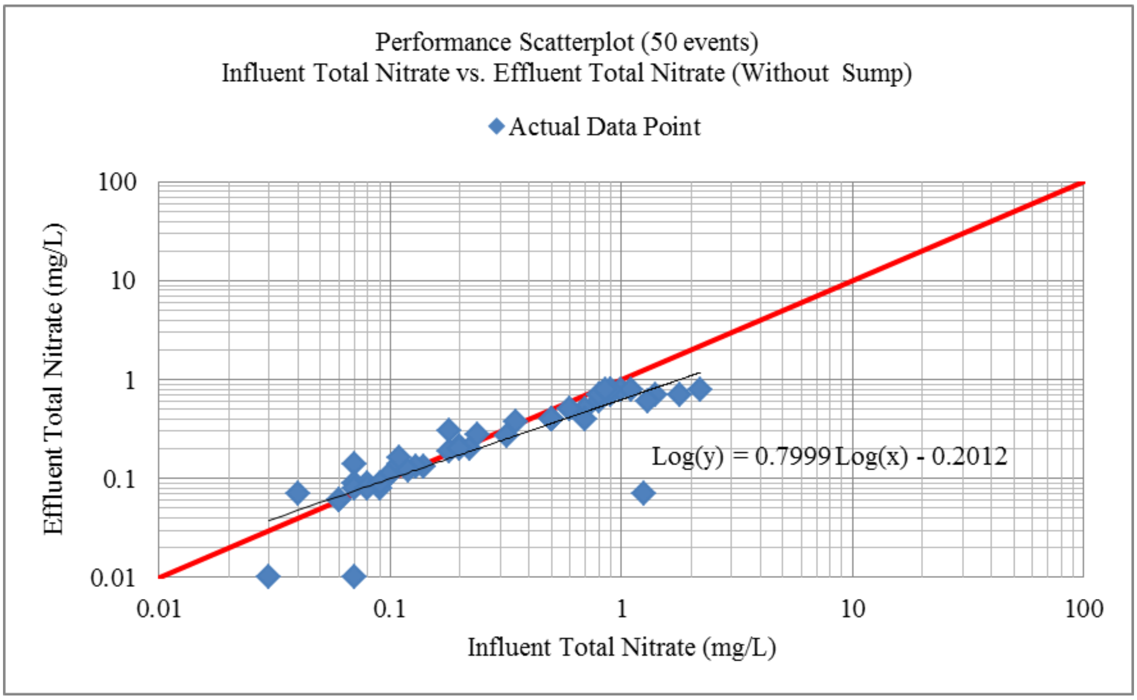
Group	N	Missing	Median	0.25	0.75
Influent DN	50.00	0.00	0.85	0.50	2.00
Effluent DN	50.00	0.00	0.70	0.40	1.00

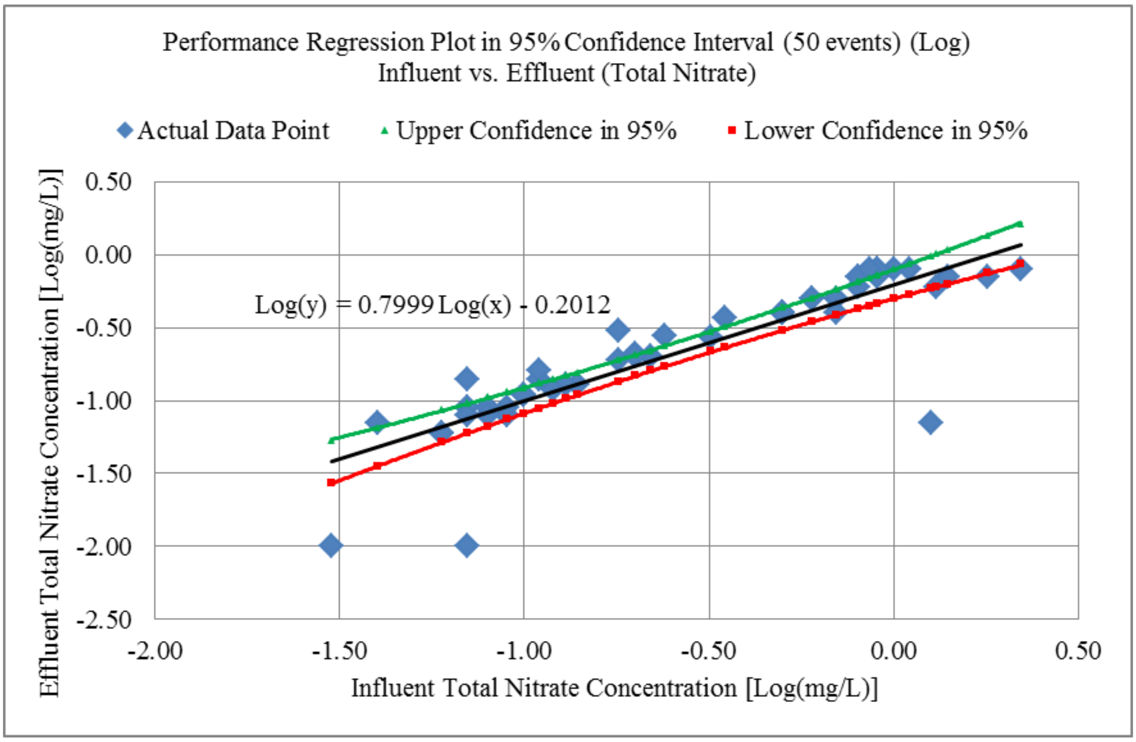
W= -776.000 T+ = 63.500 T-= -839.500
Z-Statistic (based on positive ranks) = -4.910
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.3: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Nitrogen (50 Sampled Storms)







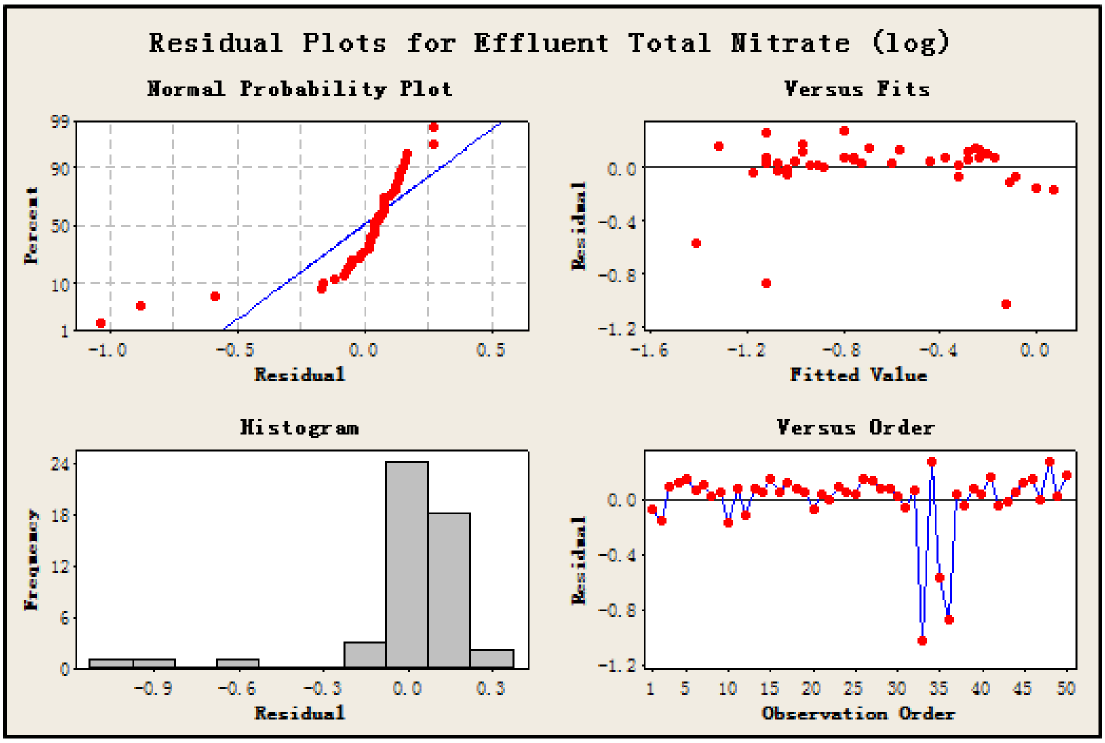
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.87
R Square	0.75
Adjusted R Square	0.74
Standard Error	0.24
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	8.02	8.02	143.07	0.00
Residual	48.00	2.69	0.06		
Total	49.00	10.71			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.20	0.05	-3.96	0.00	-0.30	-0.10	-0.30	-0.10
X Variable 1	0.80	0.07	11.96	0.00	0.67	0.93	0.67	0.93



Wilcoxon Signed Rank Test

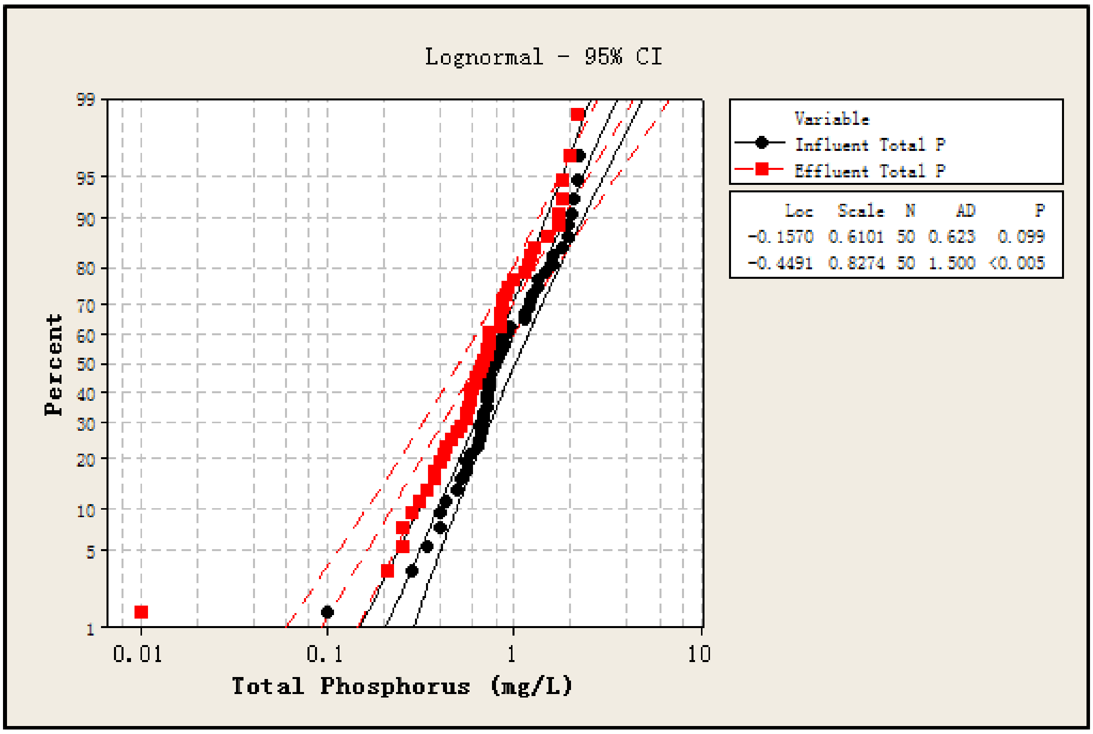
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

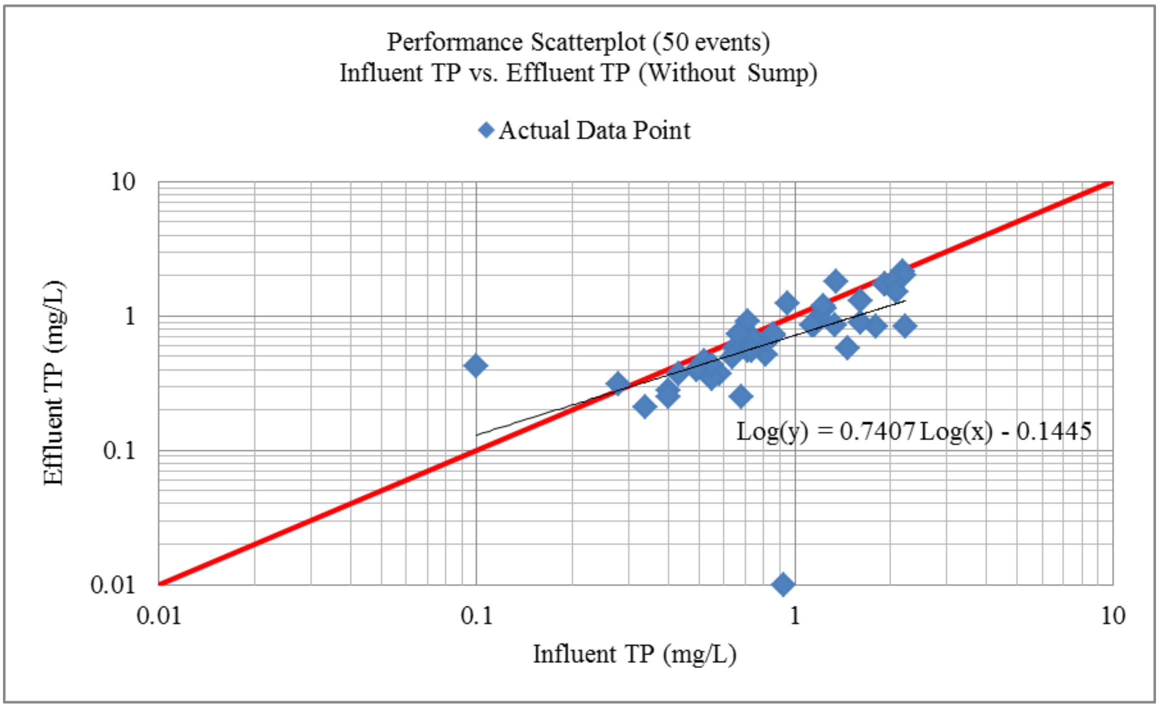
Group	N	Missing	Median	0.25	0.75
Influent Nitrate	50.00	0.00	0.23	0.09	0.80
Effluent Nitrate	50.00	2.00	0.28	0.11	0.60

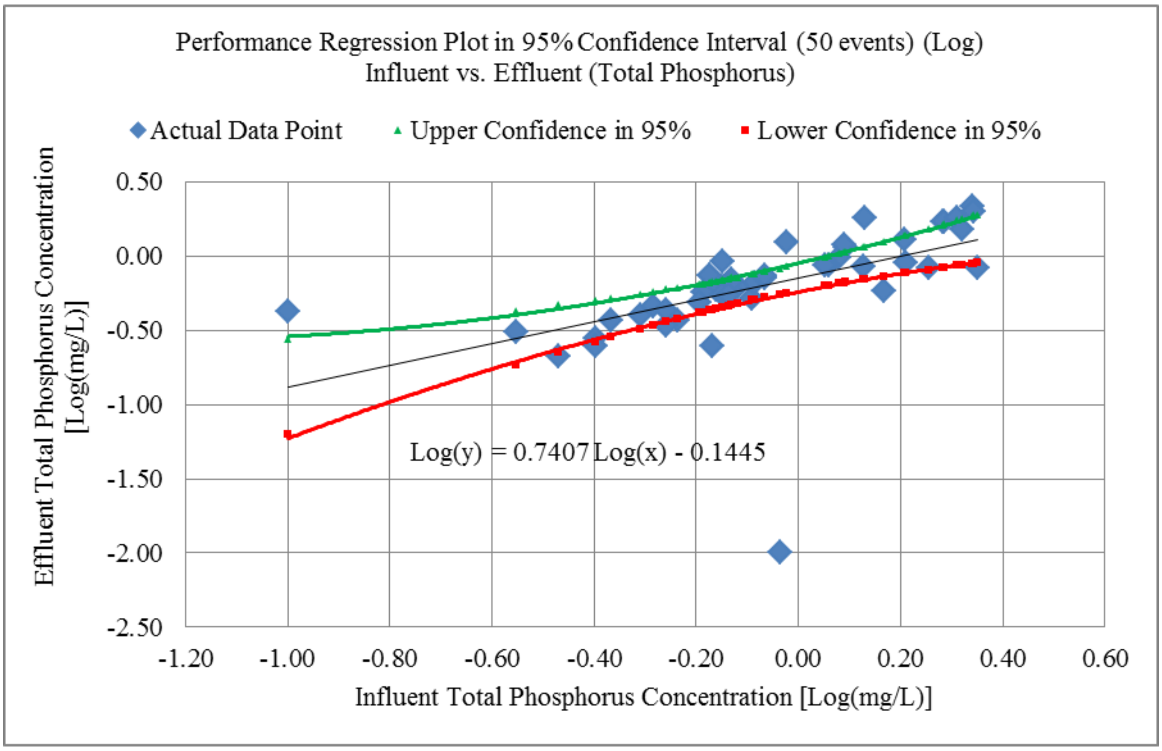
W= -532.000 T+ = 164.500 T-= -696.500
Z-Statistic (based on positive ranks) = -3.451
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.4: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Phosphorus (50 Sampled Storms)







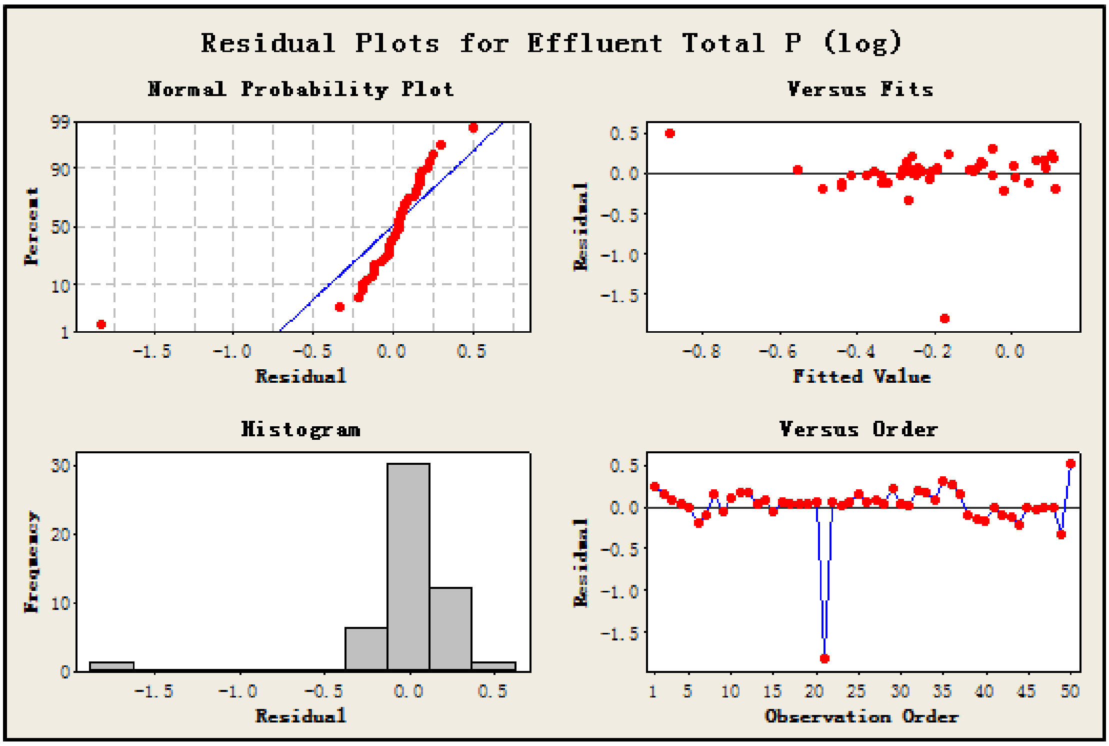
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.55
R Square	0.30
Adjusted R Square	0.28
Standard Error	0.30
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.89	1.89	20.41	0.00
Residual	48.00	4.44	0.09		
Total	49.00	6.33			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.14	0.04	-3.25	0.00	-0.23	-0.06	-0.23	-0.06
X Variable 1	0.74	0.16	4.52	0.00	0.41	1.07	0.41	1.07



Note: consistent high level of phosphorus concentrations were found from October, November, and December, 2012. Reason was unknown.

Wilcoxon Signed Rank Test

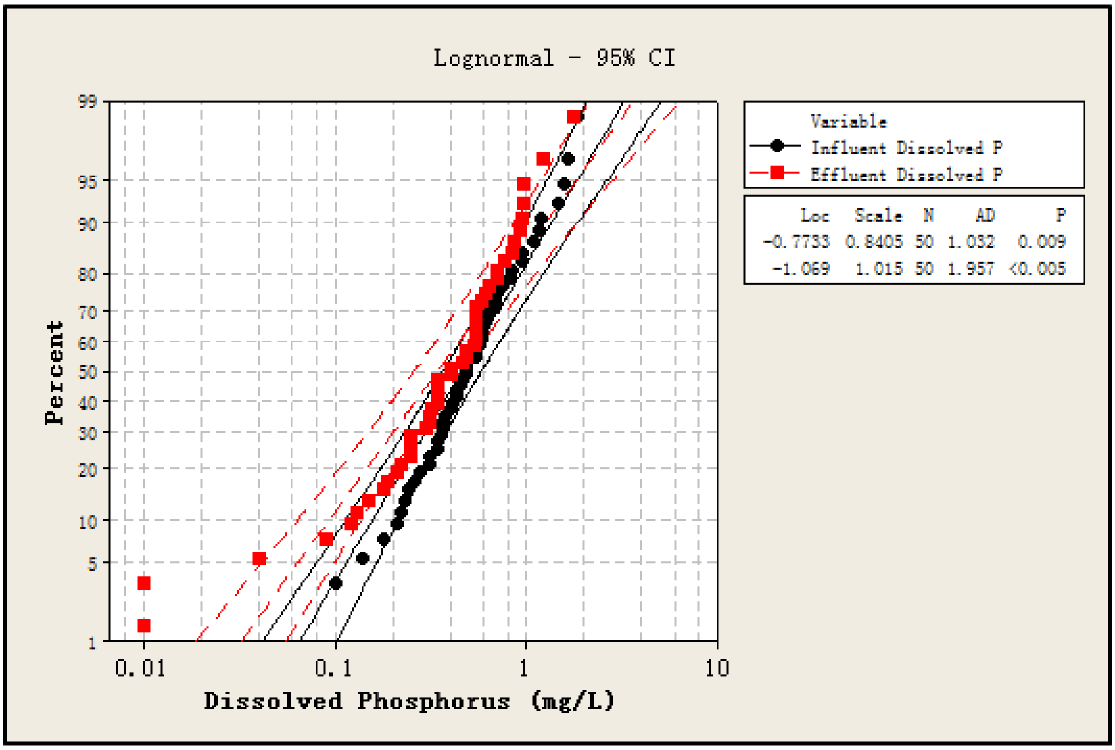
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

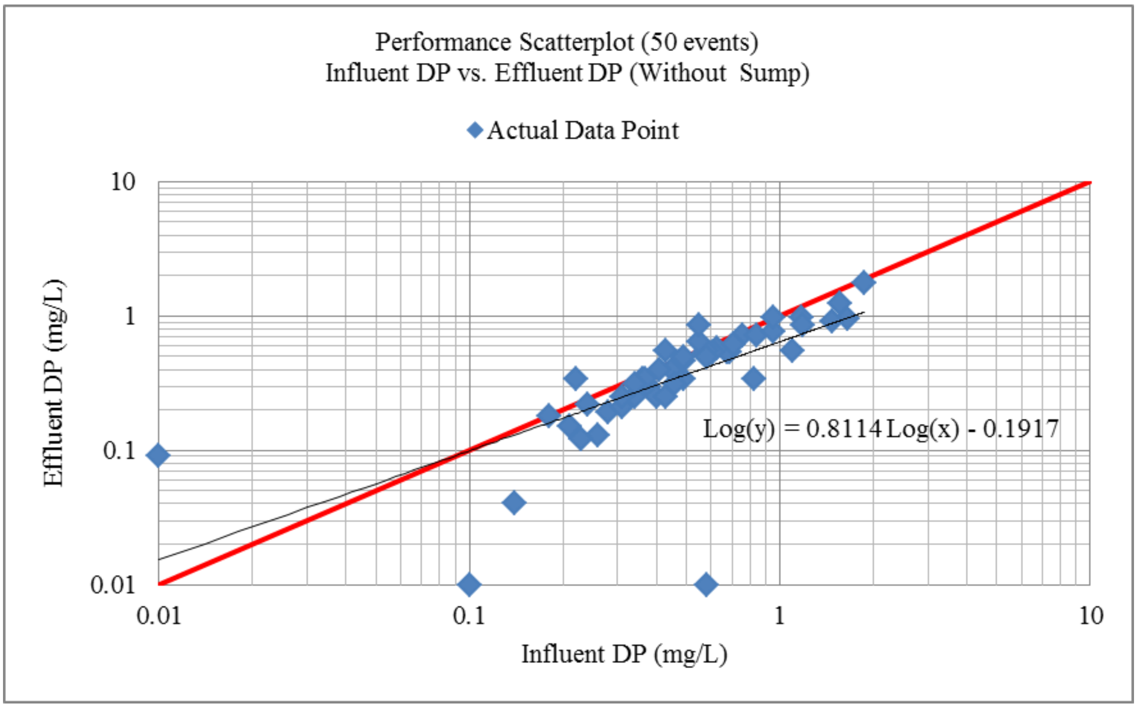
Group	N	Missing	Median	0.25	0.75
Influent TP	50.00	0.00	0.79	0.65	1.34
Effluent TP	50.00	1.00	0.69	0.48	0.95

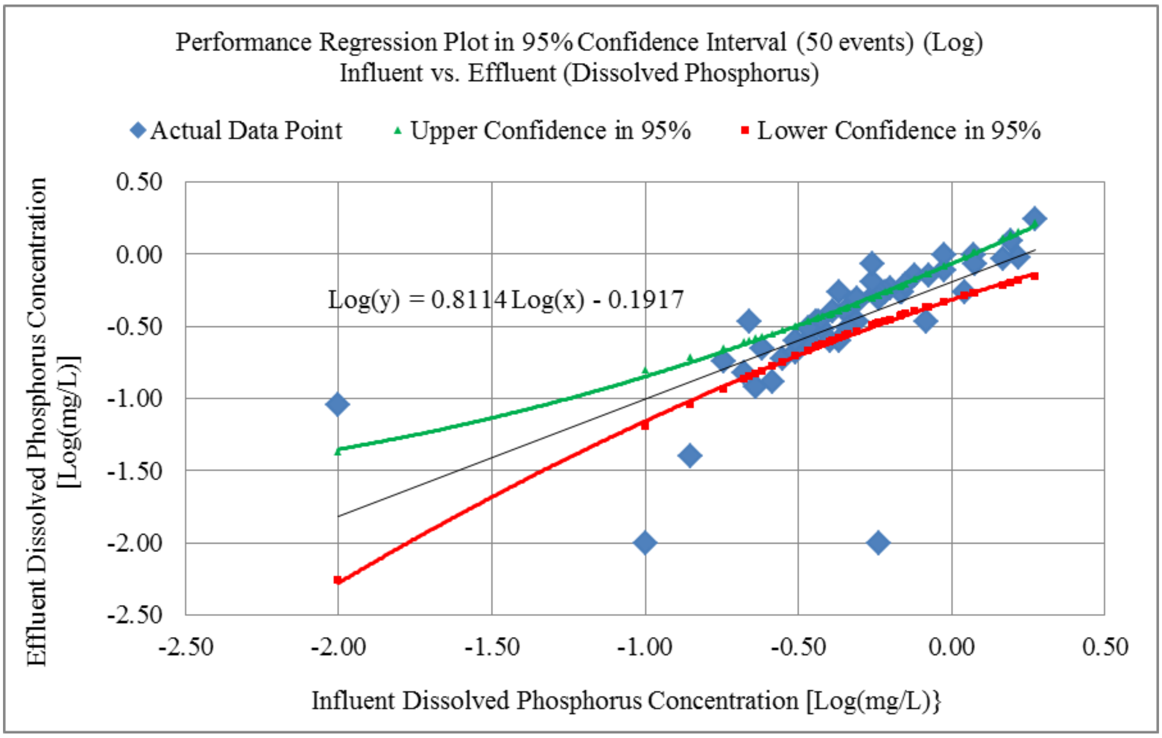
W= -887.000 T+ = 169.000 T-= -1056.000
Z-Statistic (based on positive ranks) = -4.412
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.5: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Phosphorus (50 Sampled Storms)







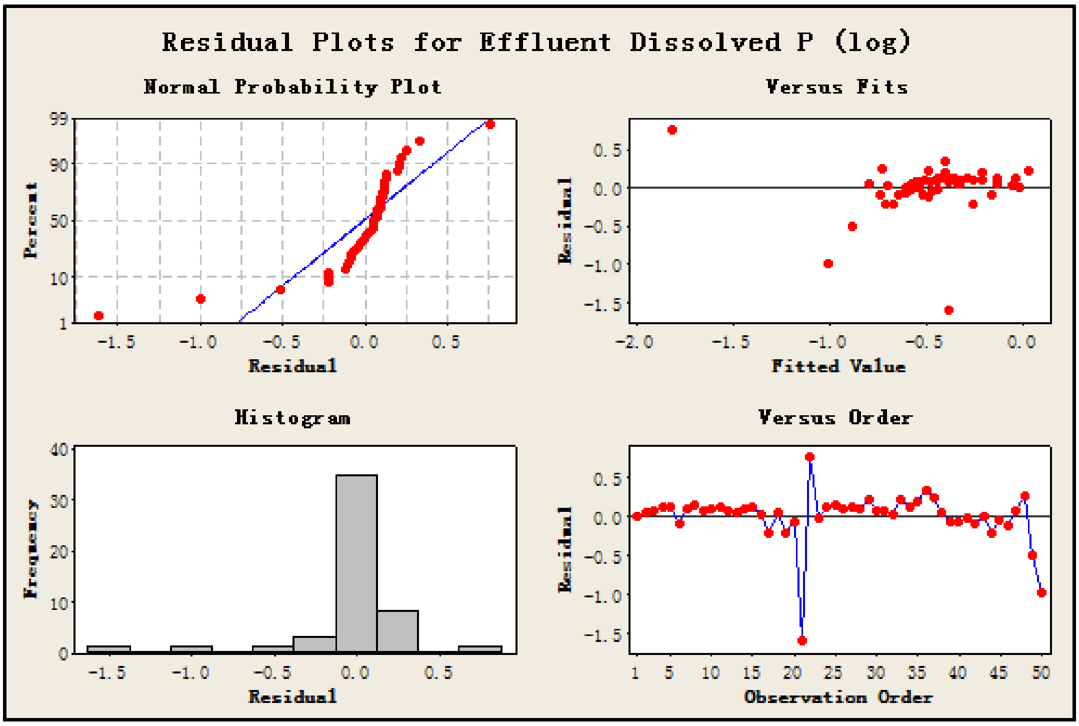
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.67
R Square	0.45
Adjusted R Square	0.44
Standard Error	0.33
Observations	50.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	4.30	4.30	39.45	0.00
Residual	48.00	5.23	0.11		
Total	49.00	9.53			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.19	0.06	-3.01	0.00	-0.32	-0.06	-0.32	-0.06
X Variable 1	0.81	0.13	6.28	0.00	0.55	1.07	0.55	1.07



Note: consistent high level of phosphorus concentrations were found from October, November, and December, 2012. Reason was unknown.

Wilcoxon Signed Rank Test

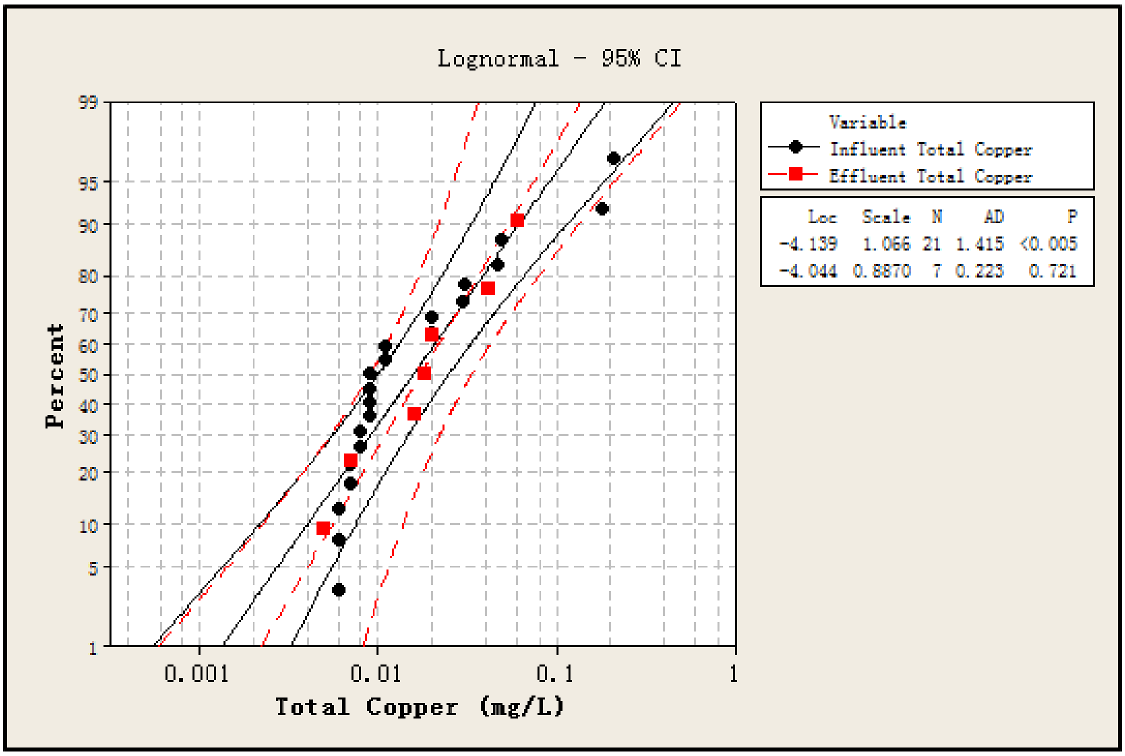
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

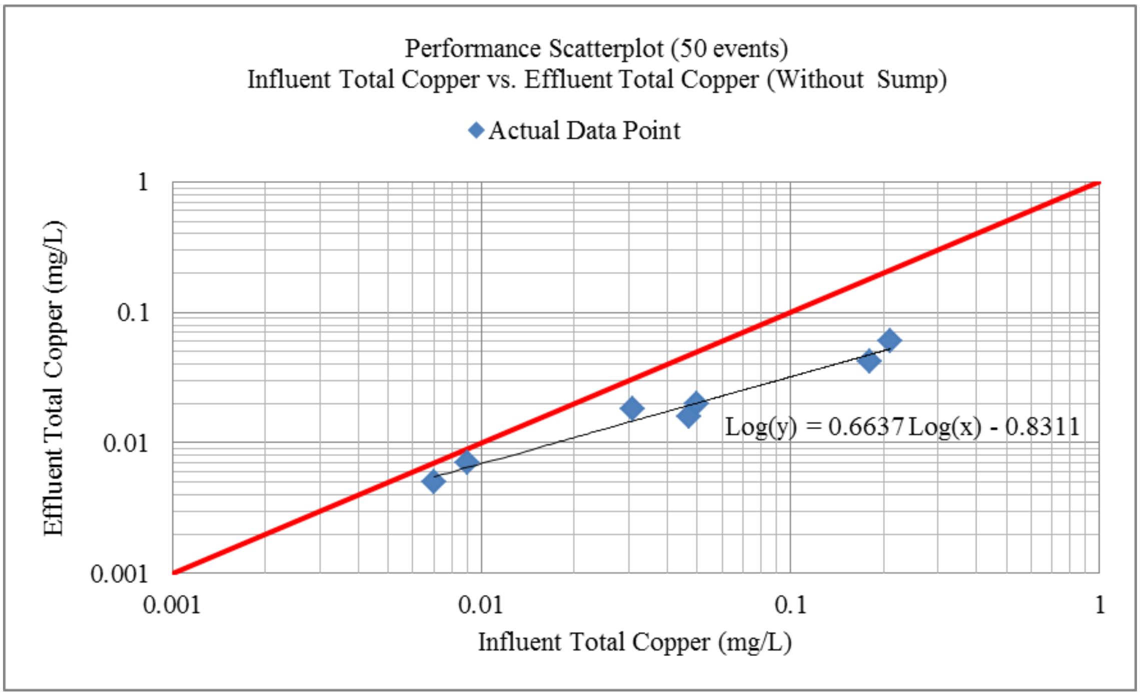
Group	N	Missing	Median	0.25	0.75
Influent DP	50.00	1.00	0.49	0.34	0.74
Effluent DP	50.00	2.00	0.43	0.25	0.63

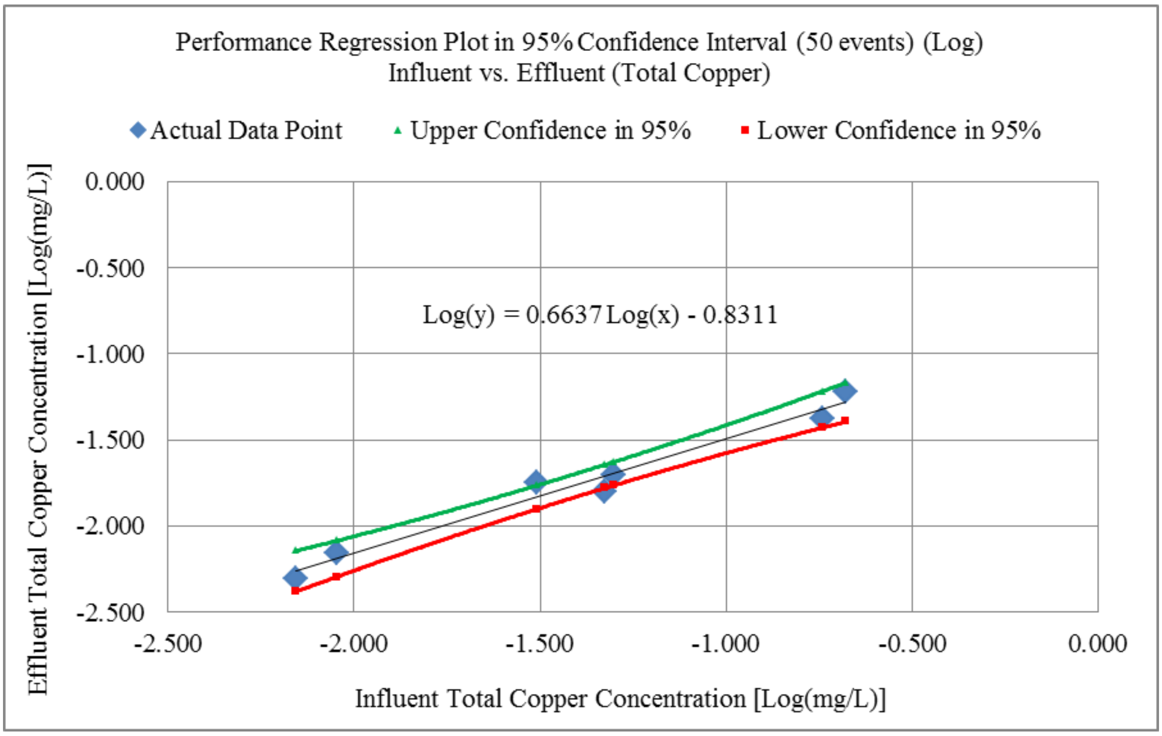
W= -799.000 T+ = 118.000 T-= -917.000
Z-Statistic (based on positive ranks) = -4.510
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.6: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Copper (50 Sampled Storms)







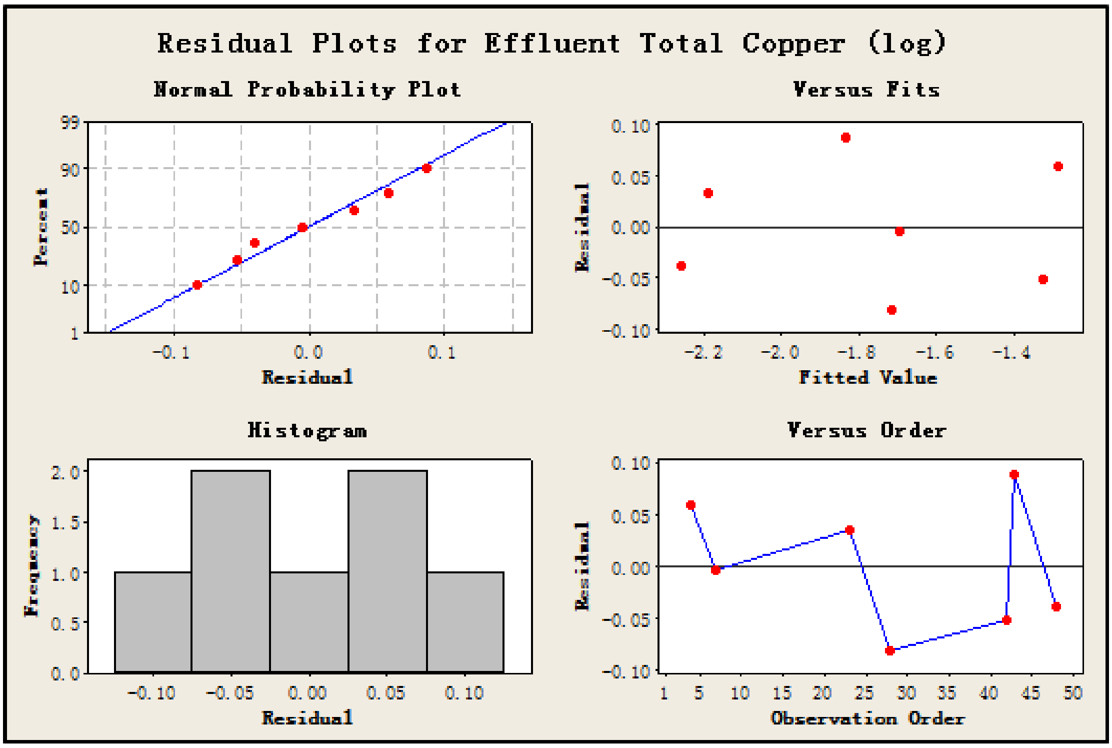
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.97
Adjusted R Square	0.97
Standard Error	0.07
Observations	7.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.87	0.87	182.85	0.00
Residual	5.00	0.02	0.00		
Total	6.00	0.89			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.83	0.07	-11.35	0.00	-1.02	-0.64	-1.02	-0.64
X Variable 1	0.66	0.05	13.52	0.00	0.54	0.79	0.54	0.79



Wilcoxon Signed Rank Test

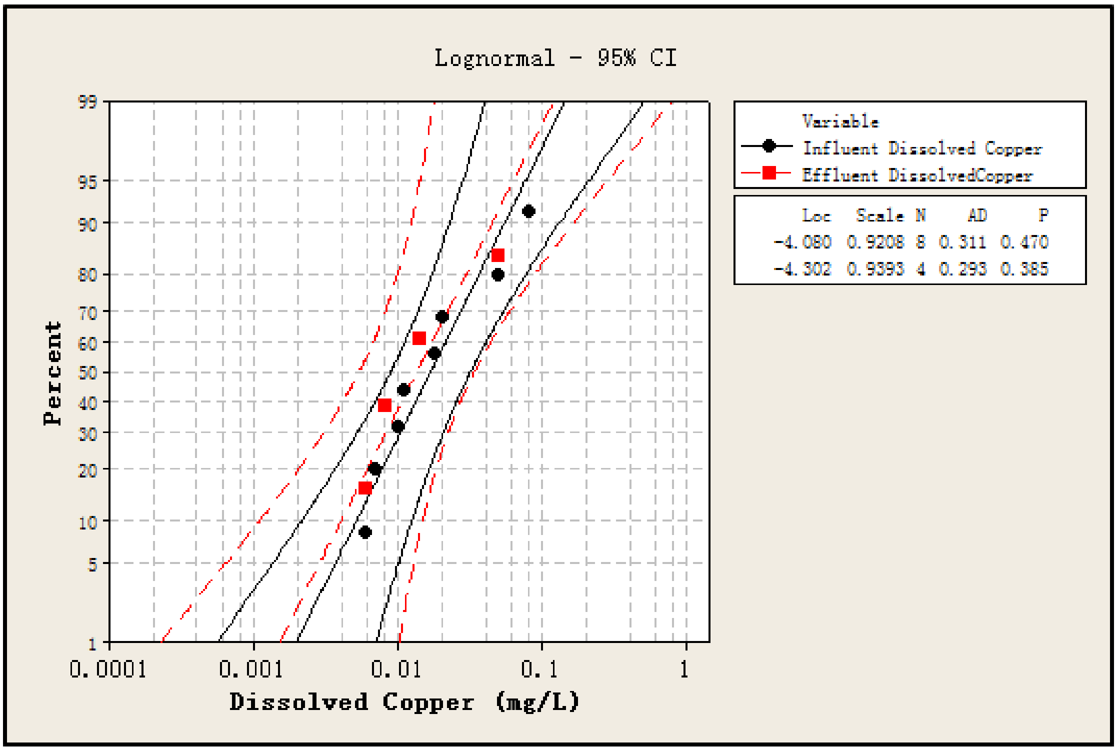
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

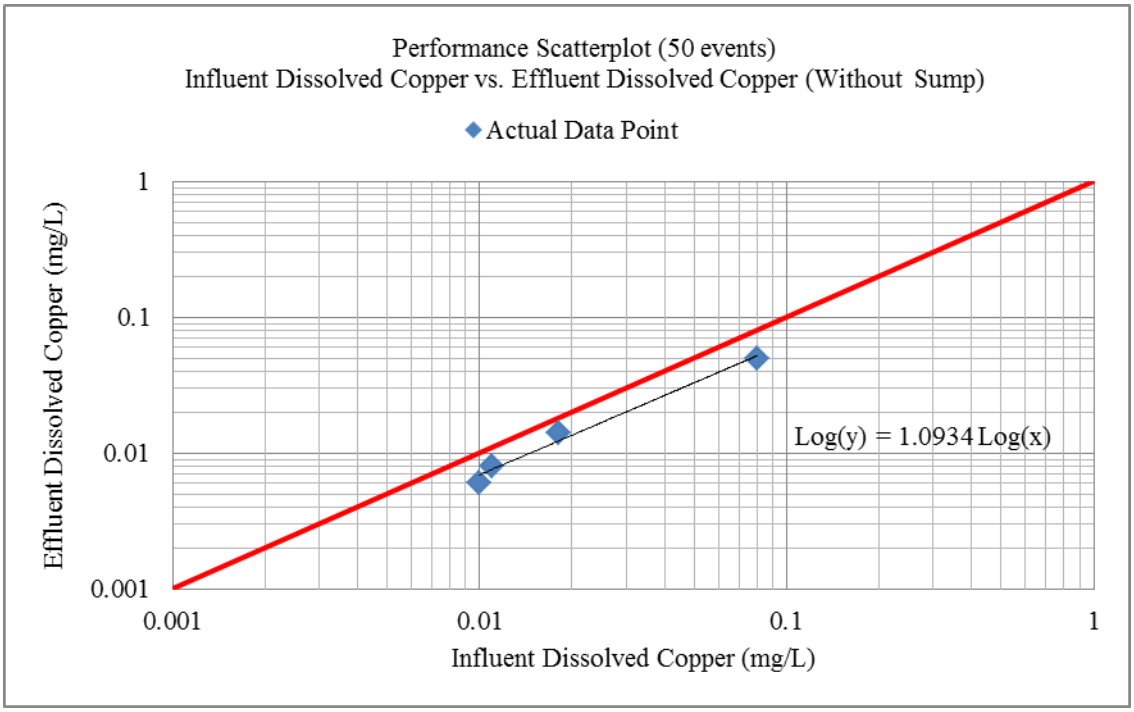
Group	N	Missing	Median	0.25	0.75
Influent Total Copper	50.00	29.00	0.01	0.01	0.03
Effluent Total Copper	50.00	43.00	0.02	0.01	0.04

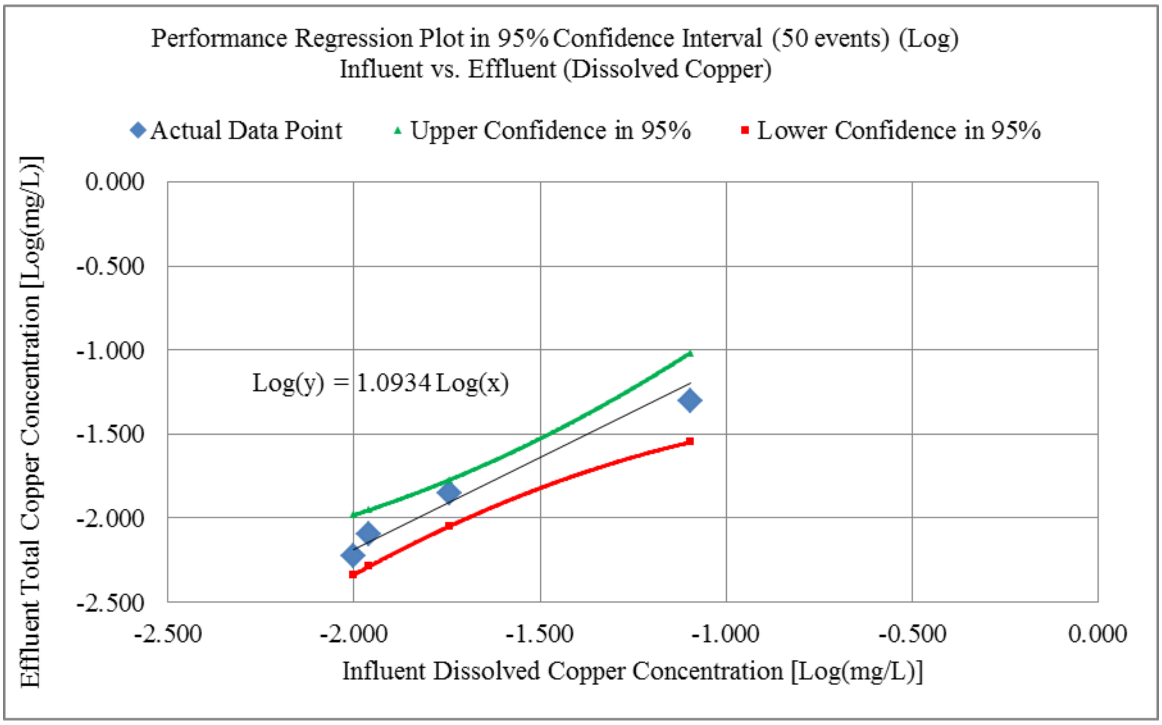
W= -28.000 T+ = 0.000 T-= -28.000
Z-Statistic (based on positive ranks) = -2.366
P(est.)= 0.022 P(exact)= 0.016

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.016).

Appendix E.7: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Copper (50 Sampled Storms)







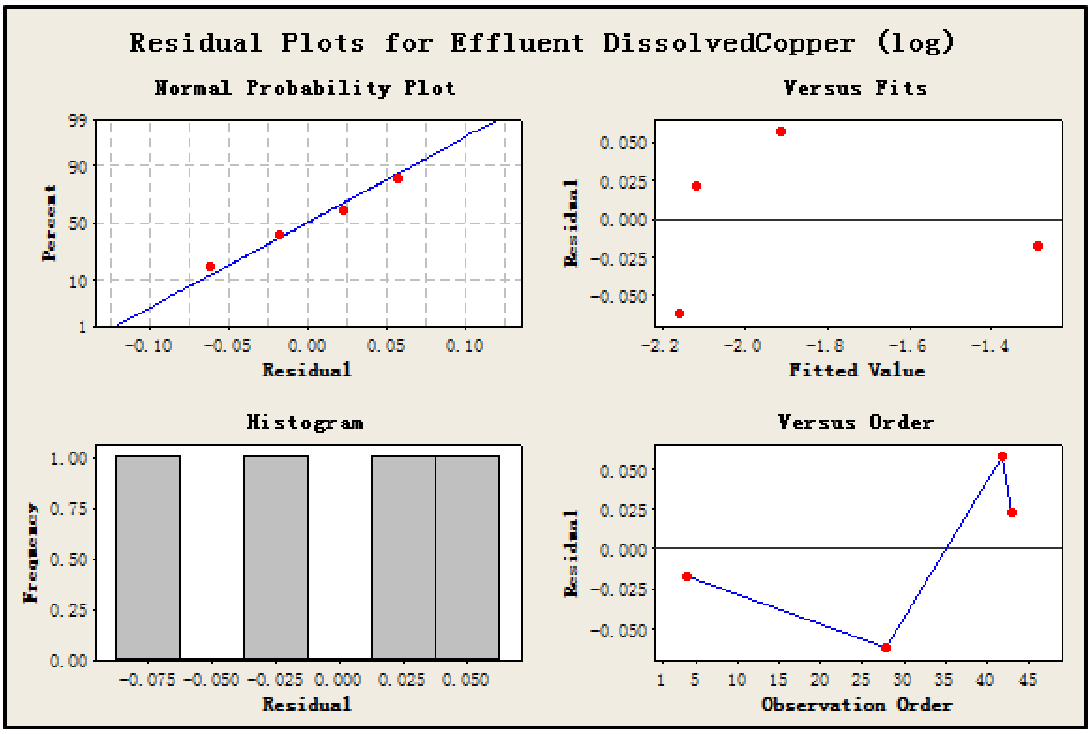
SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	1.00
Adjusted R Square	0.67
Standard Error	0.07
Observations	4.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	14.45	14.45	2634.23	0.00
Residual	3.00	0.02	0.01		
Total	4.00	14.46			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.09	0.02	51.32	0.00	1.03	1.16	1.03	1.16



Wilcoxon Signed Rank Test

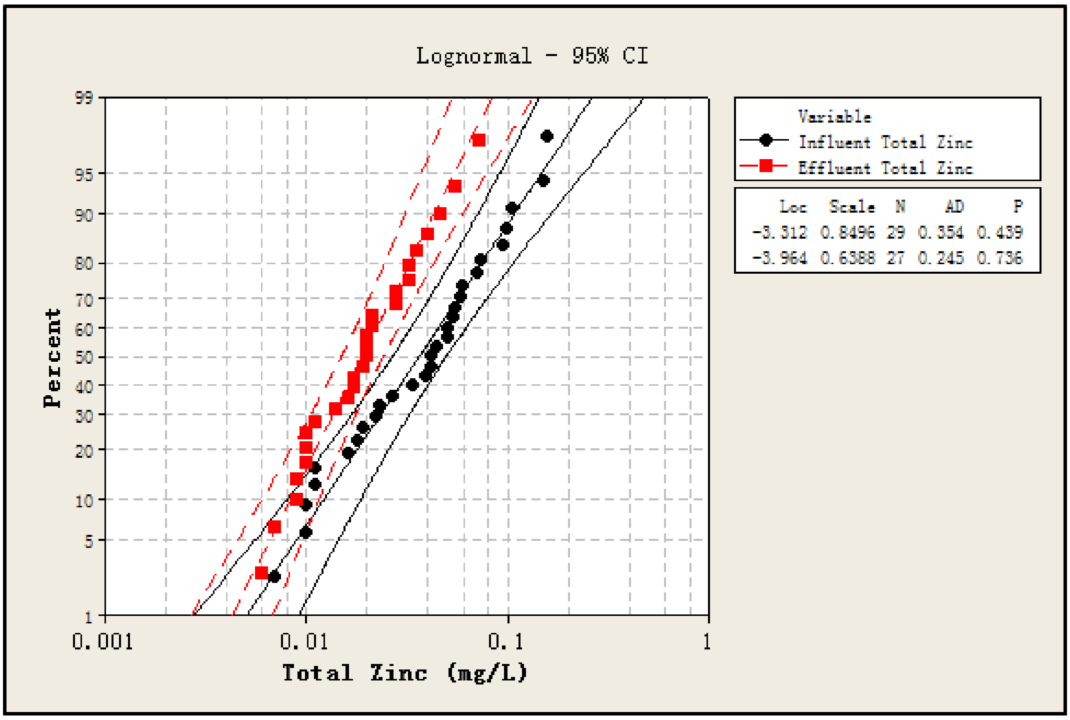
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

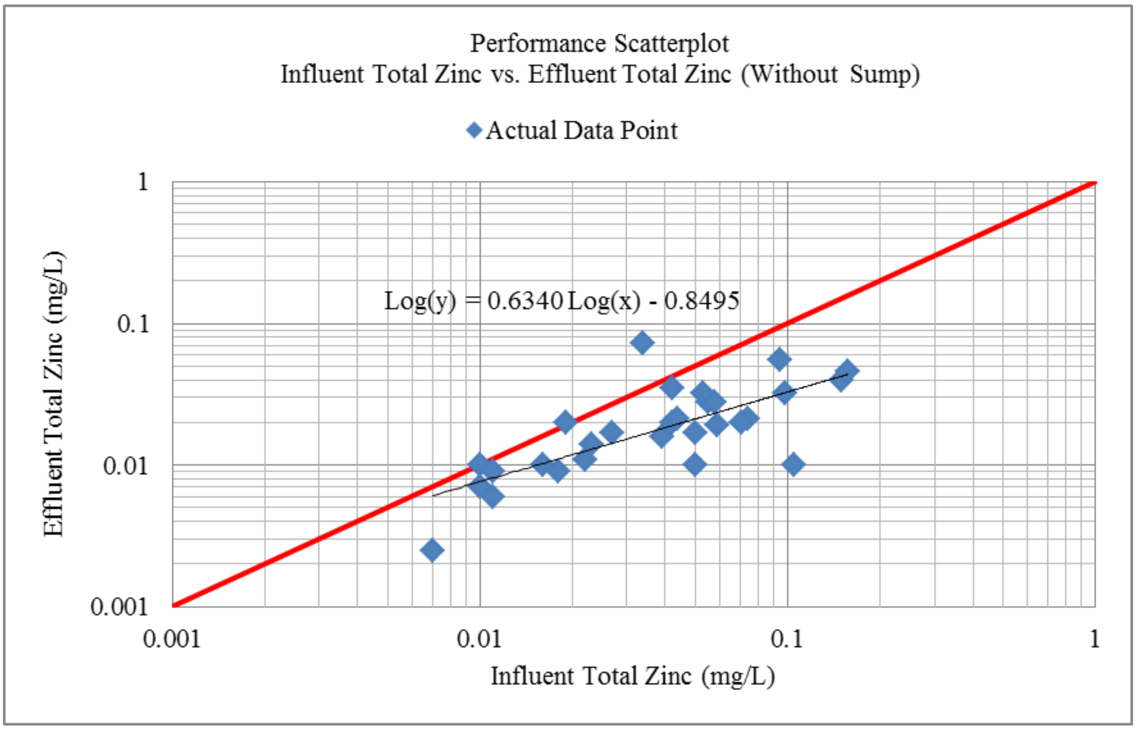
Group	N	Missing	Median	0.25	0.75
Influent Dissolved Copper	48.00	40.00	0.01	0.01	0.04
Effluent Dissolved Copper	48.00	44.00	0.01	0.01	0.04

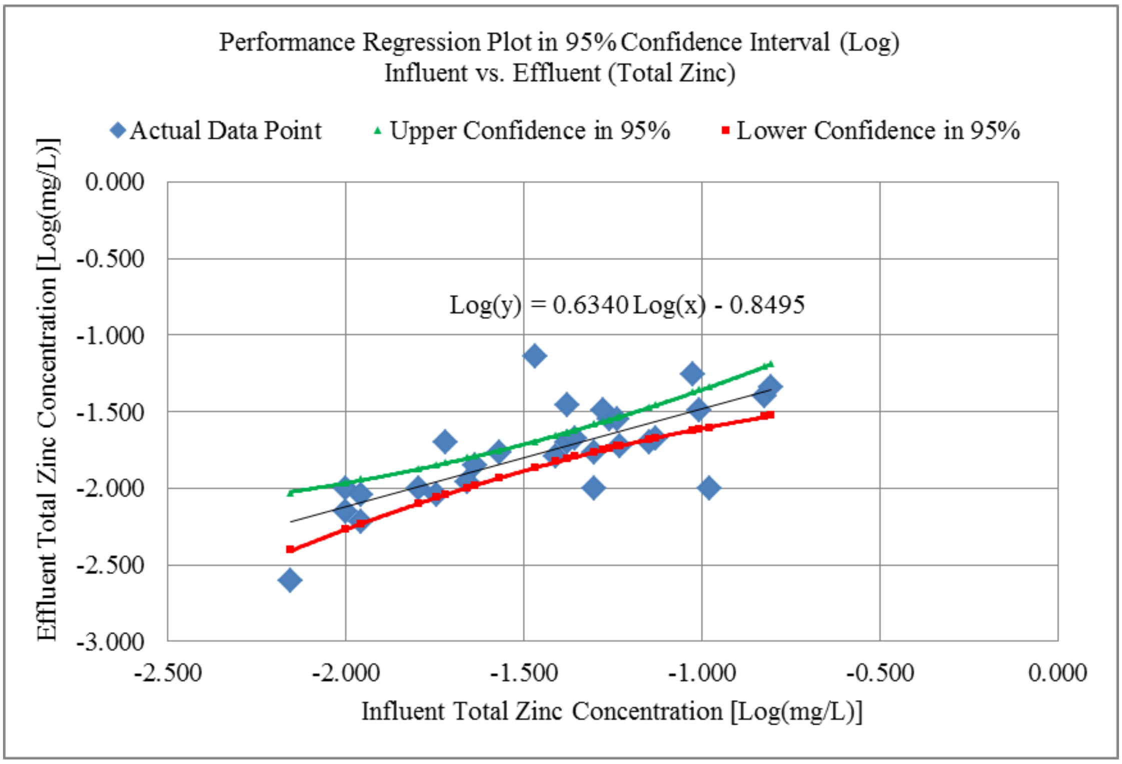
W= -10.000 T+ = 0.000 T-= -10.000
Z-Statistic (based on positive ranks) = -1.826
P(est.)= 0.100 P(exact)= 0.125

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.125).

Appendix E.8: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Total Zinc (50 Sampled Storms)







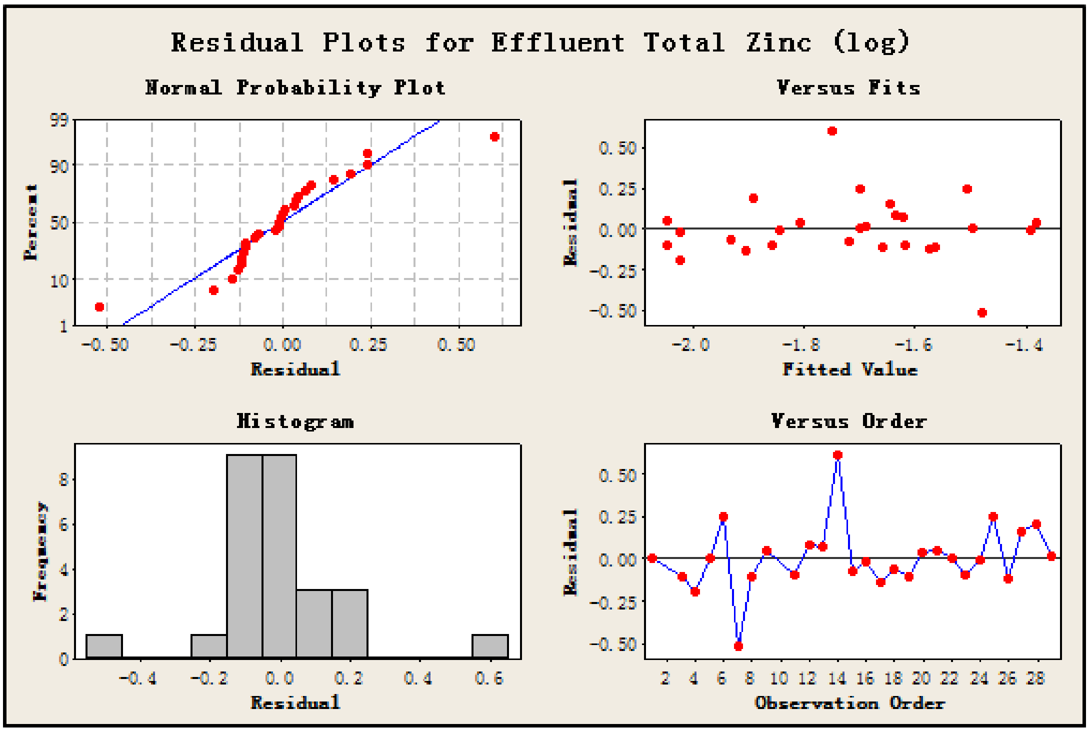
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.74
R Square	0.55
Adjusted R Square	0.53
Standard Error	0.22
Observations	29.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.53	1.53	32.43	0.00
Residual	27.00	1.28	0.05		
Total	28.00	2.81			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.8495	0.17	-5.14	0.00	-1.19	-0.51	-1.19	-0.51
X Variable 1	0.6340	0.11	5.69	0.00	0.41	0.86	0.41	0.86



Wilcoxon Signed Rank Test

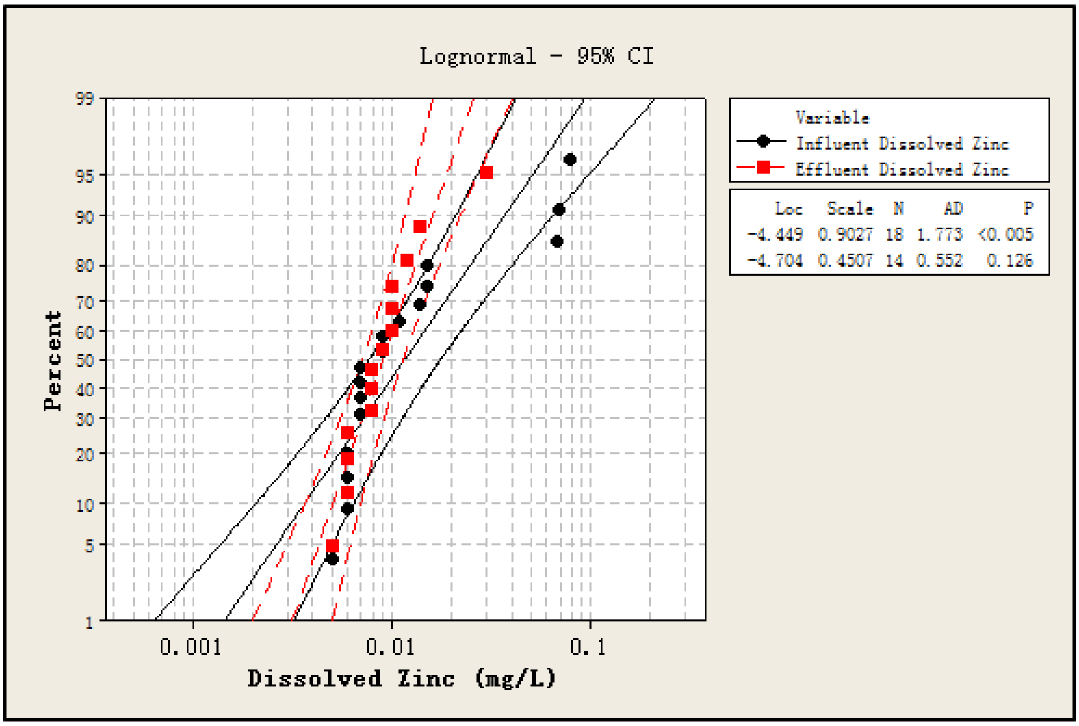
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

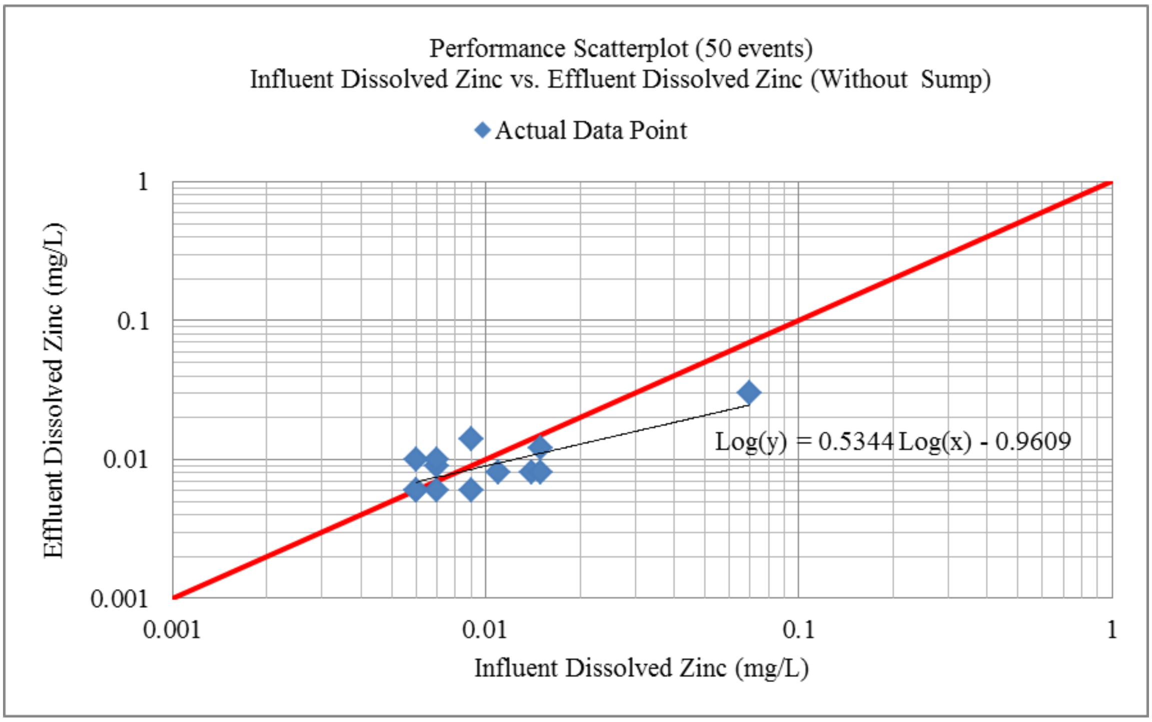
Group	N	Missing	Median	0.25	0.75
Influent Total Zinc	30.00	0.00	0.04	0.02	0.07
Effluent Total Zinc	30.00	2.00	0.02	0.01	0.03

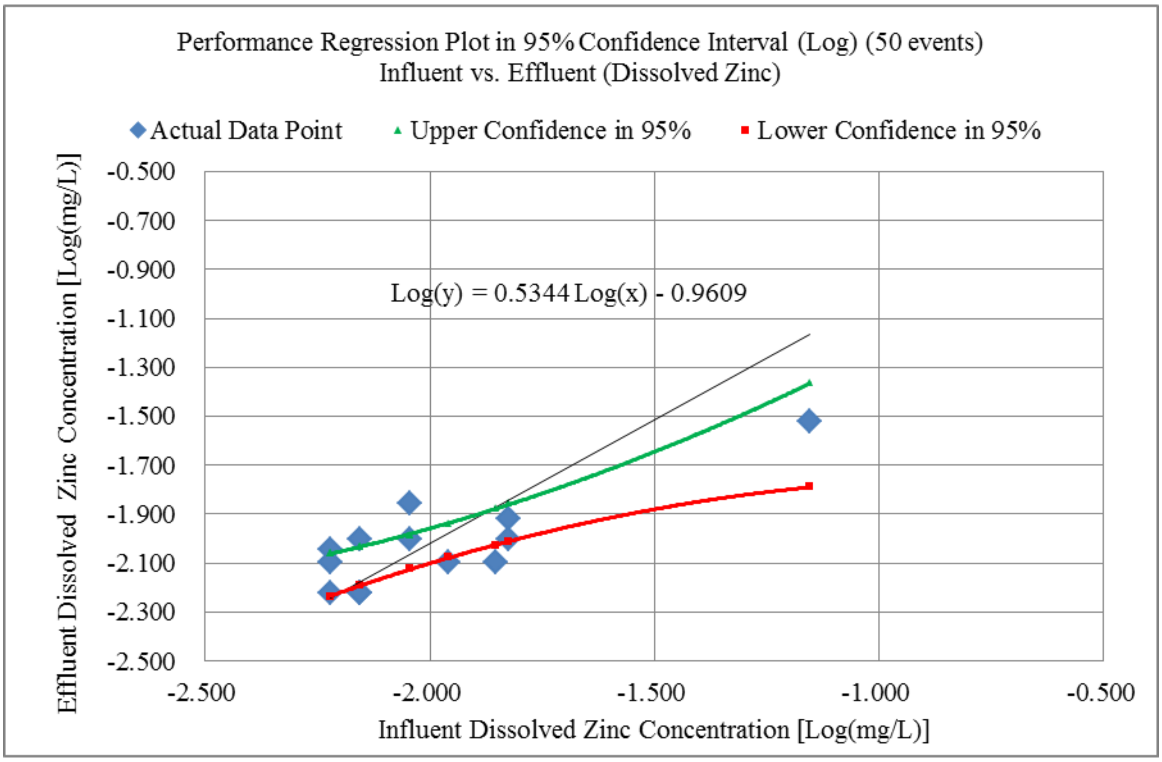
W= -340.000 T+ = 19.000 T-= -359.000
Z-Statistic (based on positive ranks) = -4.084
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.9: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Dissolved Zinc (50 Sampled Storms)







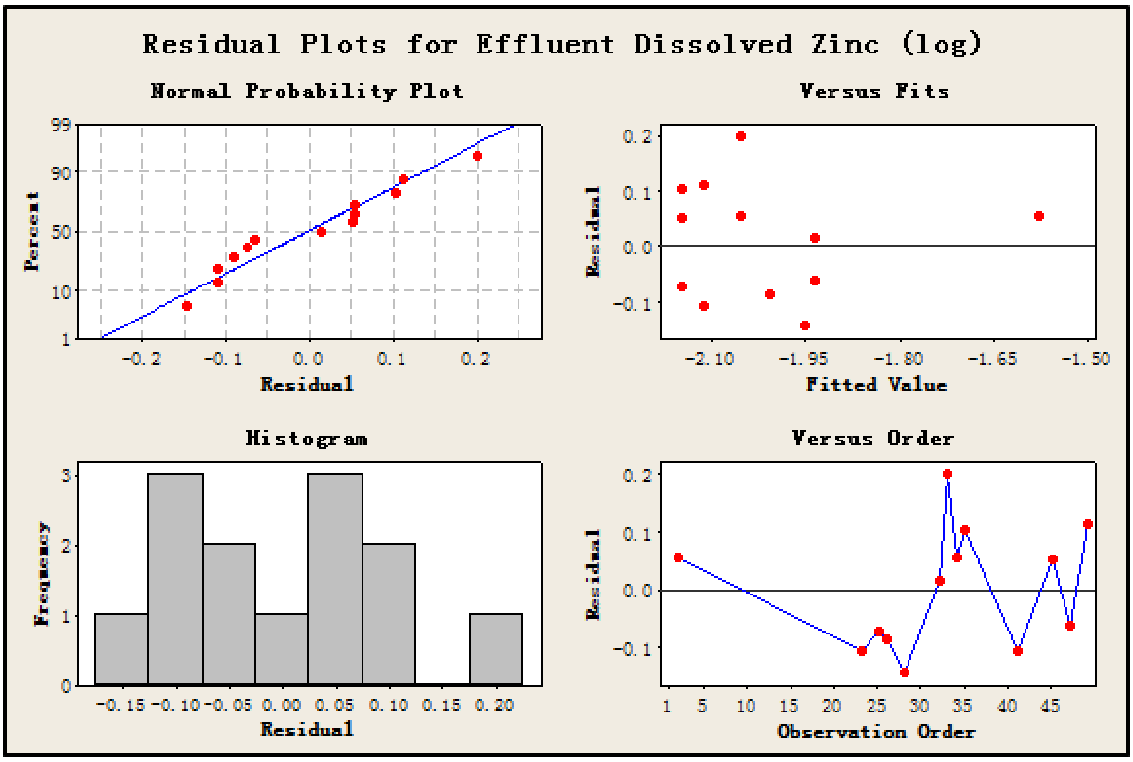
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.83
R Square	0.68
Adjusted R Square	0.66
Standard Error	0.11
Observations	13.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.29	0.29	23.82	0.00
Residual	11.00	0.13	0.01		
Total	12.00	0.43			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.9609	0.22	-4.37	0.00	-1.44	-0.48	-1.44	-0.48
X Variable 1	0.5344	0.11	4.88	0.00	0.29	0.78	0.29	0.78



Wilcoxon Signed Rank Test

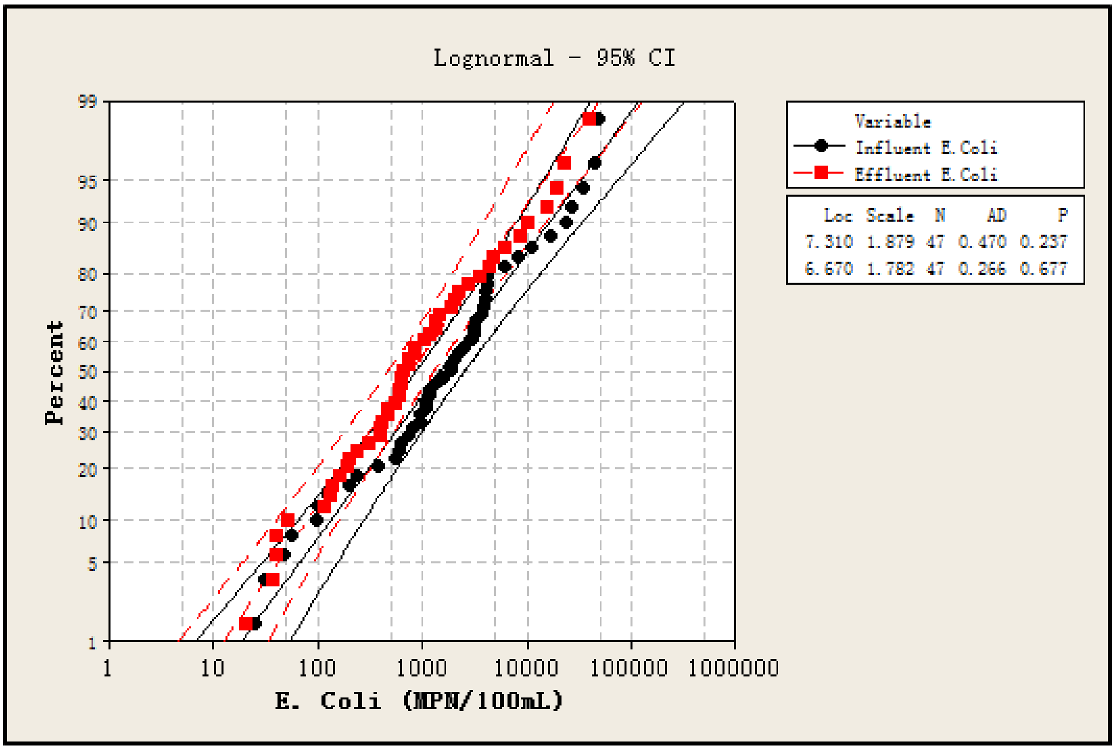
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

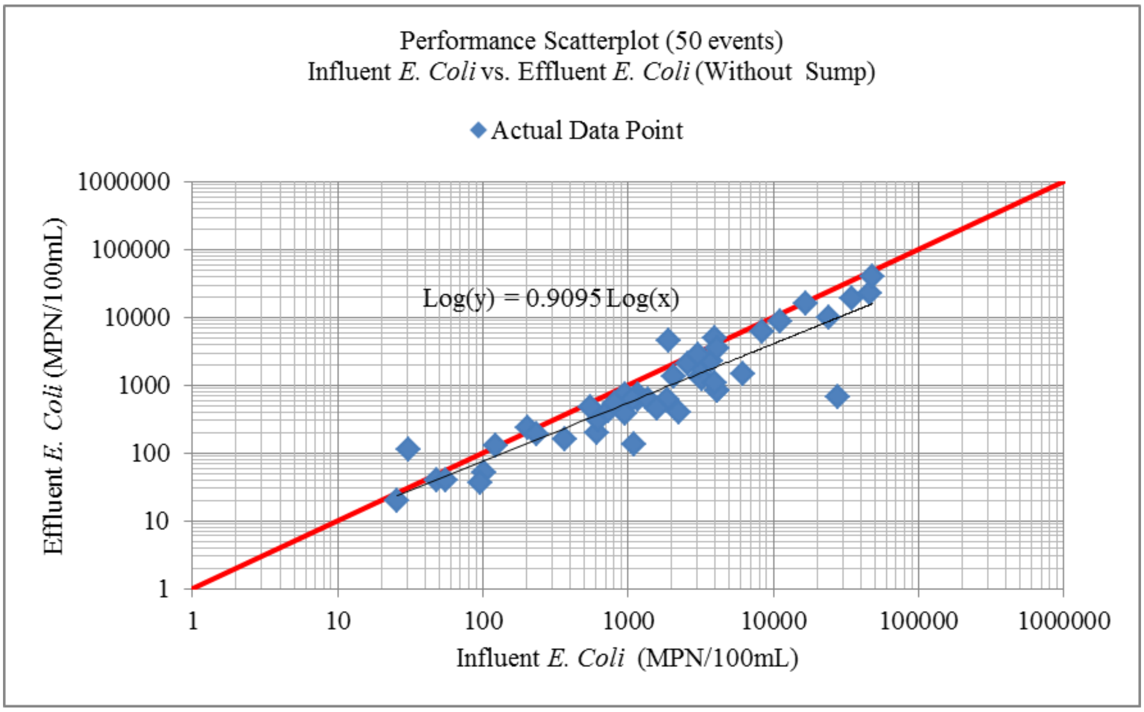
Group	N	Missing	Median	0.25	0.75
Influent Dissolved Zinc	50.00	31.00	0.01	0.01	0.02
Effluent Dissolved Zinc	50.00	35.00	0.01	0.01	0.01

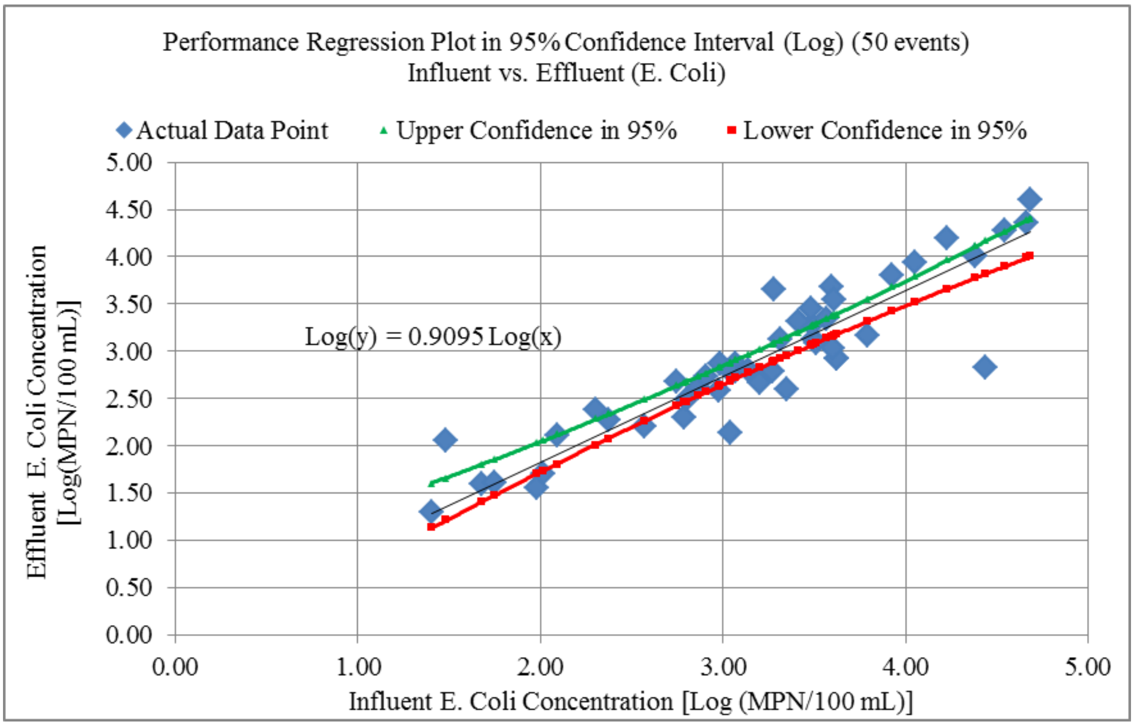
W= -29.000 T+ = 31.000 T-= -60.000
Z-Statistic (based on positive ranks) = -1.015
P(est.)= 0.327 P(exact)= 0.340

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.340).

Appendix E.10: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for *E. Coli* (50 Sampled Storms)







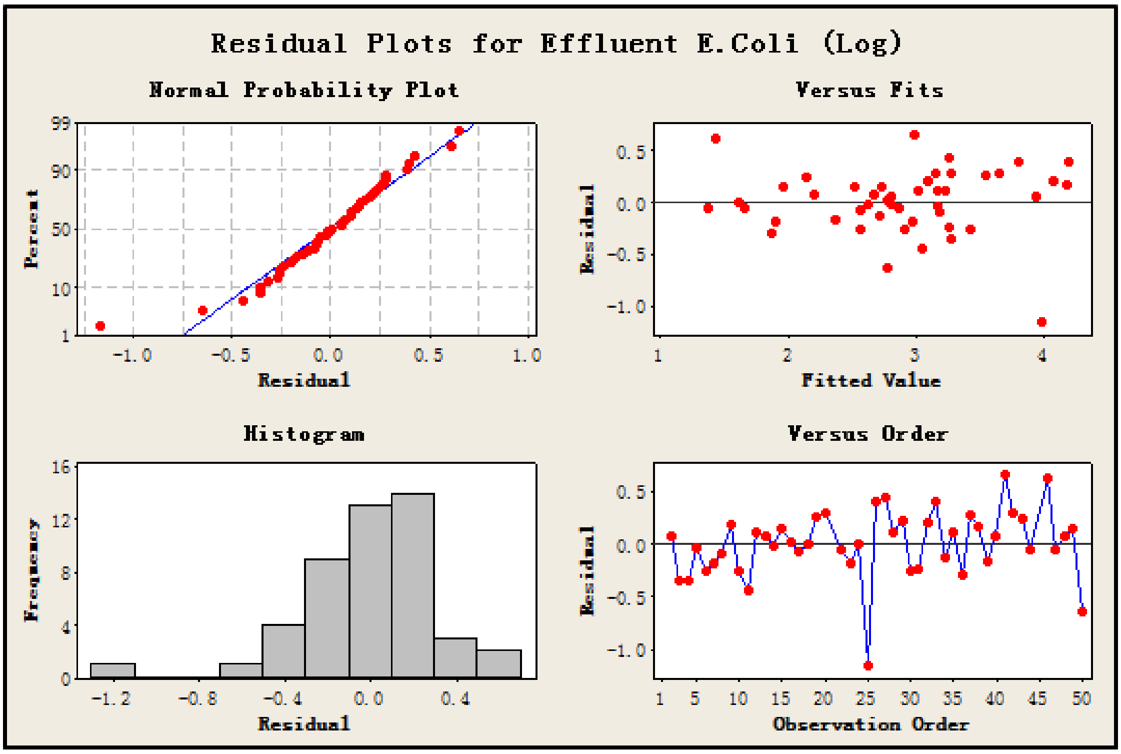
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.99
Adjusted R Square	0.97
Standard Error	0.32
Observations	47.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	417.18	417.18	4071.82	0.00
Residual	46.00	4.71	0.10		
Total	47.00	421.89			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.91	0.01	63.81	0.00	0.88	0.94	0.88	0.94

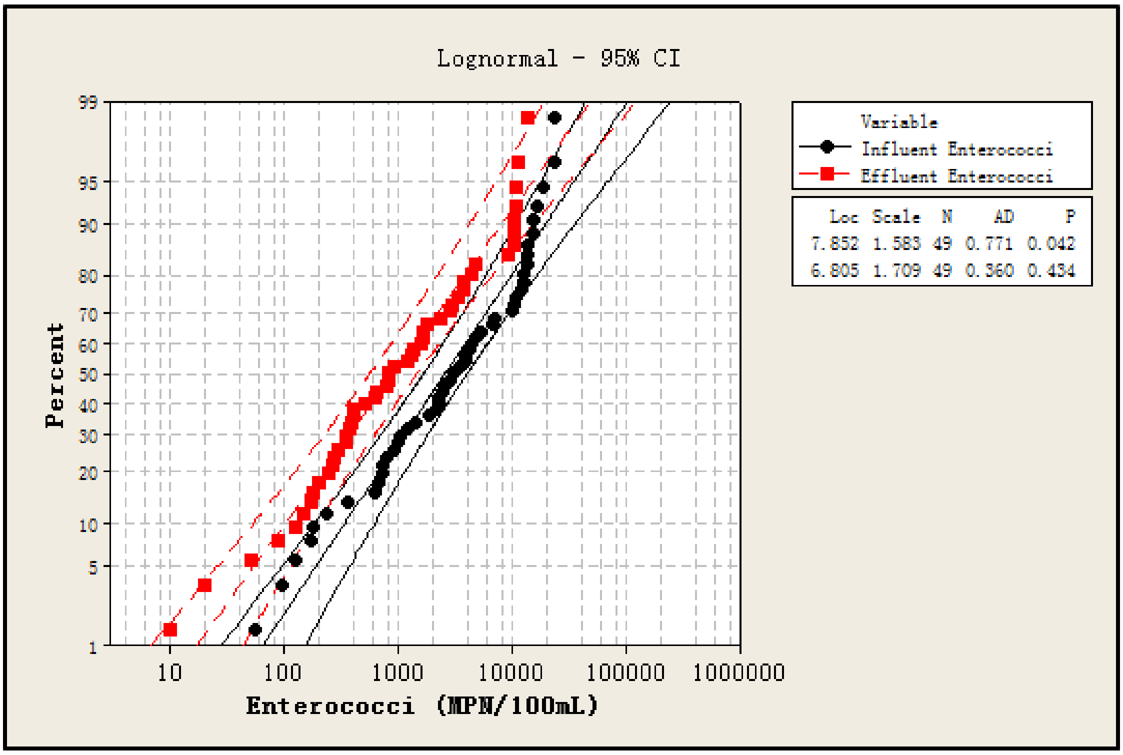


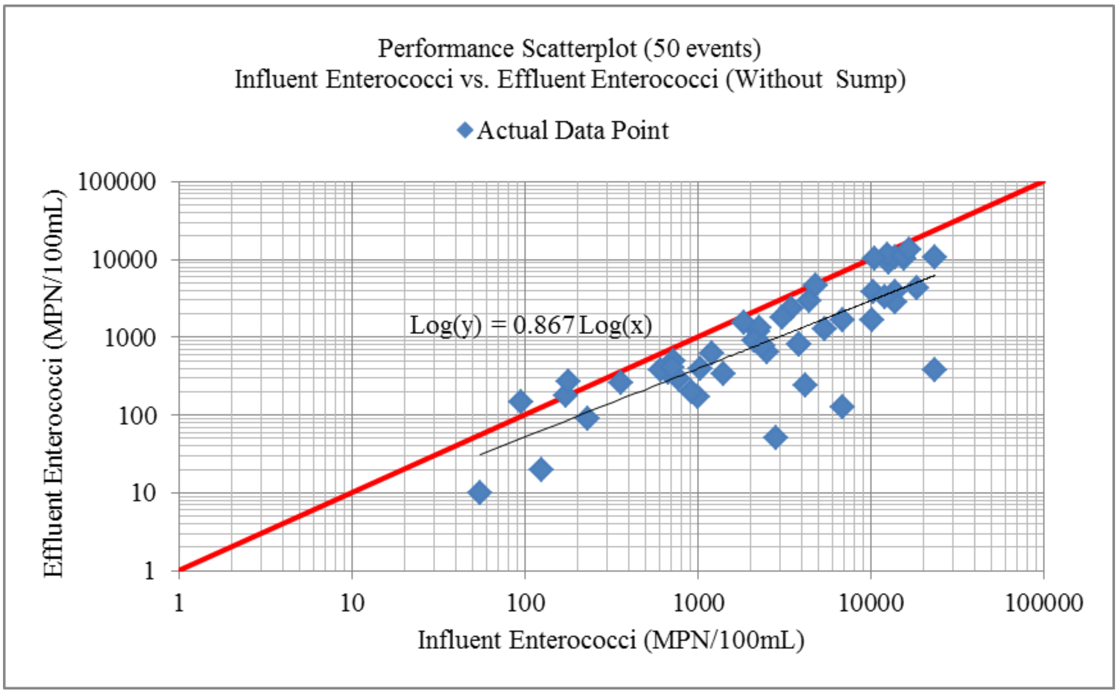
Wilcoxon Signed Rank Test					
Normality Test (Shapiro-Wilk)	Failed	(P < 0.050)			
Group	N	Missing	Median	0.25	0.75
Influent E.Coli	50.00	3.00	1870.00	610.00	4091.00
Effluent E.Coli	50.00	3.00	665.00	240.50	2224.00

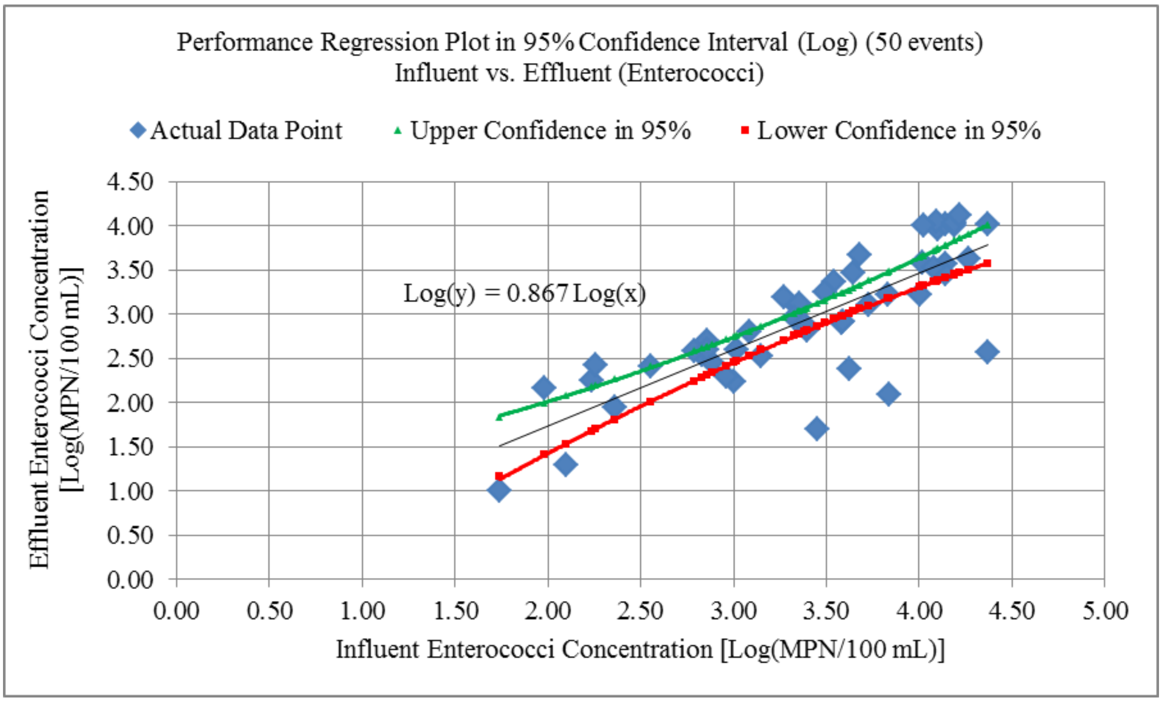
W= -970.000 T+ = 79.000 T-= -1049.000
Z-Statistic (based on positive ranks) = -5.132
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix E.11: Summary of Regression, ANOVA, Probability Analyses, and Hypothesis Test for Enterococci (50 Sampled Storms)







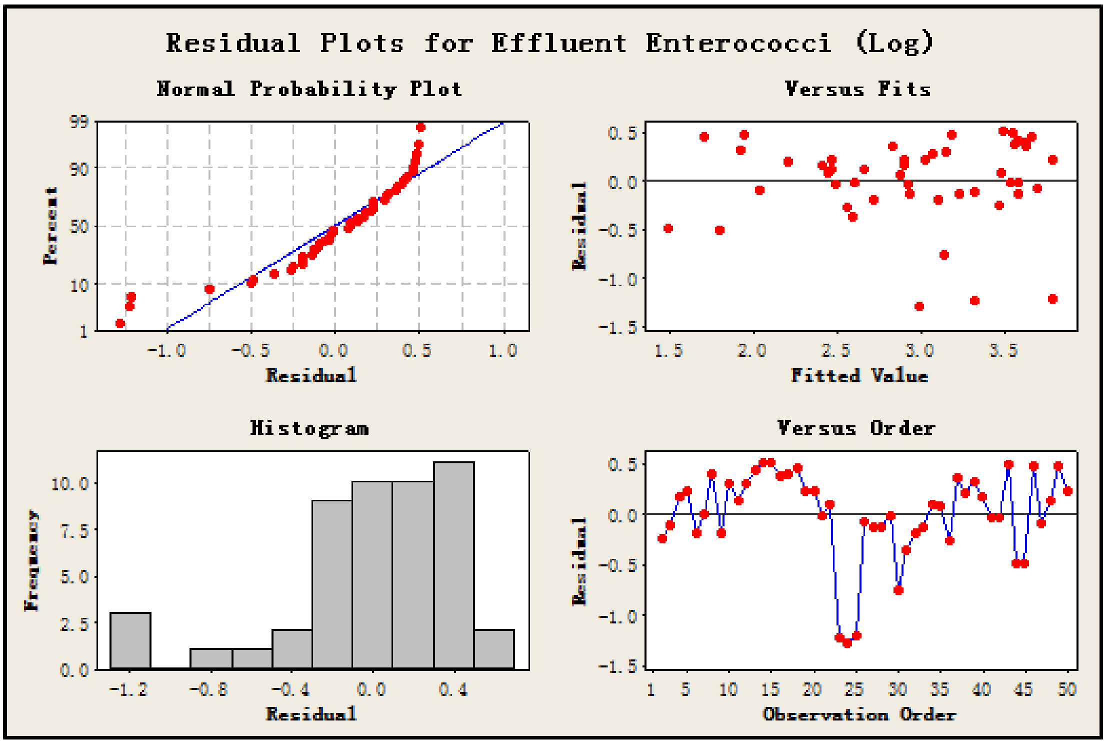
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.98
Adjusted R Square	0.96
Standard Error	0.43
Observations	49.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	445.34	445.34	2363.73	0.00
Residual	48.00	9.04	0.19		
Total	49.00	454.38			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.87	0.02	48.62	0.00	0.83	0.90	0.83	0.90



Wilcoxon Signed Rank Test

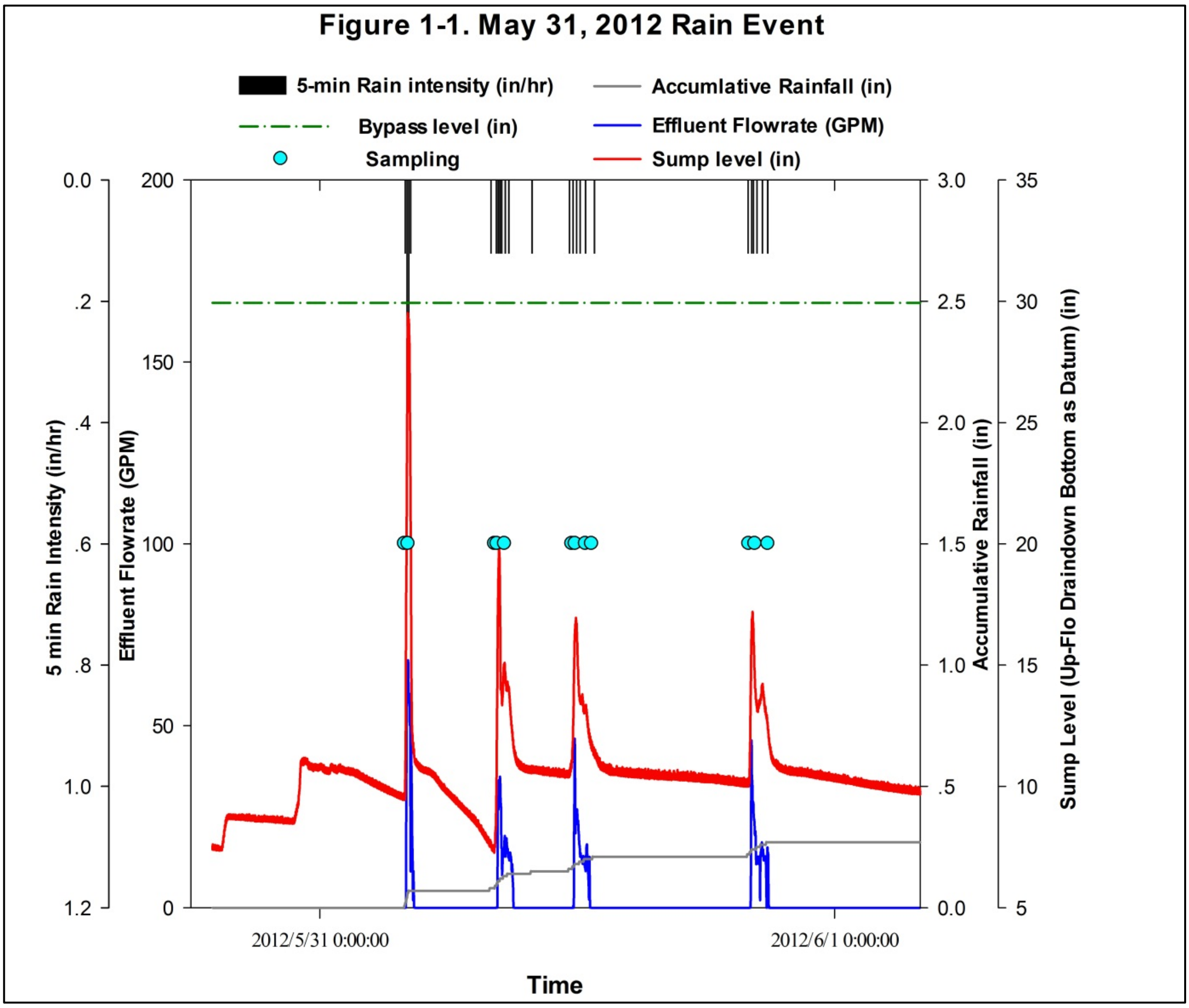
Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Group	N	Missing	Median	0.25	0.75
Influent Enterococci	50.00	1.00	3110.00	844.75	11339.00
Effluent Enterococci	50.00	1.00	820.00	278.75	3552.50

W= -1209.000 T+ = 8.000 T-= -1217.000
Z-Statistic (based on positive ranks) = -6.013
(P = <0.001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Appendix F.1: May 31, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 1-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.47
Volumetric Runoff Coefficient (Rv)	0.50

Table 1-2. May 31, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/5/31 3:57
Rain Event End Date/Time:			2012/5/31 20:49
Total Precipitation (inch):	≥ 0.1	0.27	
Total Runoff Depth (inch):	NA	0.14	
Total Outflow (gallon):	NA	3267	
Rain Duration (hours):	≥ 1	16.87	
Flow Start Date/Time:			2012/5/31 4:02
Flow End Date/Time:			2012/5/31 20:56
Flow Duration (hours):	NA	16.90	
Average Rain Intensity (in/hr):	NA	0.02	
Average Runoff Rate (gallons/min):	NA	3	
Peak 5-min Rain Intensity (in/hr):	NA	0.36	
Peak Runoff Rate (gallons/min):	NA	68	
Peak to Average Runoff Ratio:	NA	21.11	
Bypassed flow volume (gallon):	NA	0.00	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	219.97	

Table 1-3. May 31, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	12	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	>2.5	3.0	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	100	

Table 1-4. May 31, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	103	21	79.6	SM 2540D	1 mg/L	Stillbrook Lab
TSS	124	27	78.2	SM 2540D	1 mg/L	UA Lab
SSC	101	22	78.8	ASTM D3977-97B	1 mg/L	UA Lab
TDS	135	124	8.1	EPA 160.2	1 mg/L	UA Lab
VSS	71	9	87.4	SM 2540E	1 mg/L	UA Lab
Total N as N	1.6	1.1	31.3	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	1.1	0.9	18.2	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.32	0.27	15.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.92	BDL	> 97.8	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.58	BDL	> 96.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.12	BDL	> 83.3	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	0.010	BDL	> 50.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Cu	0.03	BDL	> 33.3	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Pb	0.051	0.006	88.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.15	0.04	73.3	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Coliform	> 24,196	> 24,196	N.A.	IDEXX Method	<1	UA Lab
E. Coli	> 24,196	> 24,196	N.A.	IDEXX Method	<1	UA Lab
Enterococci	13815	3765	72.7	IDEXX Method	<1	UA Lab
pH	6.64	7.05	-6.2	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	77.25	33.10	57.2	SM 2130B/EPA 180.1	0 NTU	UA Lab
Conductivity	106.20	95.60	10.0	SM 2510B/EPA 120.6	0 µS	UA Lab
Temperature	24.10	24.30	-0.8	SM 212/EPA 170.1	5 °C	UA Lab

Table 1-5. May 31, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	0.45 to 1180 µm particle	> 1180 µm particle	Total	0.45 to 1180 µm particle	> 1180 µm particle	Total	0.45 to 1180 µm particle	> 1180 µm particle	Total
UA Lab	92	9	101	20	2	22	78.8	77.8	78.2

Table 1-6. May 31, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3-250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	32484	12968	57.9	17.4	1.8	1.3

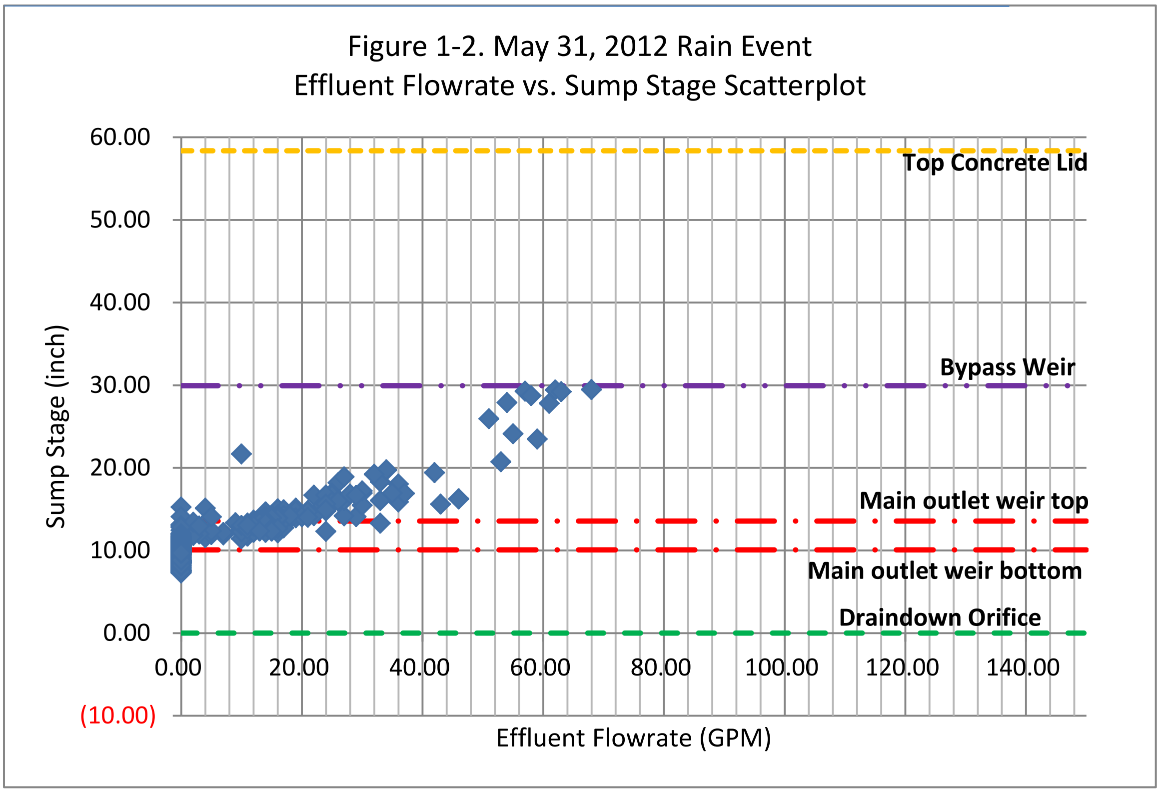
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 1-7. May 31, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Millipore Membrane Filter, 0.45µm	130	118	124	24	30	27
Millipore Glass Fiber Filter, 0.7µm	126	124	125	22	22	22

Note: The average TSS values from 0.45µm membrane filter are reported as the formal TSS results. The TSS values from 0.7µm glass fiber filter are to test the repeatability of the method and the significance of difference caused by filters type and pore size.

Table 1-8. May 31, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100mL)		
Constituents	Dilution 1 (5X)	Dilution 2 (10X)	Average	Dilution 1 (5X)	Dilution 2 (10X)	Average
Total Coliform	> 12,098	> 24,196	> 24,196	> 12,098	> 24,196	> 24,196
E. Coli	> 12,098	> 24,196	> 24,196	> 12,098	> 24,196	> 24,196
Enterococci	12098	15531	13815	4082	3448	3765

Table 1-9. May 31, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Millipore Glass Fiber Filter, 0.7µm	74	68	71	10	8	9



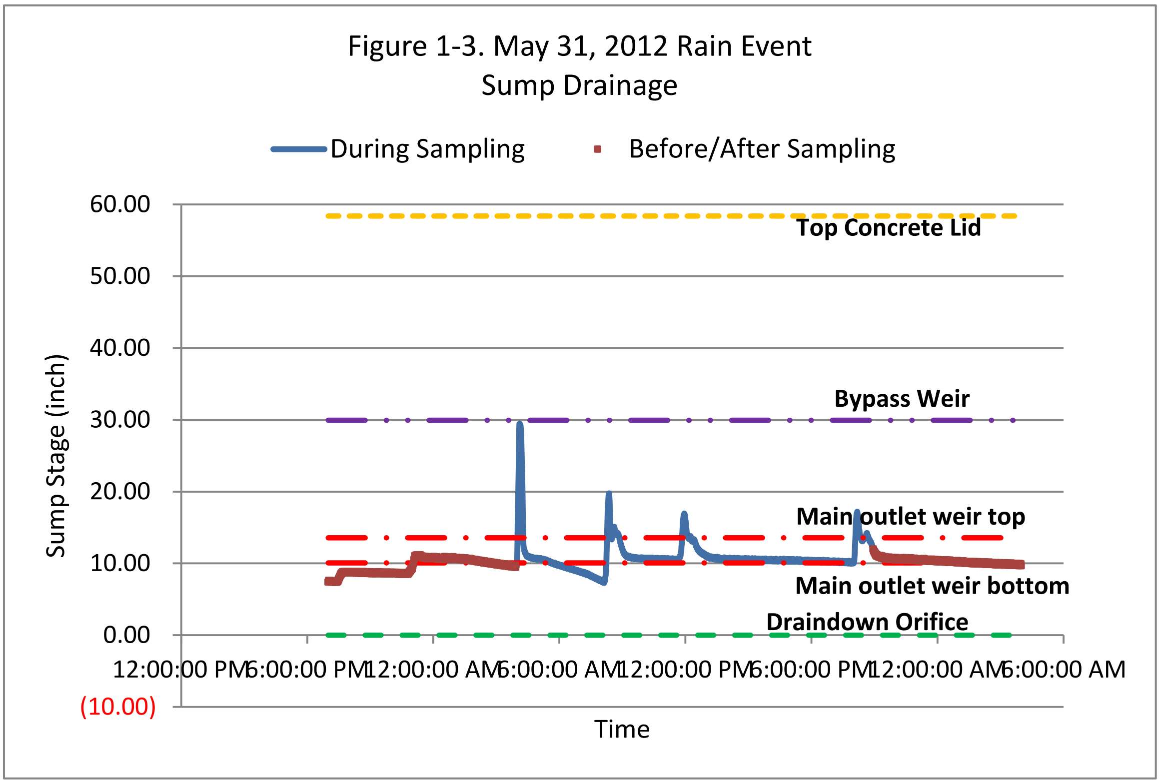


Figure 1-3. May 31, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
Time

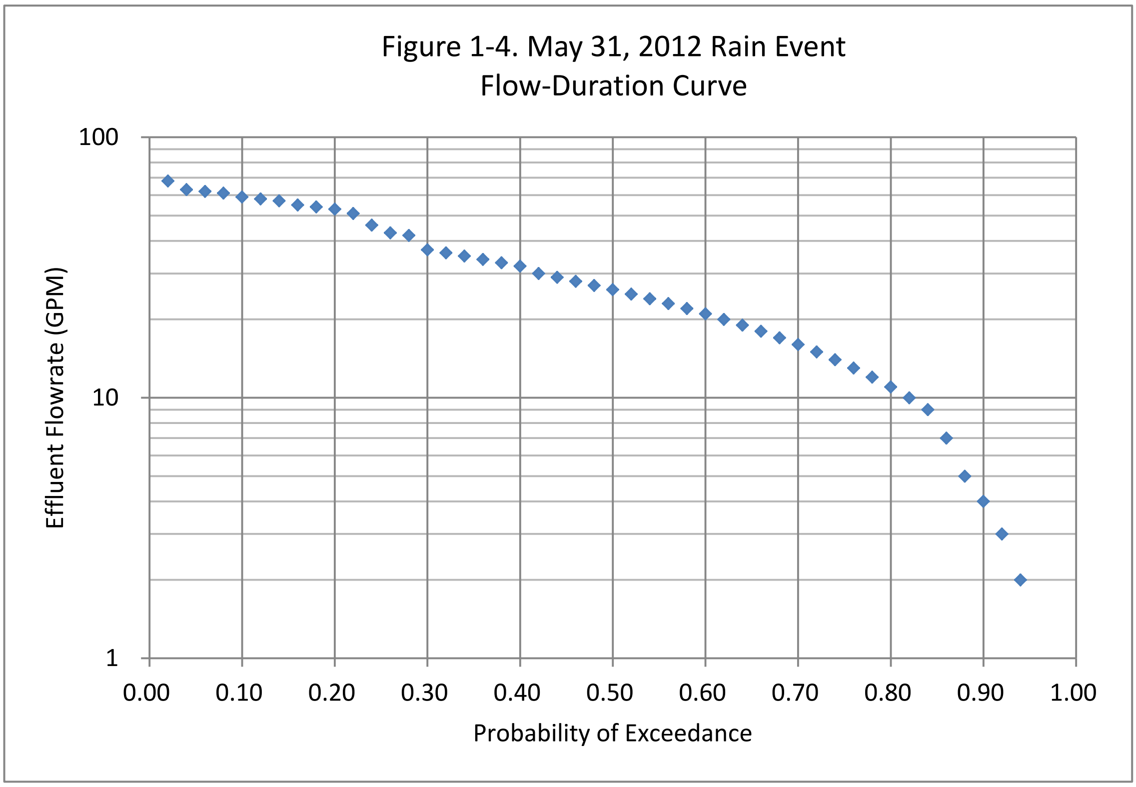
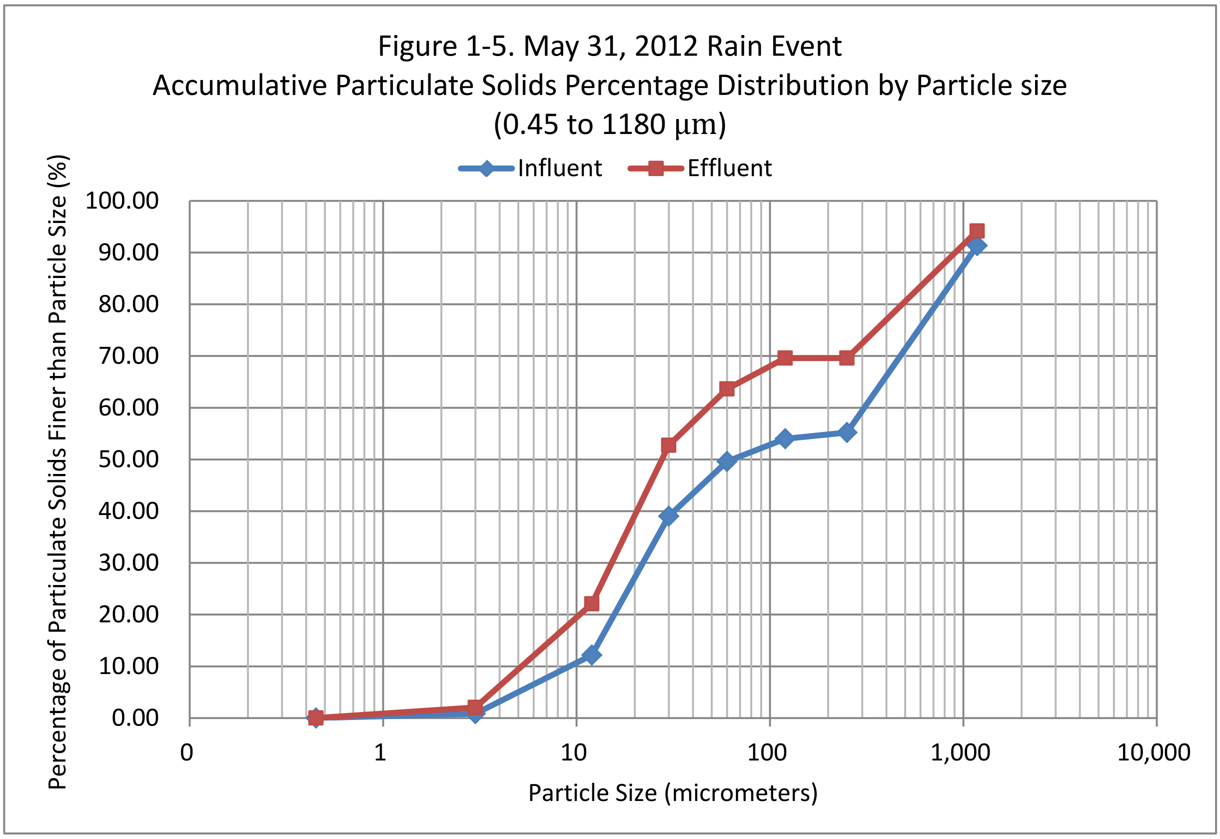
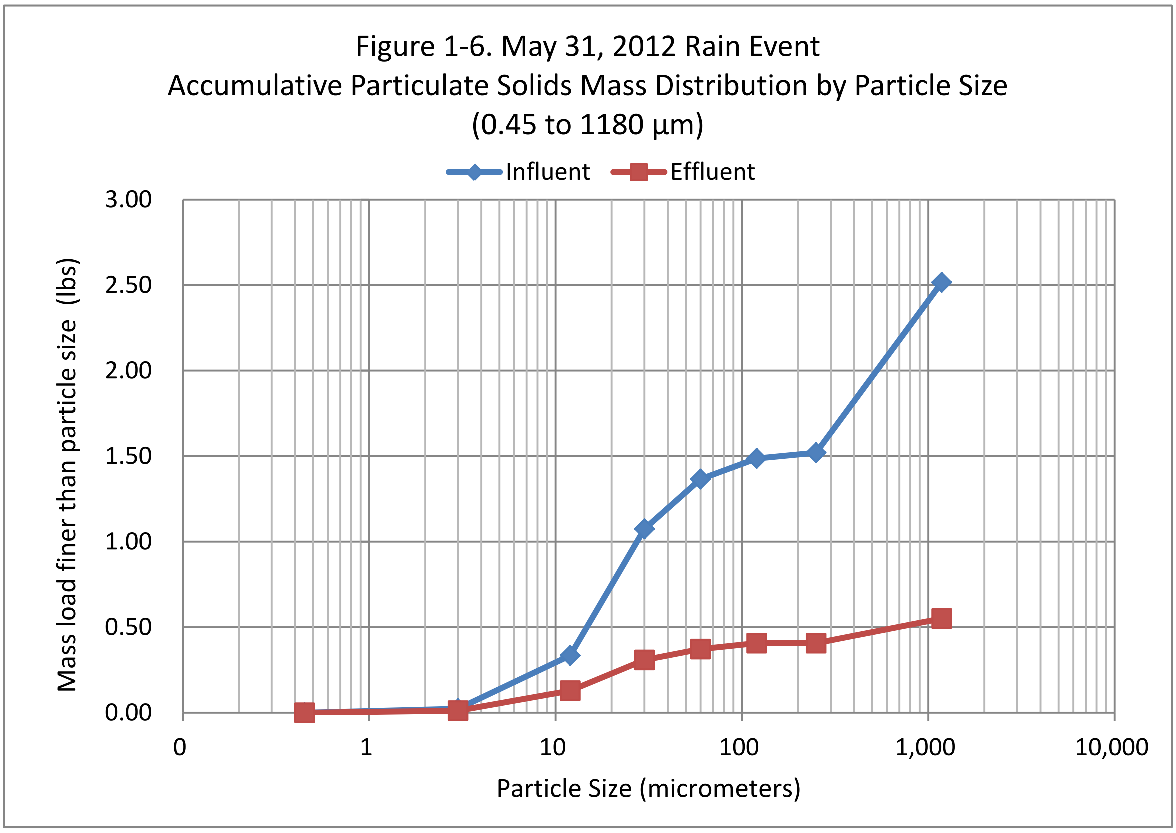


Figure 1-4. May 31, 2012 Rain Event
Flow-Duration Curve
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 0.24 lbs larger than 1180 µm and the effluent had 0.03 lbs larger than 1180 µm (8.64% and 5.83% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 1-10. May 31, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (µm)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.90	0.53	0.84	2.05	0.02	0.01	0.01	48.27
3 to 12	12.06	5.15	11.32	20.03	0.31	0.12	0.19	62.40
12 to 30	28.62	7.88	26.87	30.64	0.74	0.18	0.56	75.77
30 to 60	11.26	2.80	10.58	10.91	0.29	0.06	0.23	78.09
60 to 120	4.68	1.54	4.39	5.97	0.12	0.03	0.09	71.13
120 to 250	1.29	0.00	1.21	0.00	0.03	0.00	0.03	100.00
250 to 1180	38.51	6.32	36.15	24.56	1.00	0.14	0.85	85.56
>1180	9.20	1.50	8.64	5.83	0.24	0.03	0.20	85.65
Total	106.51	25.71	100.00	100.00	2.75	0.58	2.17	78.75

Table 1-11. May 31, 2012 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.84	2.05	0.02	0.01
<12	12.16	22.08	0.33	0.13
<30	39.03	52.72	1.07	0.31
<60	49.60	63.63	1.37	0.37
<120	54.00	69.60	1.49	0.41
<250	55.21	69.60	1.52	0.41
<1180	91.36	94.17	2.52	0.55
>1180	100.00	100.00	2.75	0.58

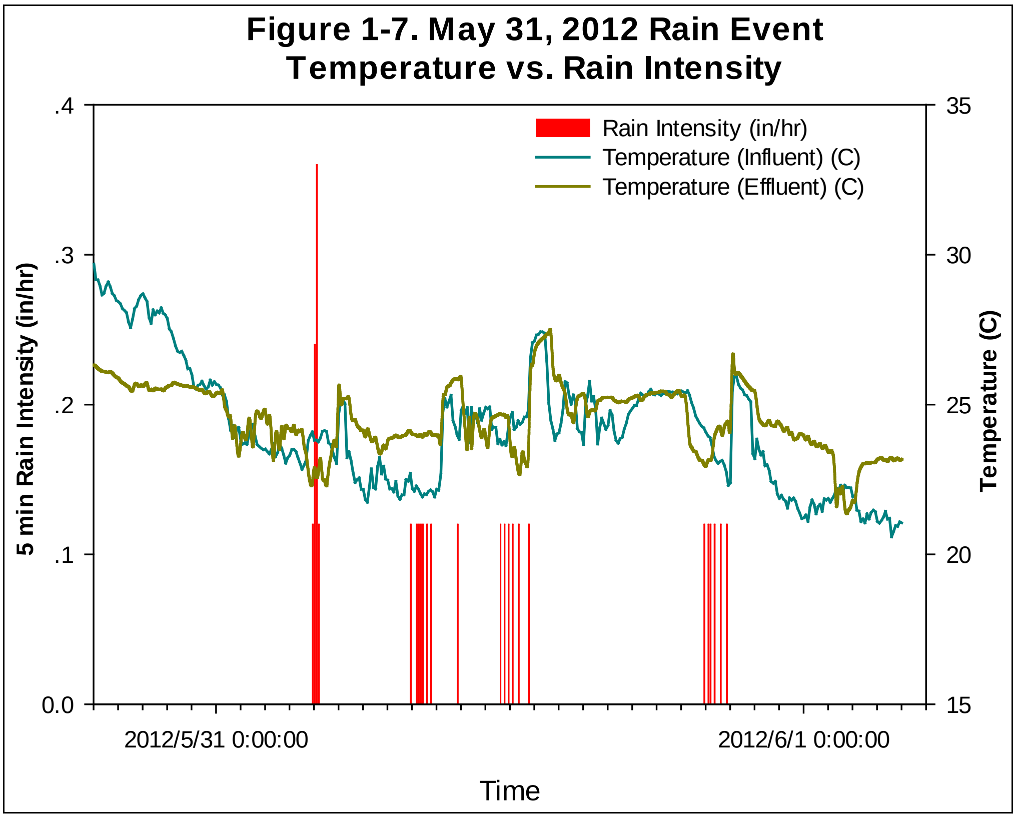


Figure 1-7. May 31, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
.4
.3
.2
.1
0.0
35
30
25
20
15
2012/5/31 0:00:00
2012/6/1 0:00:00
Time

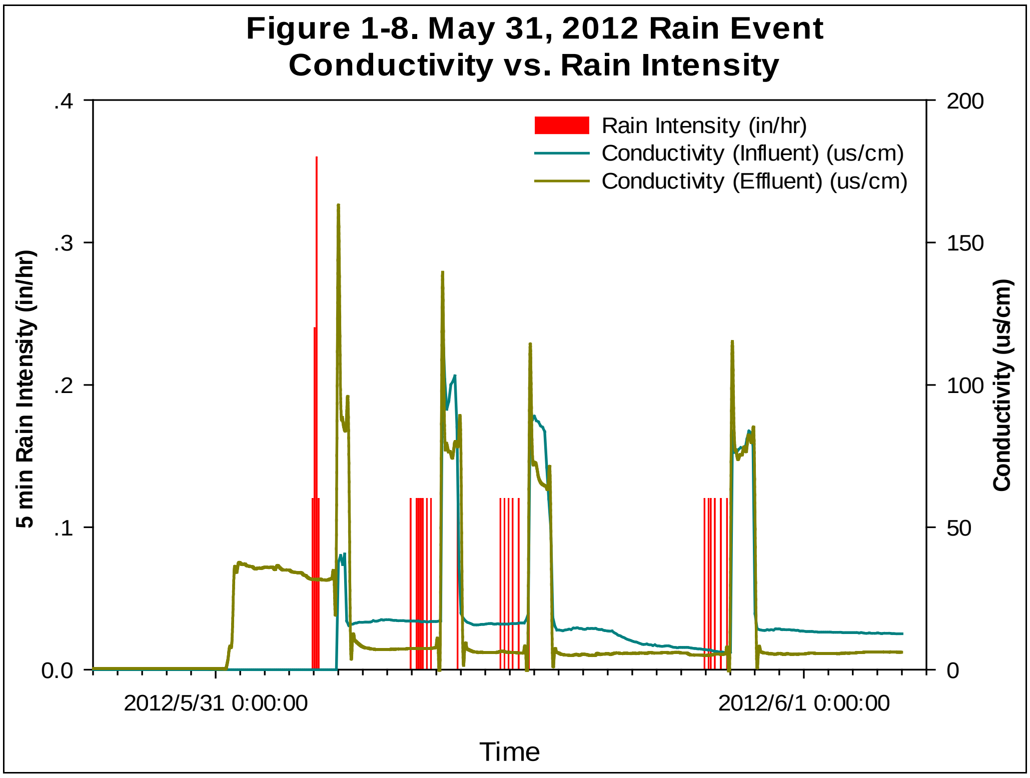


Figure 1-8. May 31, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
.4
.3
.2
.1
0.0
200
150
100
50
0
2012/5/31 0:00:00
2012/6/1 0:00:00
Time

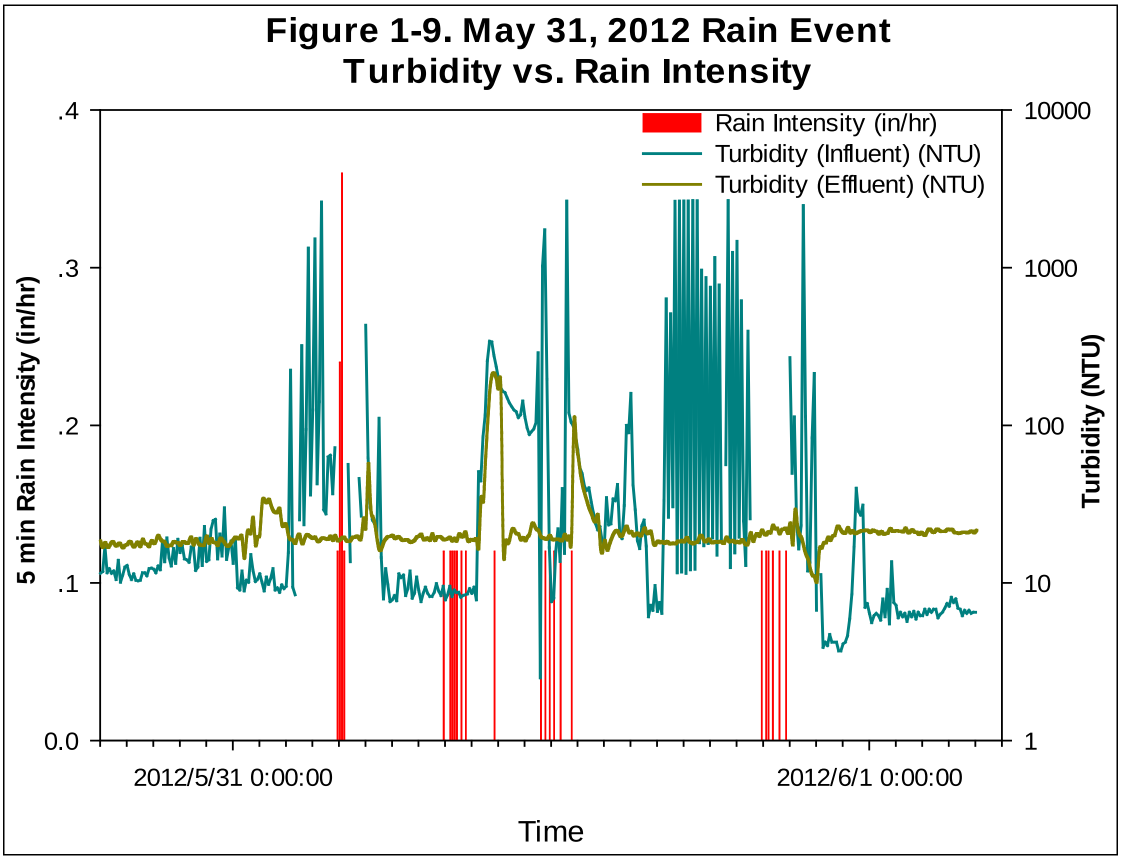
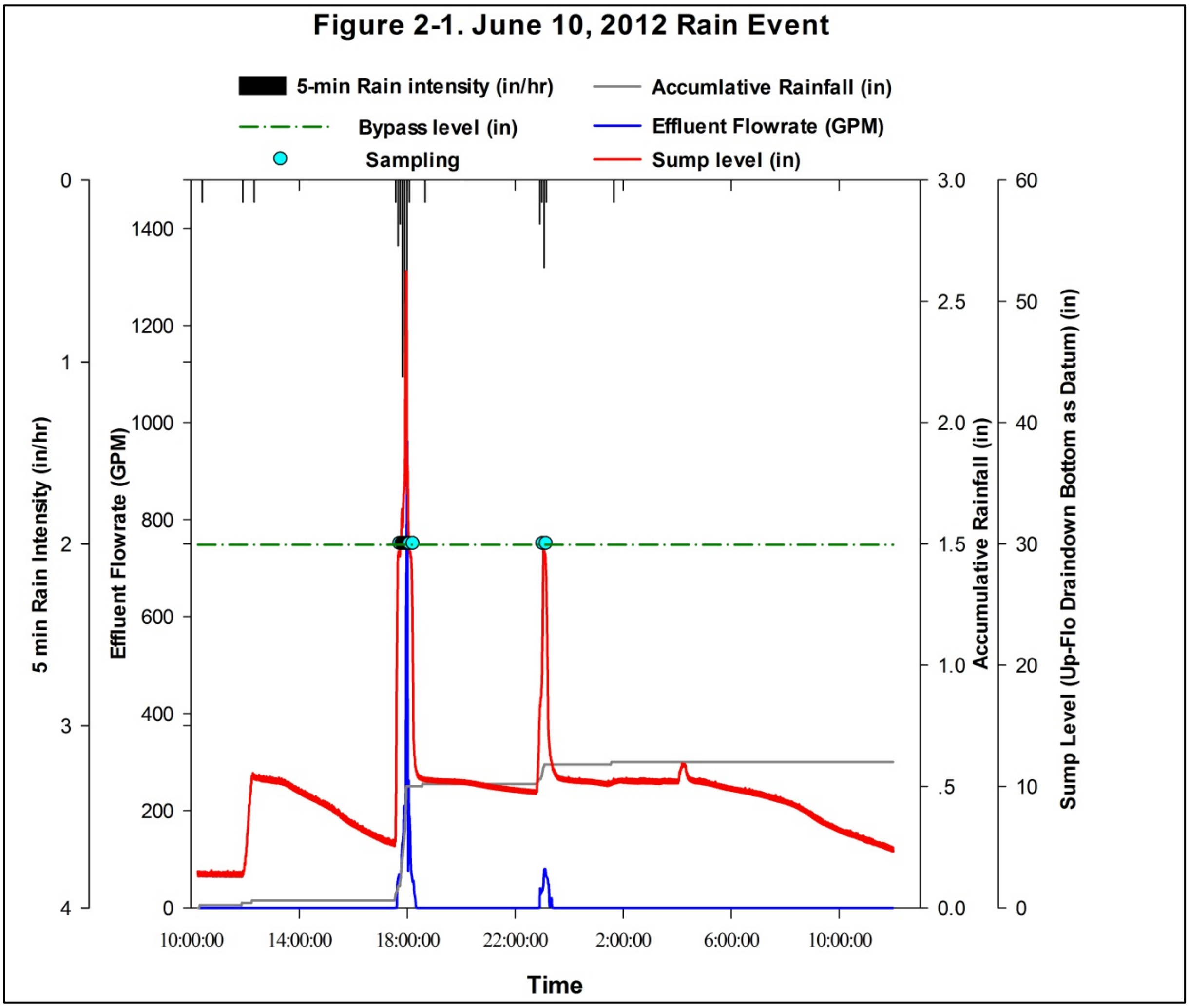


Figure 1-9. May 31, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
.4
.3
.2
.1
0.0
Turbidity (NTU)
10000
1000
100
10
1
2012/5/31 0:00:00
2012/6/1 0:00:00
Time

Appendix F.2: June 10, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 2-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.91
Volumetric Runoff Coefficient (Rv)	1.51

Table 2-2. June 10, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/6/10 10:19
Rain Event End Date/Time:			2012/6/11 1:34
Total Precipitation (inch):	≥ 0.1	0.60	
Total Runoff Depth (inch):	NA	0.91	
Total Outflow (gallon):	NA	8240	
Rain Duration (hours):	≥ 1	15.25	
Flow Start Date/Time:			2012/6/10 17:37
Flow End Date/Time:			2012/6/10 23:23
Flow Duration (hours):	NA	5.77	
Average Rain Intensity (in/hr):	NA	0.04	
Average Runoff Rate (gallons/min):	NA	24	
Peak 5-min Rain Intensity (in/hr):	NA	2.64	
Peak Runoff Rate (gallons/min):	NA	962	
Peak to Average Runoff Ratio:	NA	40.39	
Bypassed flow volume (gallon):	NA	2054	
Percentage of Bypassed Flow (%):	NA	24.93	
Inter-Event Time since prior rain (hours)	≥ 6.0	246.37	

Table 2-3. June 10, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	16	
Volume per Subsample (mL):	250.00	250	
Total Volume for Event (L):	> 2.5	4.0	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	90.28	

Table 2-4. June 10, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	29	5	82.8	SM 2540D	1 mg/L	Stillbrook Lab
TSS	69	9	87.0	SM 2540D	1 mg/L	UA Lab
SSC	80	12	85.3	ASTM D3977-97B	1 mg/L	UA Lab
TDS	45	38	15.6	EPA 160.2	1 mg/L	UA Lab
VSS	44	7	84.1	SM 2540E	1 mg/L	UA Lab
Total N as N	0.8	0.7	12.5	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.4	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	N.A.	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.14	0.13	7.1	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.28	0.31	-10.7	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	0.09	> -77.8	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	N.A.	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	N.A.	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.05	BDL	> 60.0	EPA 200.8	0.02 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	N.A.	EPA 200.8	0.02 mg/L	Stillbrook Lab
Total Coliform	> 24,196	> 24,196	N.A.	IDEXX Method	<1	UA Lab
E. Coli	1366	624	54.3	IDEXX Method	<1	UA Lab
Enterococci	10381	3798	63.4	IDEXX Method	<1	UA Lab
pH	6.51	6.78	-4.1	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	18.75	6.30	66.4	SM 2130B/EPA 180.1	0 NTU	UA Lab
Conductivity	29.10	31.80	-9.3	SM 2510B/EPA 120.6	0 µS	UA Lab
Temperature	23.50	23.90	-1.7	SM 212/EPA 170.1	5 °C	UA Lab

Table 2-5. June 10, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	0.45 to 1180 µm particle	> 1180 µm particle	Total	0.45 to 1180 µm particle	> 1180 µm particle	Total	0.45 to 1180 µm particle	> 1180 µm particle	Total
UA Lab	58	22	80	9	3	12	84.5	87.5	85.3

Table 2-6. June 10, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3-250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	12773	4292	41.6	10.0	3.3	2.3

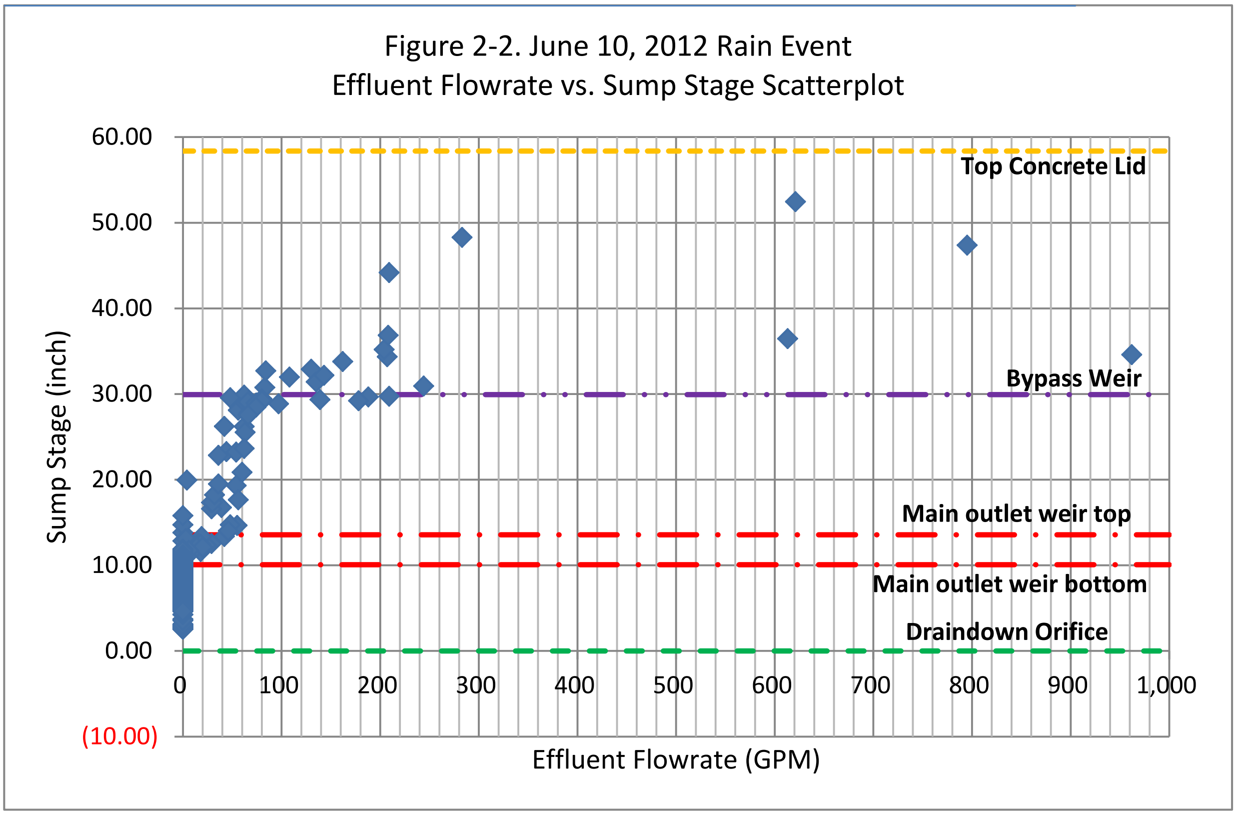
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 2-7. June 10, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Millipore Membrane Filter, 0.45µm	76	62	69	8	10	9
Millipore Glass Fiber Filter, 0.7µm	68	66	67	10	12	11

Note: The average TSS values from 0.45µm membrane filter are reported as the formal TSS results. The TSS values from 0.7µm glass fiber filter are to test the repeatability of the method and the significance of difference caused by filter type and pore size.

Table 2-8. June 10, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (5X)	Dilution 2 (10X)	Average	Dilution 1 (5X)	Dilution 2 (10X)	Average
Total Coliform	> 12,098	> 24,196	> 24,196	> 12,098	> 24,196	> 24,196
E. Coli	1378	1354	1366	563	684	624
Enterococci	12098	8664	10381	3244	4352	3798

Table 2-9. June 10, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Millipore Glass Fiber Filter, 0.7µm	42	46	44	8	6	7



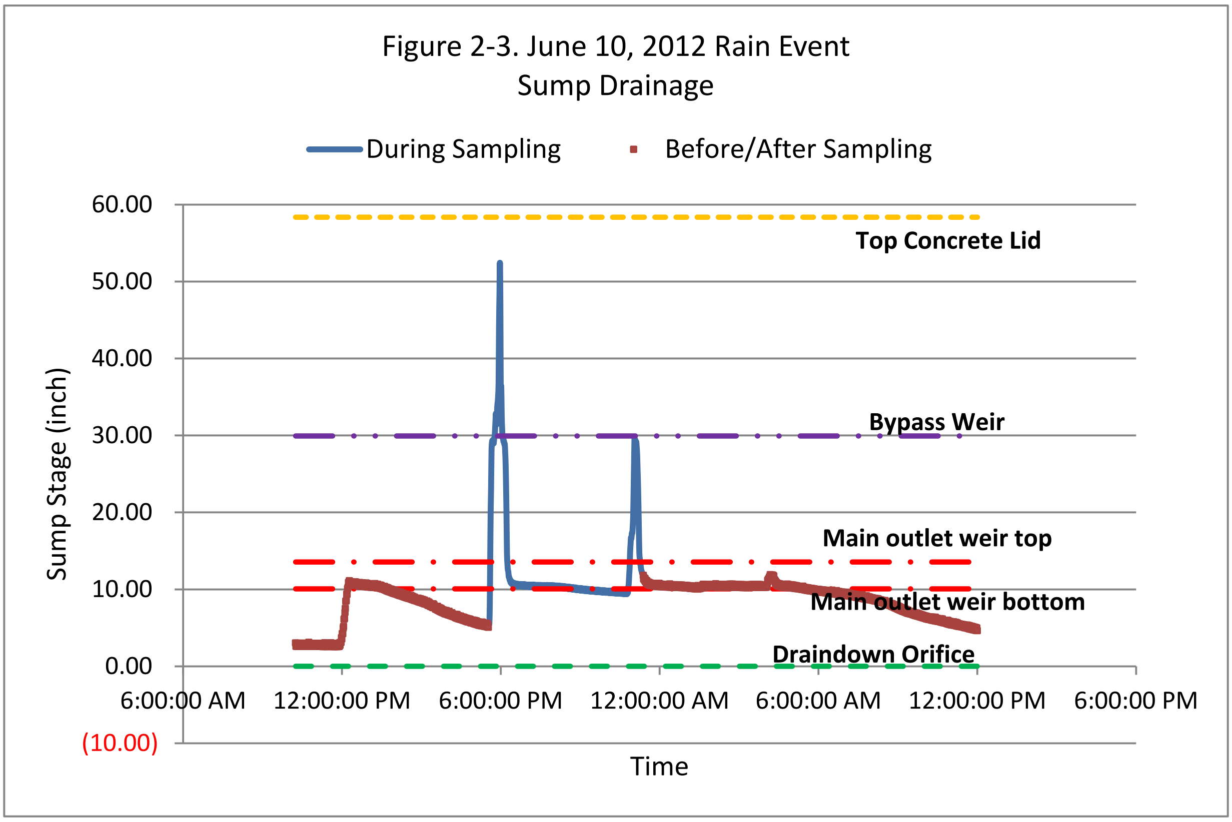


Figure 2-3. June 10, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
Time

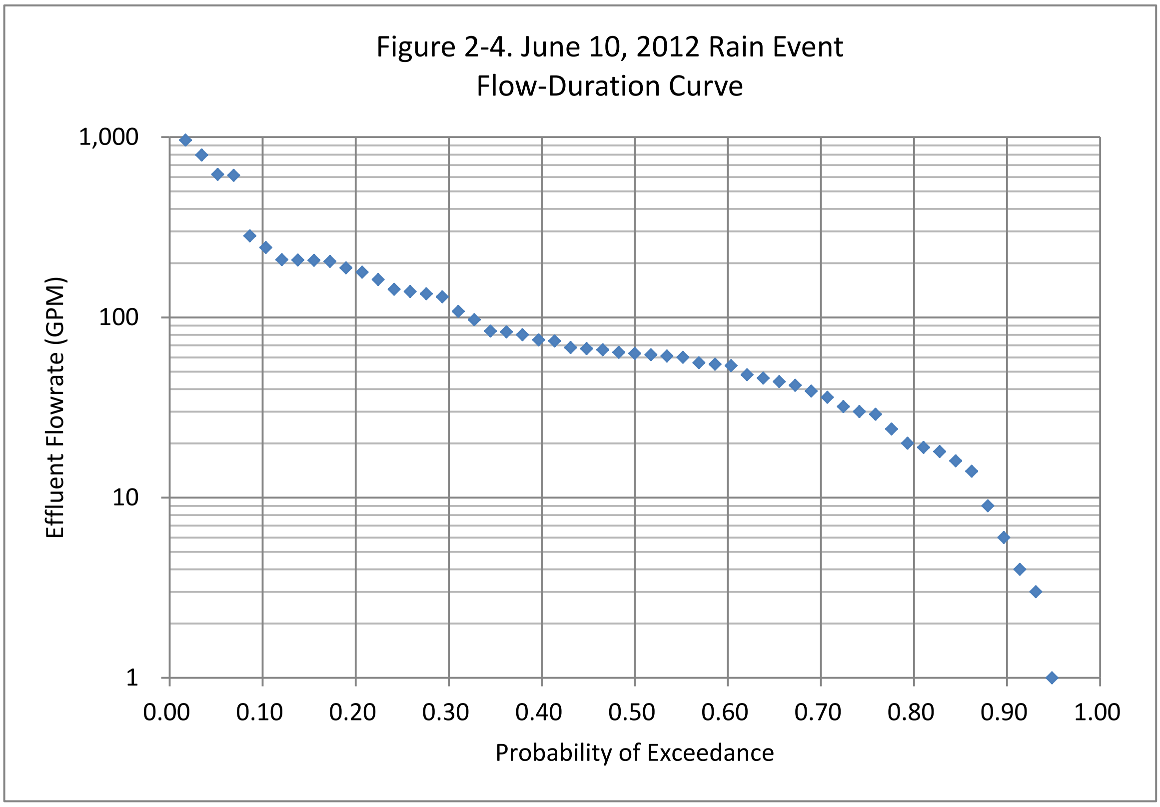


Figure 2-4. June 10, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 2-5. June 10, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

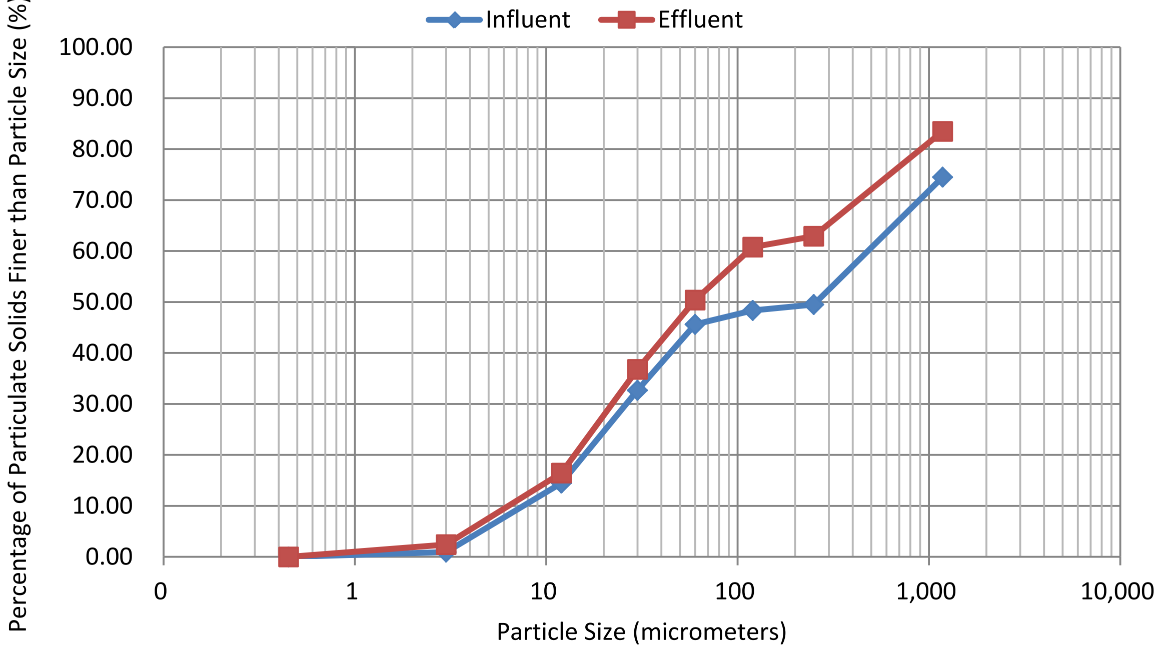
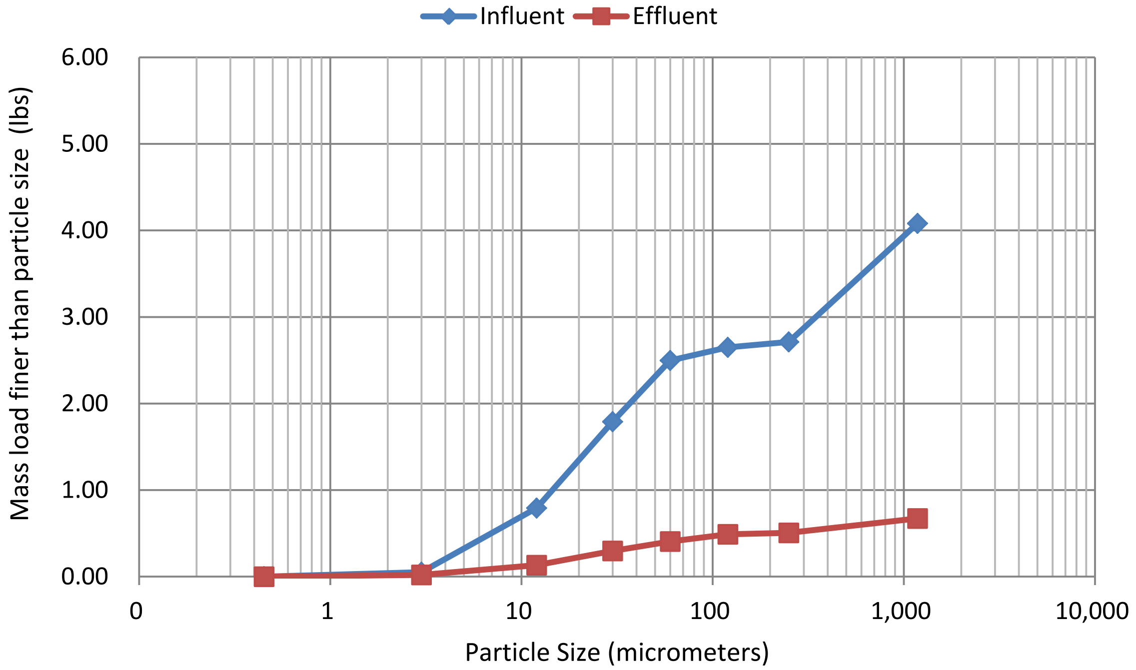


Figure 2-6. June 10, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 1.40 lbs larger than 1180 µm and the effluent had 0.13 lbs larger than 1180 µm (25.50% and 16.53% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 2-10. June 10, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.80	0.40	0.93	2.42	0.05	0.02	0.03	61.94
3 to 12	11.58	2.32	13.52	14.03	0.74	0.11	0.63	84.75
12 to 30	15.61	3.36	18.23	20.34	1.00	0.16	0.84	83.60
30 to 60	11.06	2.25	12.92	13.61	0.71	0.11	0.60	84.51
60 to 120	2.35	1.71	2.75	10.37	0.15	0.08	0.07	44.49
120 to 250	1.00	0.35	1.16	2.14	0.06	0.02	0.05	73.01
250 to 1180	21.40	3.40	24.99	20.56	1.37	0.17	1.20	87.91
>1180	21.83	2.73	25.50	16.53	1.40	0.13	1.26	90.47
Total	85.63	16.53	100.00	100.00	5.48	0.81	4.67	85.30

Table 2-11. June 10, 2012 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass (lbs)		Accumulative Mass Percentage (%)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.05	0.02	0.93	2.42
<12	0.79	0.13	14.46	16.45
<30	1.79	0.30	32.69	36.79
<60	2.50	0.41	45.60	50.40
<120	2.65	0.49	48.35	60.77
<250	2.71	0.51	49.51	62.90
<1180	4.08	0.67	74.50	83.47
>1180	5.48	0.81	100.00	100.00

Figure 2-7. June 10, 2012 Rain Event
Temperature vs. Rain Intensity

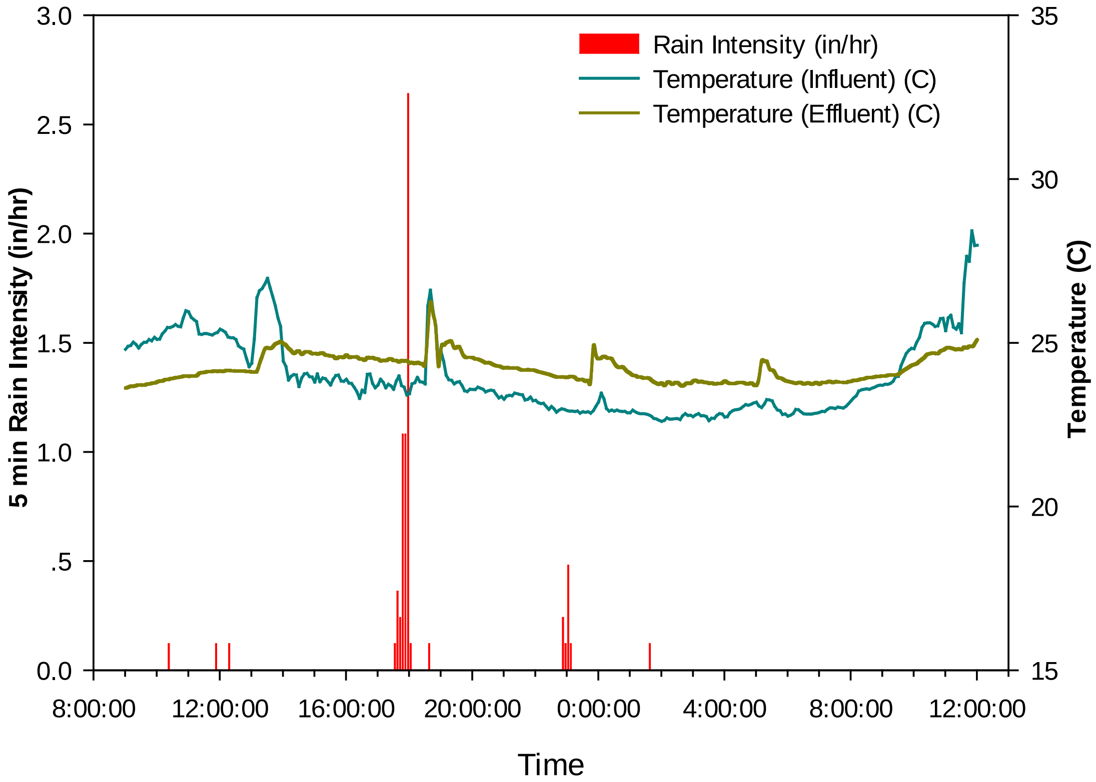
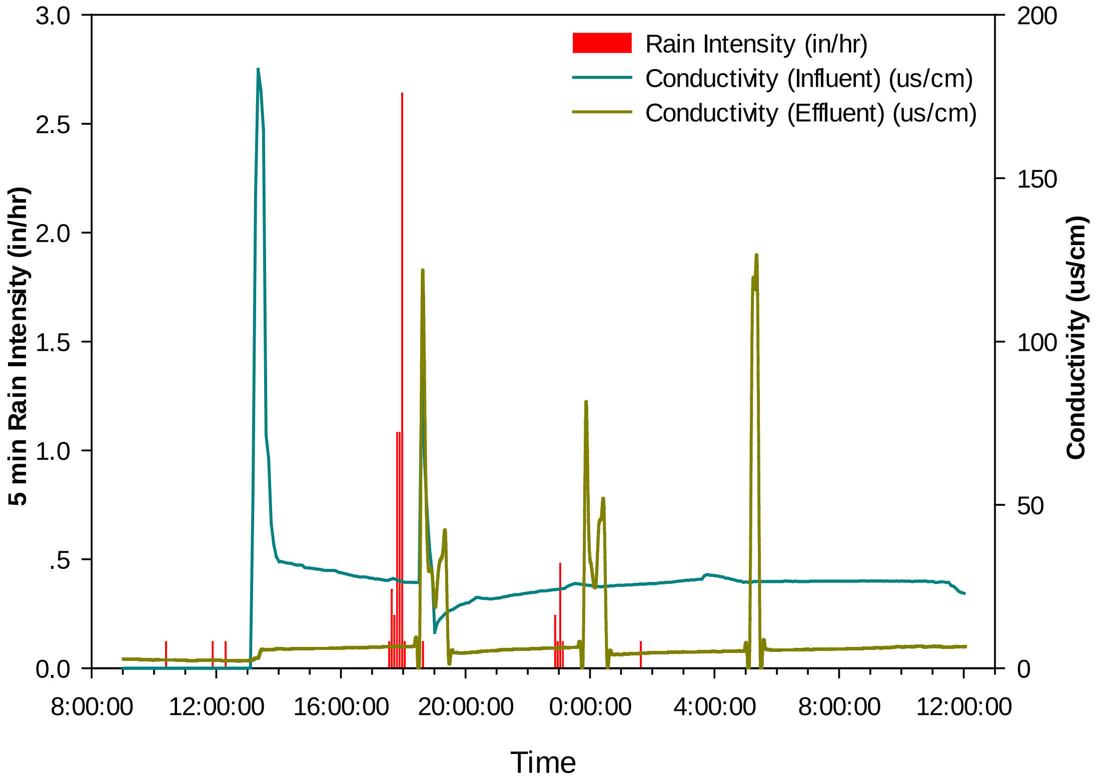


Figure 2-8. June 10, 2012 Rain Event
Conductivity vs. Rain Intensity



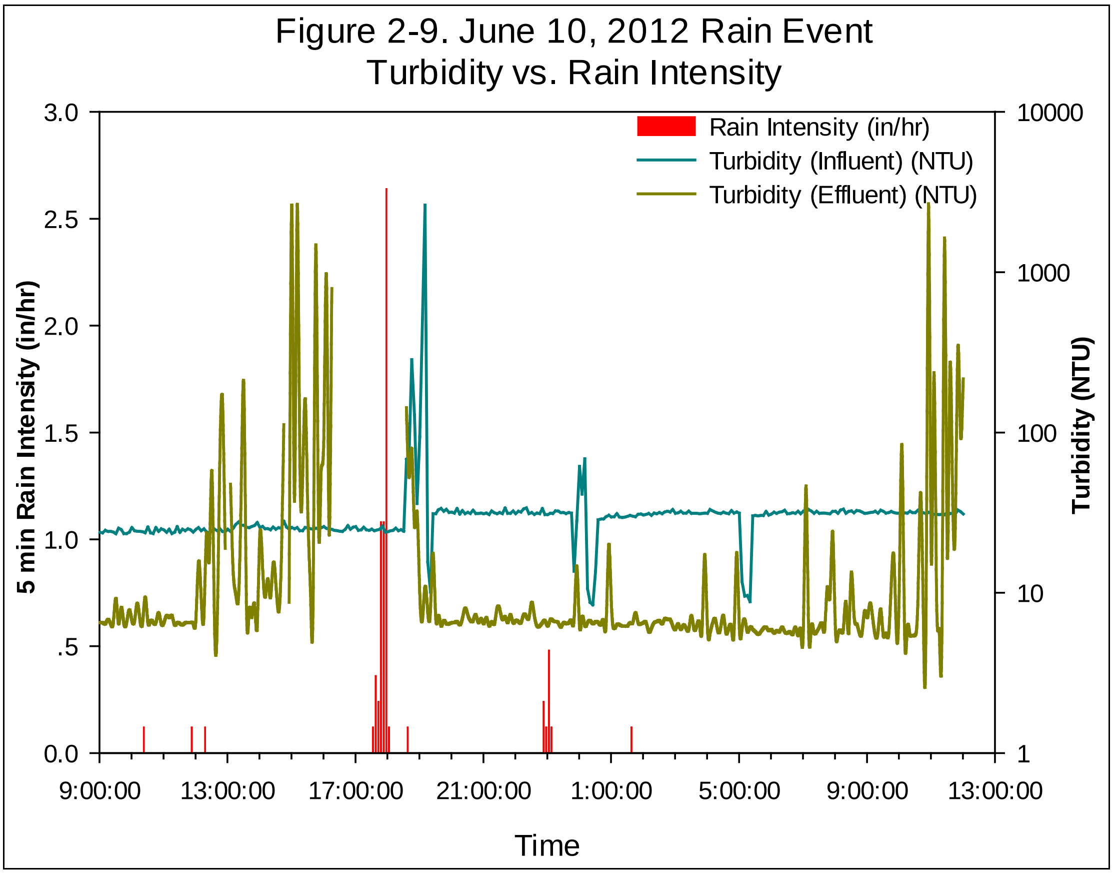
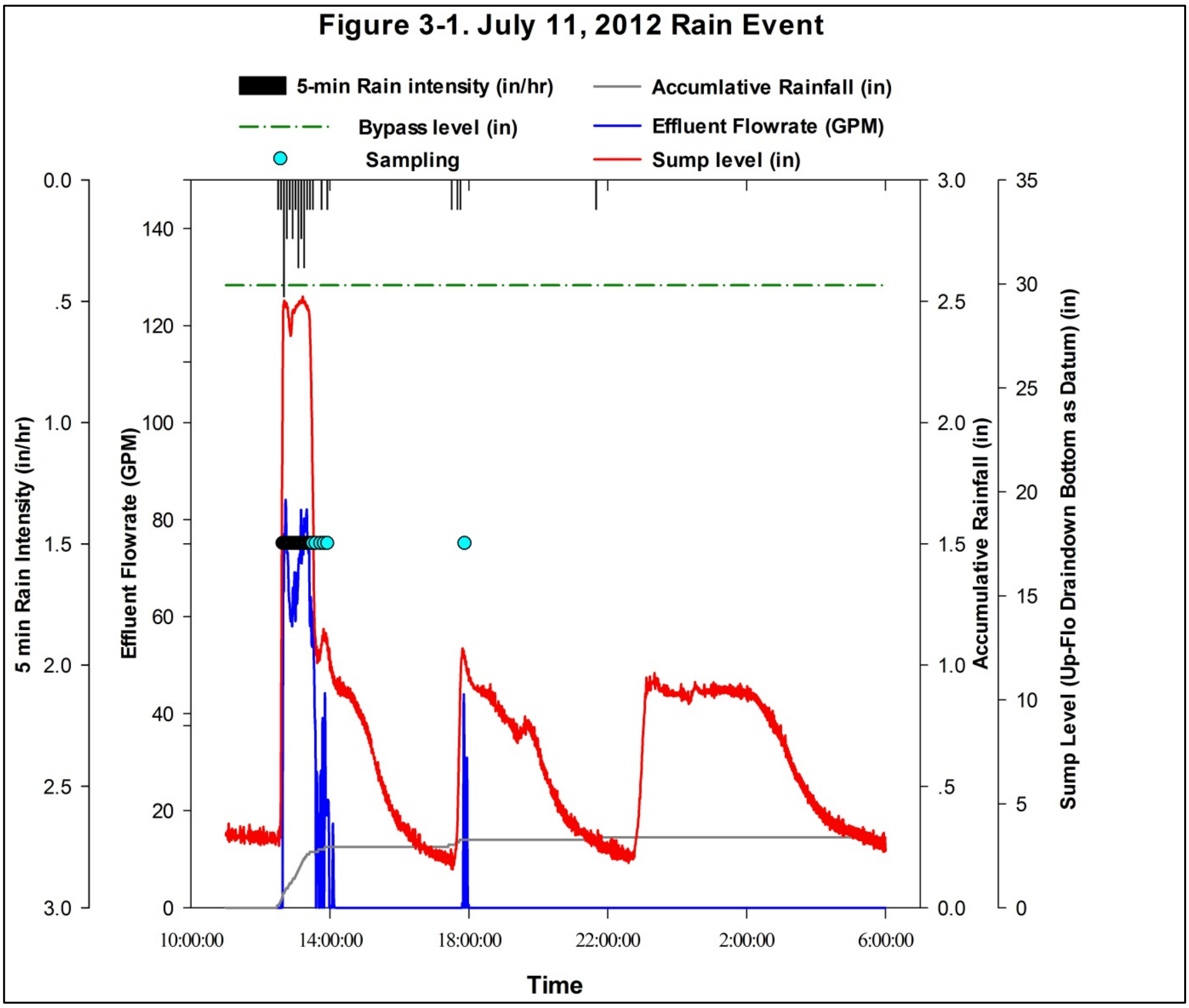


Figure 2-9. June 10, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
9:00:00
13:00:00
17:00:00
21:00:00
1:00:00
5:00:00
9:00:00
13:00:00
Time

Appendix F.3: July 11, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 3-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.43
Volumetric Runoff Coefficient (Rv)	1.10

Table 3-2. July 11, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/7/11 12:29
Rain Event End Date/Time:			2012/7/11 21:39
Total Precipitation (inch):	≥ 0.1	0.29	
Total Runoff Depth (inch):	NA	0.32	
Total Outflow (gallon):	NA	4464	
Rain Duration (hours):	≥ 1	9.17	
Flow Start Date/Time:			2012/7/11 12:39
Flow End Date/Time:			2012/7/11 17:58
Flow Duration (hours):	NA	5.32	
Average Rain Intensity (in/hr):	NA	0.03	
Average Runoff Rate (gallons/min):	NA	14	
Peak 5-min Rain Intensity (in/hr):	NA	0.48	
Peak Runoff Rate (gallons/min):	NA	83	
Peak to Average Runoff Ratio:	NA	5.93	
Bypassed flow volume (gallon):	NA	0	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	20.63	

Table 3-3. July 11, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	36	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	9.0	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	96.84	

Table 3-4. July 11, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	63	16	74.6	SM 2540D	1 mg/L	Stillbrook Lab
TSS	119	12	89.5	SM 2540D	1 mg/L	UA Lab
SSC	114	15	86.8	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	120	12	90.4	ASTM D3977-97B	1 mg/L	UA Lab
TDS	63	74	-16.7	EPA 160.2	1 mg/L	UA Lab
VSS	54	9	83.3	SM 2540E	1 mg/L	UA Lab
Total N as N	1.2	1.0	16.7	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.6	-20.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.20	0.21	-5.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.74	0.58	21.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.49	0.34	30.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.009	0.007	22.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.005	BDL	> 0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.074	0.021	71.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.007	0.006	14.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	12,630	> 73.9	IDEXX Method	<1	UA Lab
E. Coli	103	51	50.5	IDEXX Method	<1	UA Lab
Enterococci	6853	125	98.2	IDEXX Method	<1	UA Lab
pH	6.51	6.60	-1.4	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	24.50	8.06	67.1	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	59.1	75.9	-28.4	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	26.3	26.3	0.0	SM 212/EPA 170.1	5 °C	UA Lab

Table 3-5. July 11, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	114	NA*	NA*	15	NA*	NA*	86.8	NA*	NA*
UA Lab	112	8	120	11	0	12	90.0	95.9	90.4

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 3-6. July 11, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	30953	4008	97	10	3.1	2.5

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 3-7. July 11, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	120	118	119	13	12	12
Millipore Membrane Filter, 0.45µm	126	130	128	11	11	11

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 3-8. July 11, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24,196	> 48,392	> 48,392	12997	12262	12630
E. Coli	146	60	103	20	82	51
Enterococci	6488	7218	6853	105	144	125

Table 3-9. July 11, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	55	53	54	9	9	9

Figure 3-2. July 11, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot

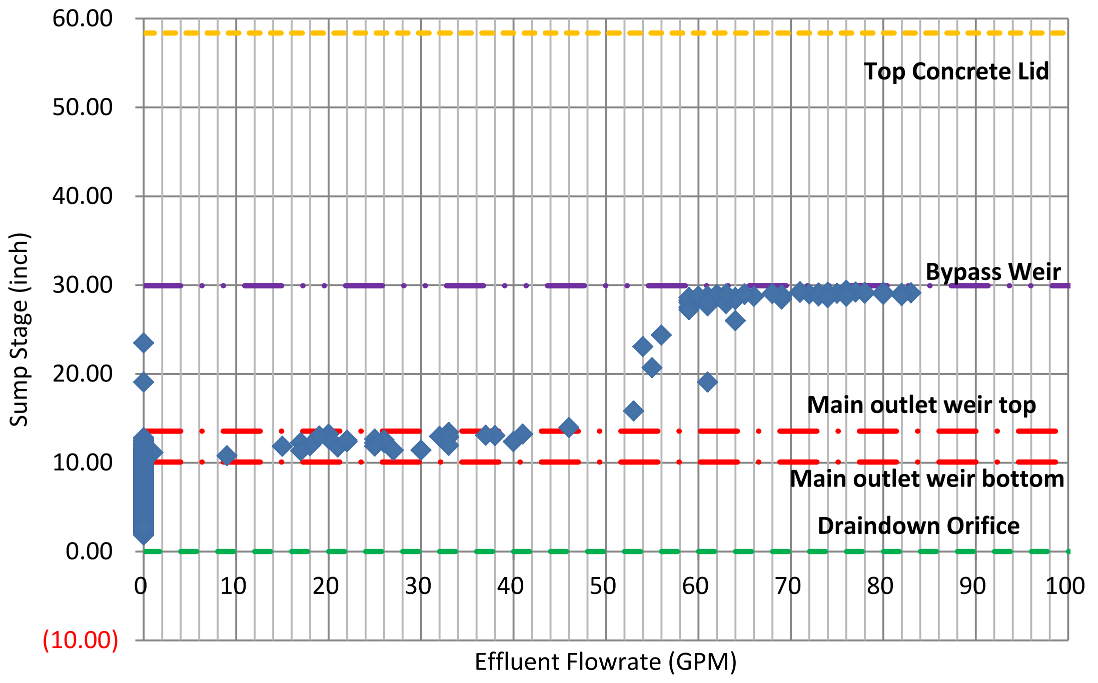


Figure 3-3. July 11, 2012 Rain Event
Sump Drainage

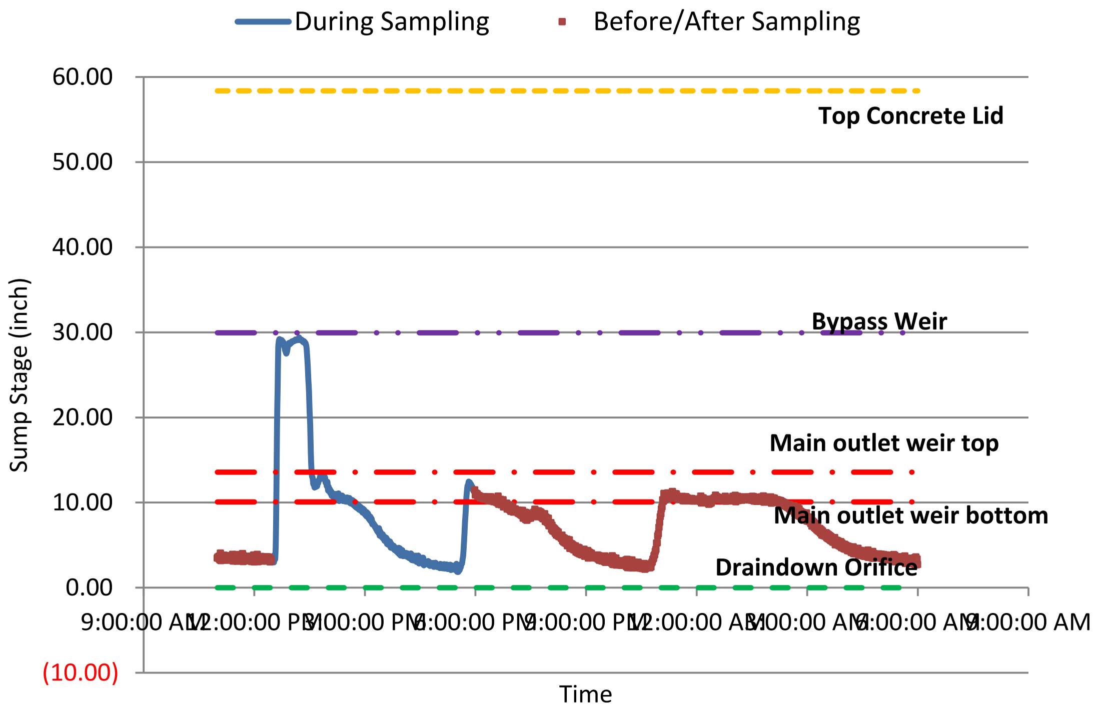
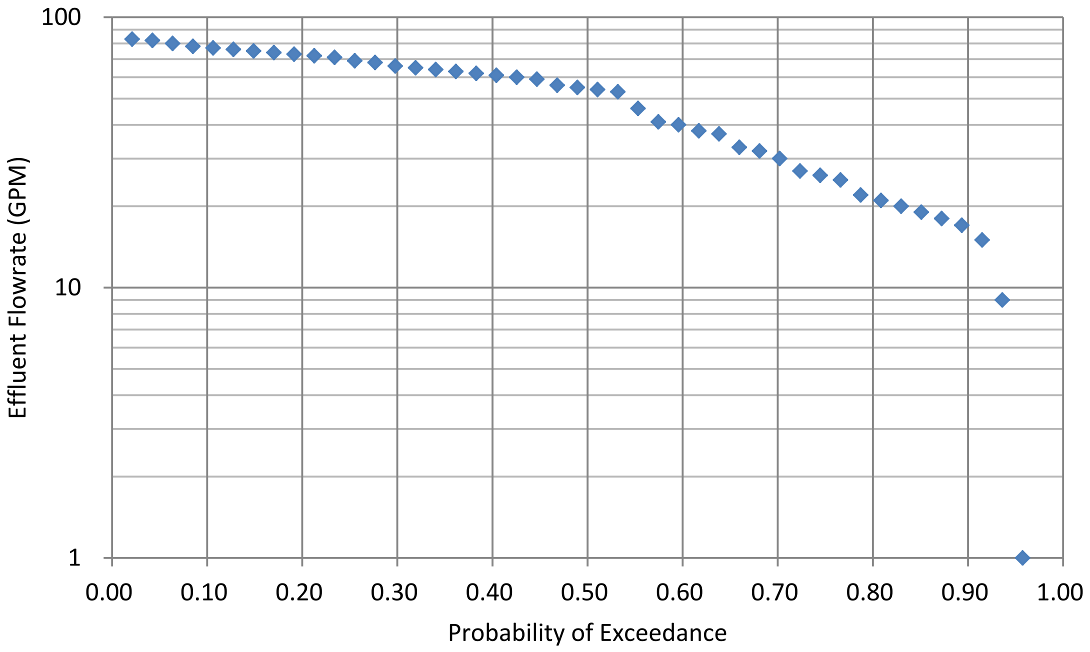
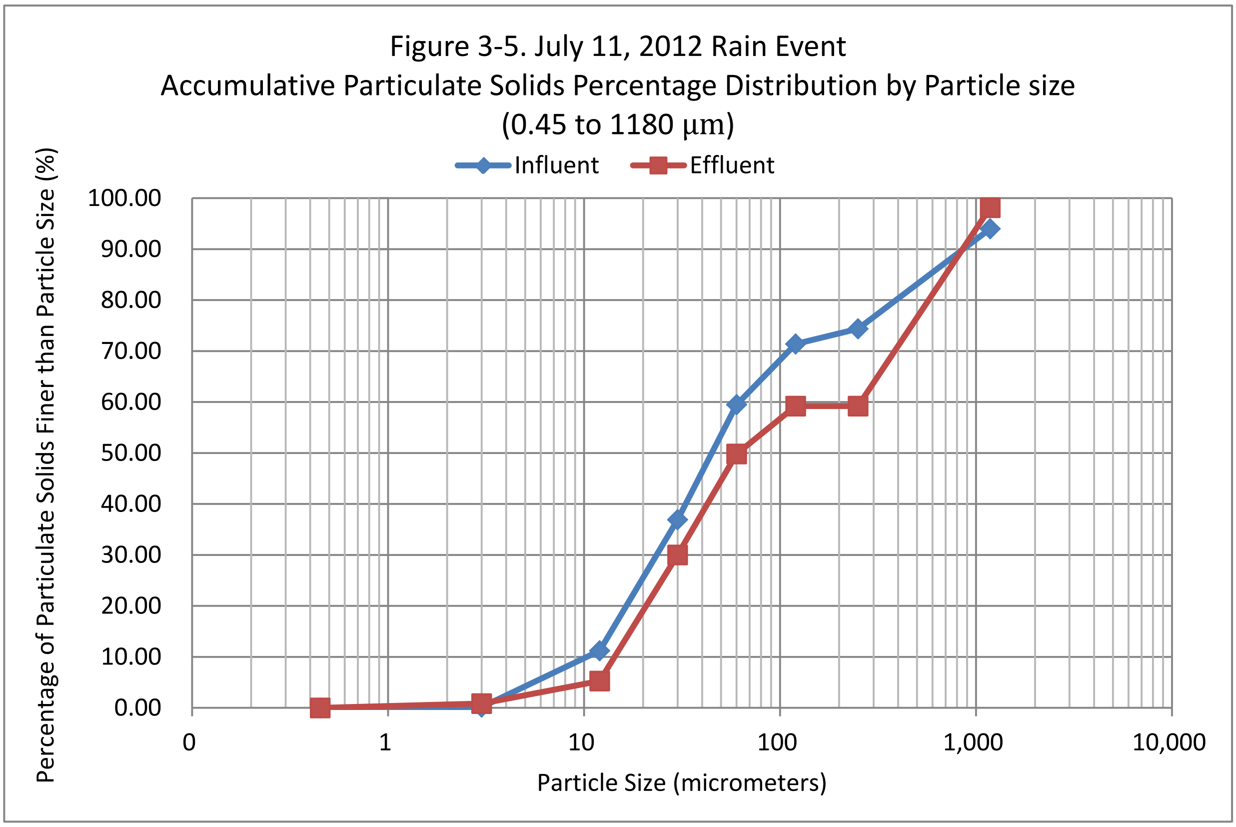
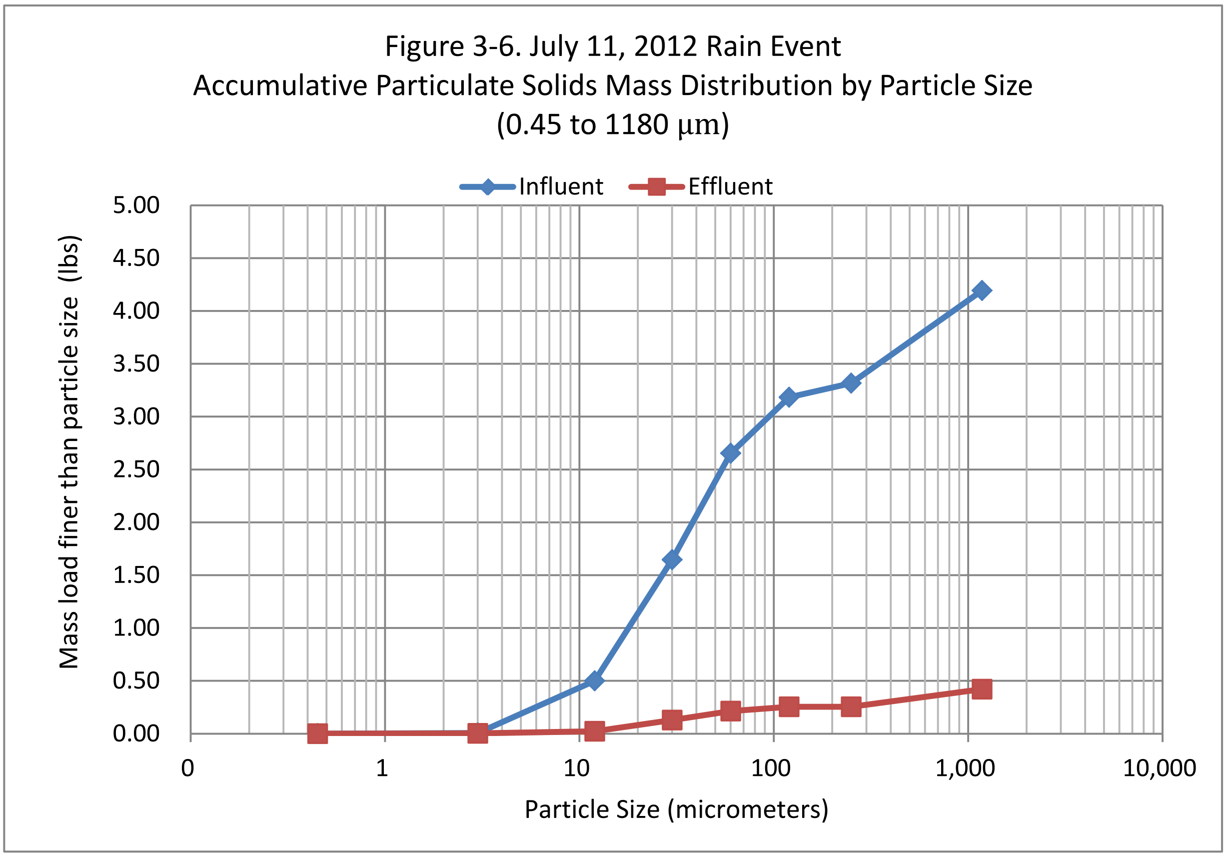


Figure 3-4. July 11, 2012 Rain Event
Flow-Duration Curve







Not shown: The influent sample had 0.27 lbs larger than 1180 µm and the effluent had 0.01 lbs larger than 1180 µm (6.00% and 1.87% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 3-10. July 11, 2012 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.20	0.15	0.15	0.85	0.01	0.00	0.00	46.22
3 to 12	14.48	0.77	11.05	4.41	0.49	0.02	0.47	96.16
12 to 30	33.67	4.30	25.70	24.75	1.15	0.11	1.04	90.75
30 to 60	29.59	3.44	22.58	19.80	1.01	0.08	0.92	91.58
60 to 120	15.59	1.63	11.90	9.40	0.53	0.04	0.49	92.41
120 to 250	3.89	0.00	2.97	0.00	0.13	0.00	0.13	100.00
250 to 1180	25.74	6.76	19.65	38.91	0.88	0.17	0.71	80.97
>1180	7.86	0.33	6.00	1.87	0.27	0.01	0.26	97.00
Total	131	17	100.00	100.00	4.46	0.43	4.03	90.39

Table 3-11. July 11, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.15	0.85	0.01	0.00
<12	11.21	5.26	0.50	0.02
<30	36.90	30.01	1.65	0.13
<60	59.48	49.81	2.65	0.21
<120	71.39	59.22	3.18	0.25
<250	74.36	59.22	3.32	0.25
<1180	94.00	98.13	4.19	0.42
>1180	100.00	100.00	4.46	0.43

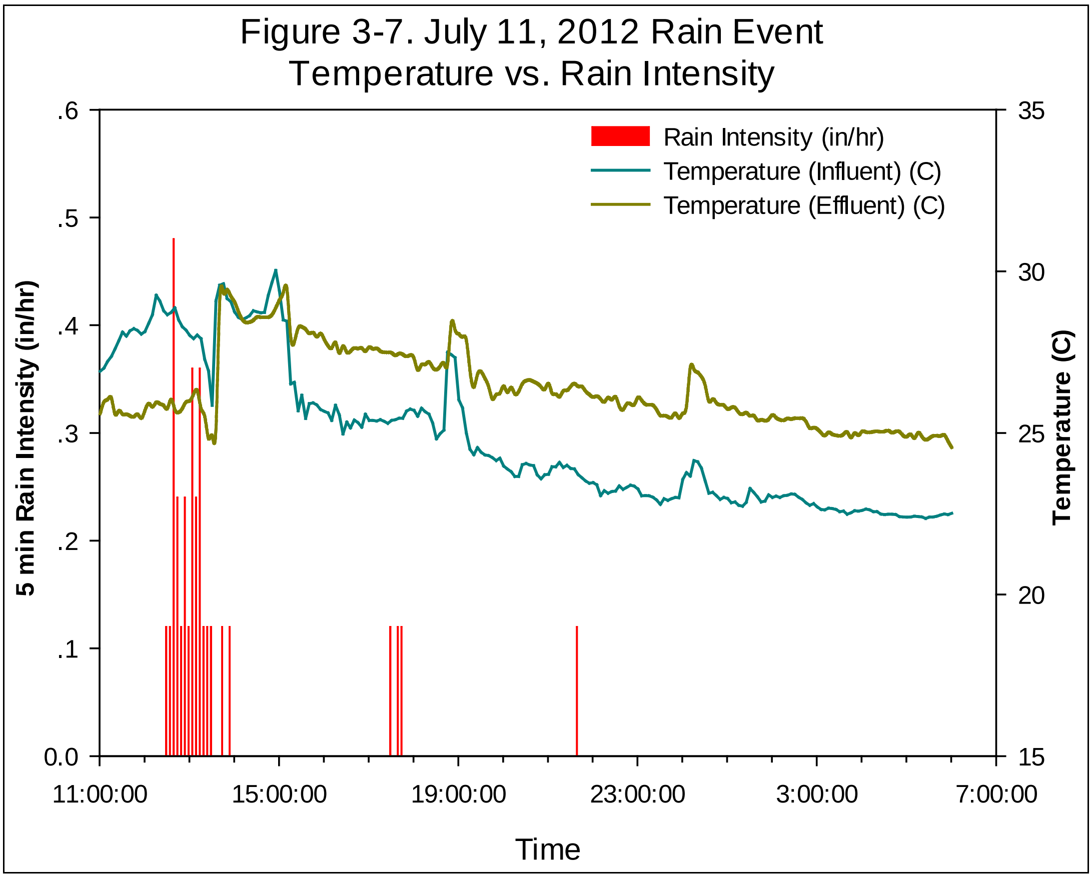


Figure 3-7. July 11, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
.6
.5
.4
.3
.2
.1
0.0
35
30
25
20
15
11:00:00
15:00:00
19:00:00
23:00:00
3:00:00
7:00:00
Time

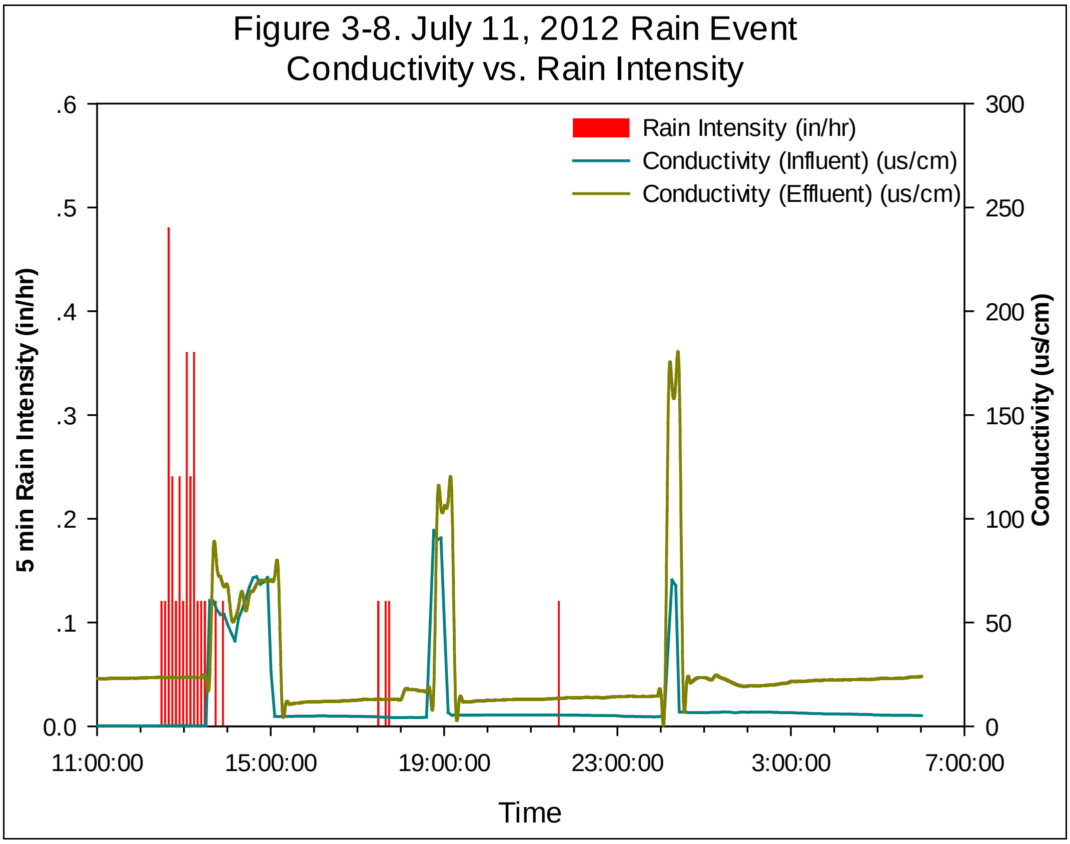


Figure 3-8. July 11, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
.6
.5
.4
.3
.2
.1
0.0
300
250
200
150
100
50
0
11:00:00
15:00:00
19:00:00
23:00:00
3:00:00
7:00:00
Time

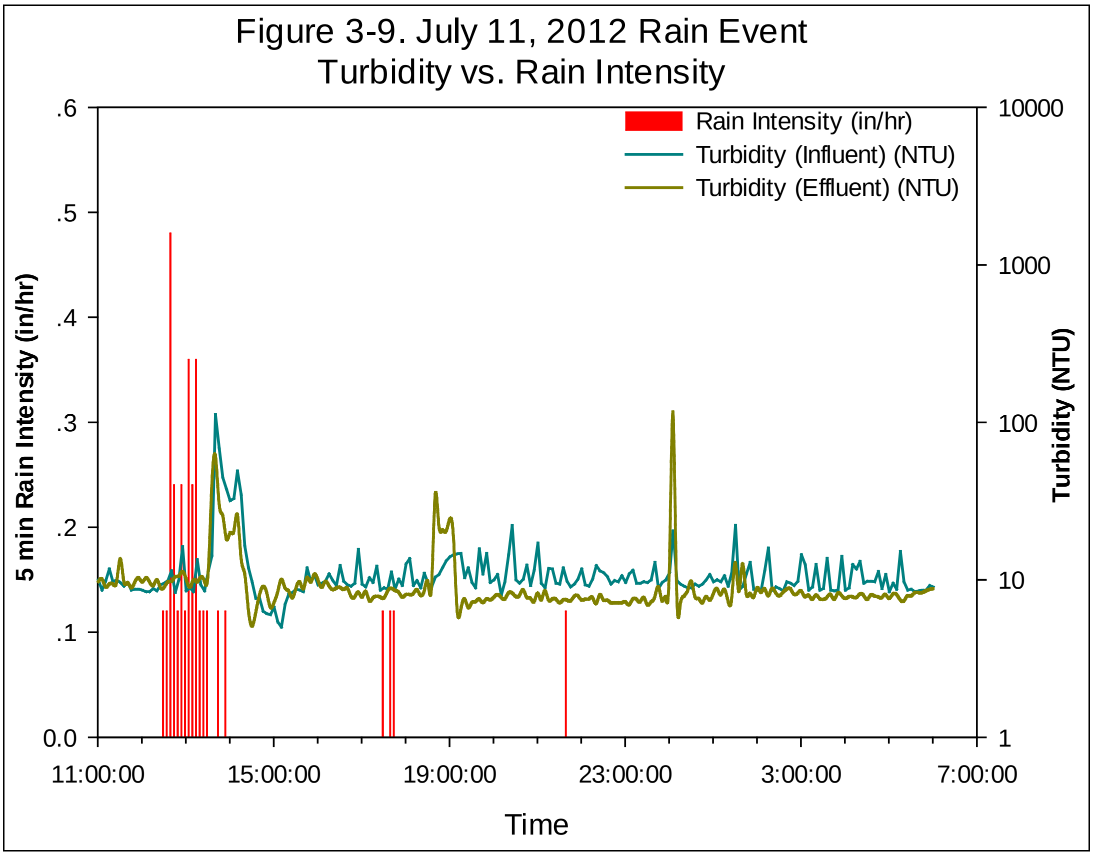
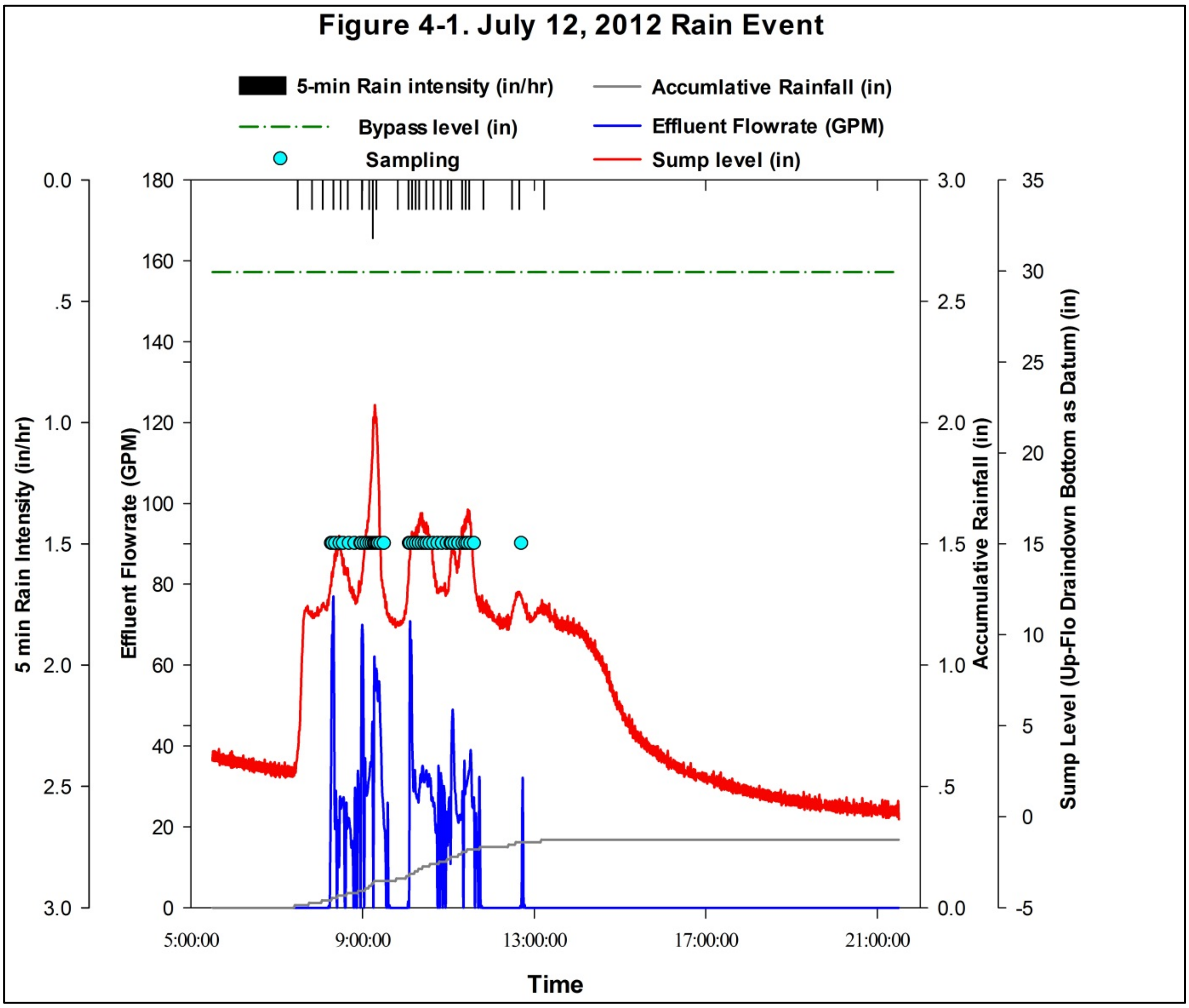


Figure 3-9. July 11, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
0.0
.1
.2
.3
.4
.5
.6
1
10
100
1000
10000
11:00:00
15:00:00
19:00:00
23:00:00
3:00:00
7:00:00
Time

Appendix F.4: July 12, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 4-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.80
Volumetric Runoff Coefficient (Rv)	0.96

Table 4-2. July 12, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/7/12 7:25
Rain Event End Date/Time:			2012/7/12 13:10
Total Precipitation (inch):	≥ 0.1	0.28	
Total Runoff Depth (inch):	NA	0.27	
Total Outflow (gallon):	NA	5062	
Rain Duration (hours):	≥ 1	5.75	
Flow Start Date/Time:			2012/7/12 8:15
Flow End Date/Time:			2012/7/12 12:45
Flow Duration (hours):	NA	4.50	
Average Rain Intensity (in/hr):	NA	0.05	
Average Runoff Rate (gallons/min):	NA	19	
Peak 5-min Rain Intensity (in/hr):	NA	0.24	
Peak Runoff Rate (gallons/min):	NA	77	
Peak to Average Runoff Ratio:	NA	4.11	
Bypassed flow volume (gallon):	NA	0	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	18.93	

Table 4-3. July 12, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	42	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	10.5	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	98.24	

Table 4-4. July 12, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	16	10	37.5	SM 2540D	1 mg/L	Stillbrook Lab
TSS	31	3	90.5	SM 2540D	1 mg/L	UA Lab
SSC	39	8	79.5	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	34	4	89.0	ASTM D3977-97B	1 mg/L	UA Lab
TDS	44	50	-13.5	EPA 160.2	1 mg/L	UA Lab
VSS	7	2	76.9	SM 2540E	1 mg/L	UA Lab
Total N as N	1.2	1.1	8.3	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.10	0.11	-10.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.86	0.71	17.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.49	0.46	6.1	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.011	0.006	45.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	17329	7766	55.2	IDEXX Method	<1	UA Lab
E. Coli	48	40	17.2	IDEXX Method	<1	UA Lab
Enterococci	2831	51	98.2	IDEXX Method	<1	UA Lab
pH	6.61	6.84	-3.5	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	7.43	4.61	37.9	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	53.4	64.2	-20.2	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	28.1	26.9	4.3	SM 212/ EPA 170.1	5 °C	UA Lab

Table 4-5. July 12, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	39	NA*	NA*	8	NA*	NA*	79.5	NA*	NA*
UA Lab	33	2	34	4	0	4	88.7	93.5	89.0

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 4-6. July 12, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	12599	5376	17	4	1.4	0.8

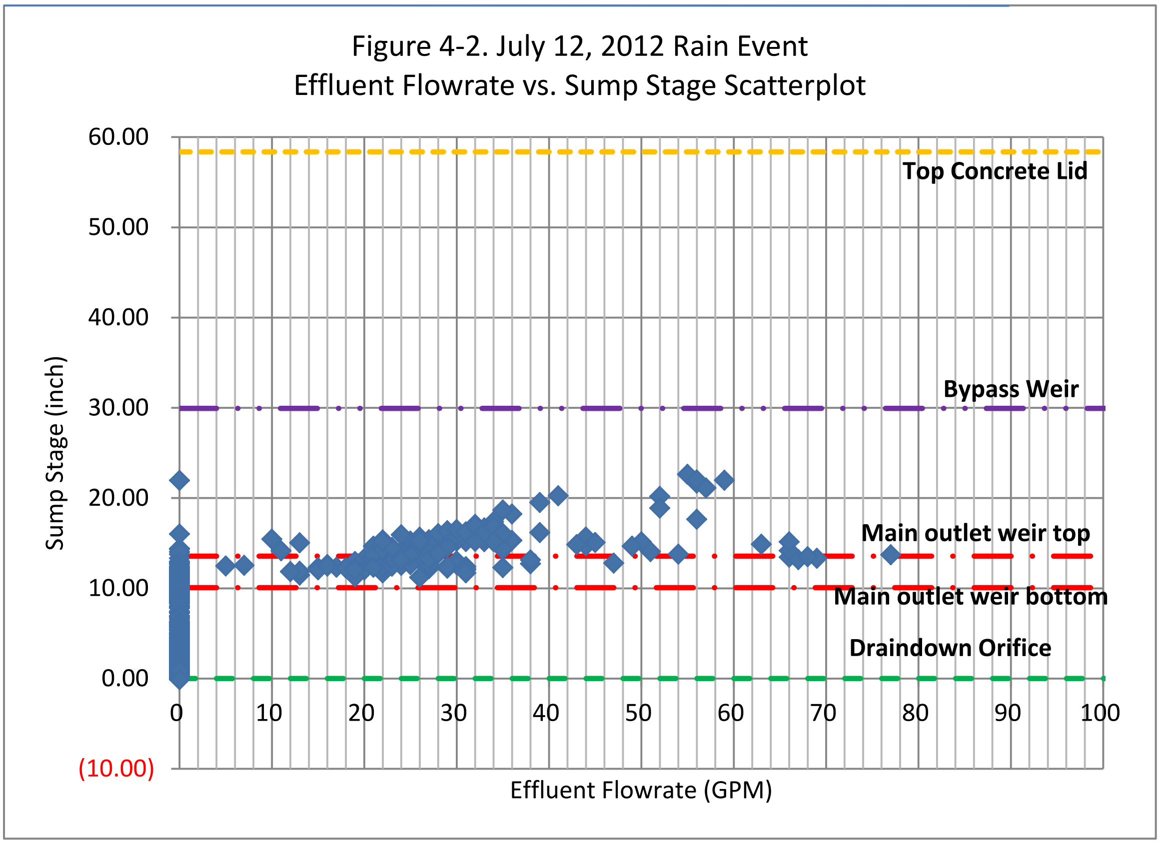
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 4-7. July 12, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	30	33	31	3	3	3
Millipore Membrane Filter, 0.45µm	32	32	32	3	1	2

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 4-8. July 12, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (5X)	Dilution 2 (10X)	Average	Dilution 1 (5X)	Dilution 2 (10X)	Average
Total Coliform	> 12,098	17329	17329	8665	6867	7766
E. Coli	55	41	48	49	31	40
Enterococci	2586	3076	2831	26	75	51

Table 4-9. July 12, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	7	6	7	2	1	2



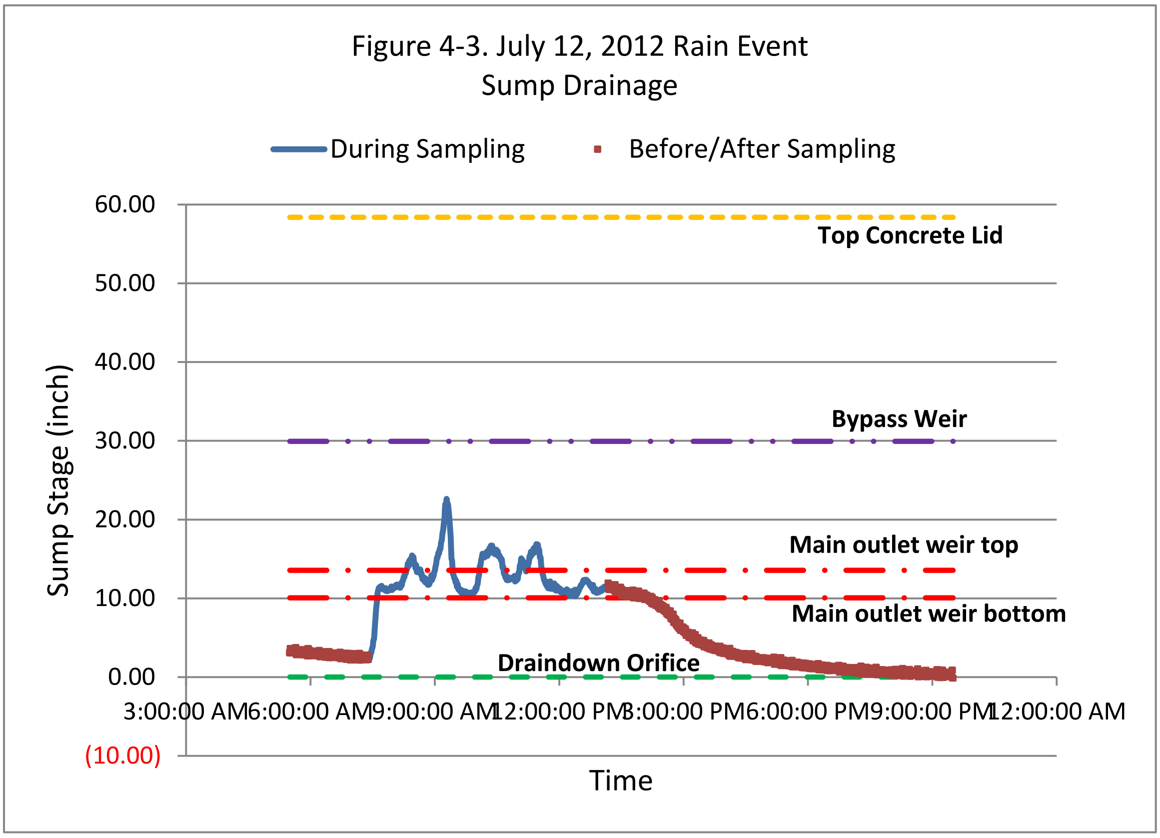


Figure 4-3. July 12, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
3:00:00 AM 6:00:00 AM 9:00:00 AM 12:00:00 PM 3:00:00 PM 6:00:00 PM 9:00:00 PM 12:00:00 AM
Time

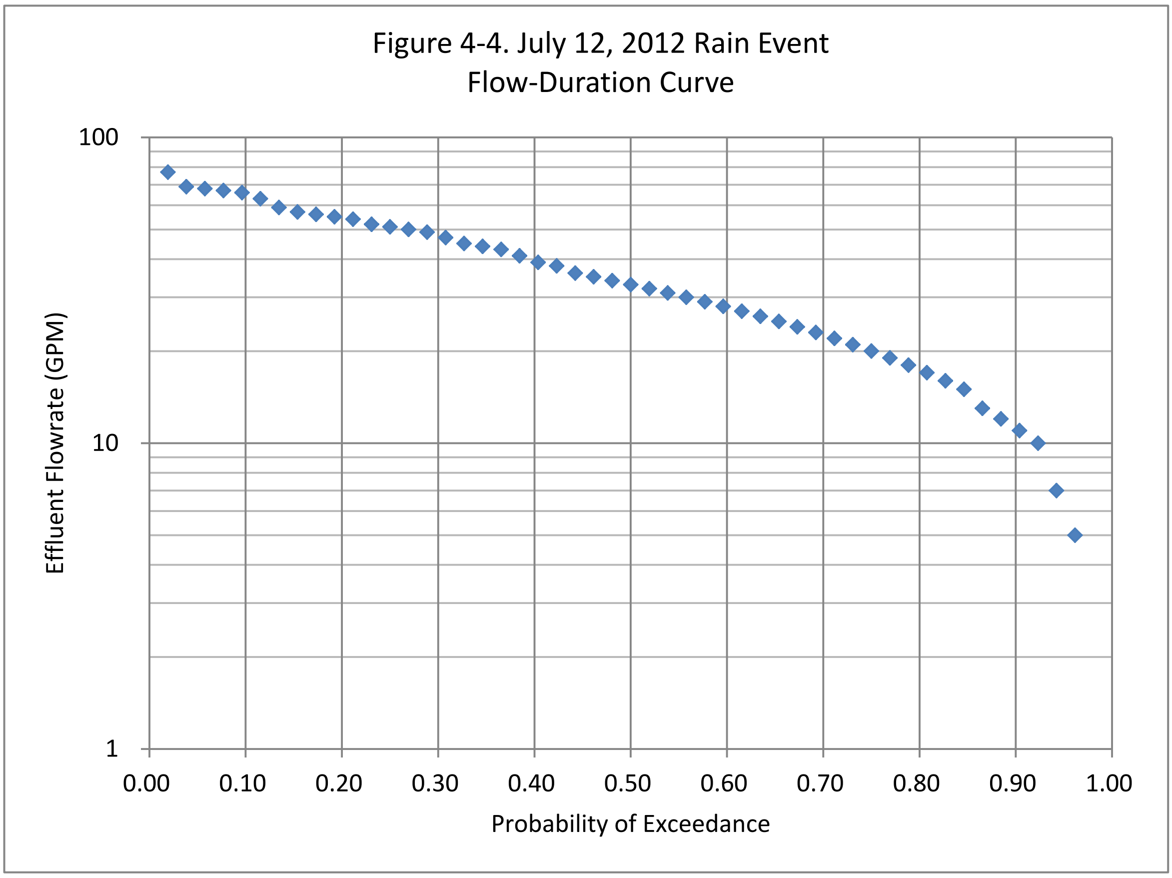
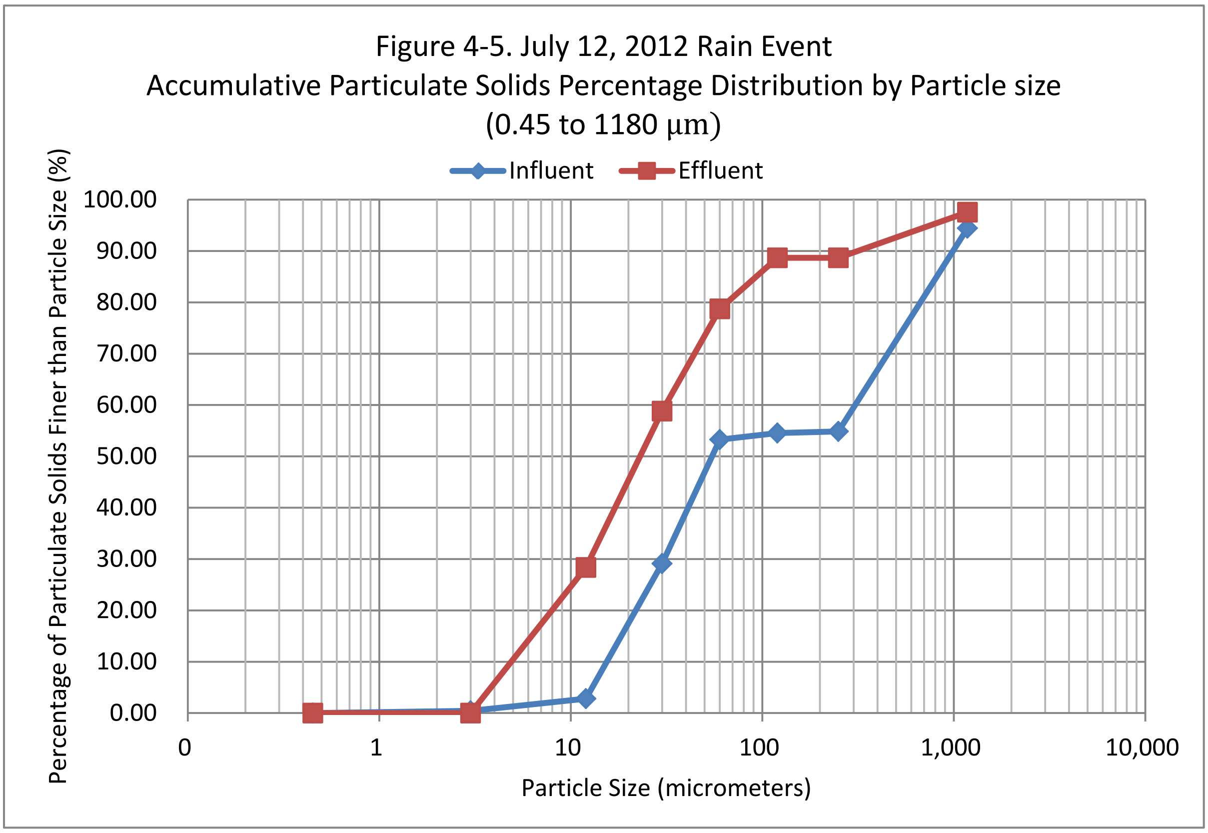
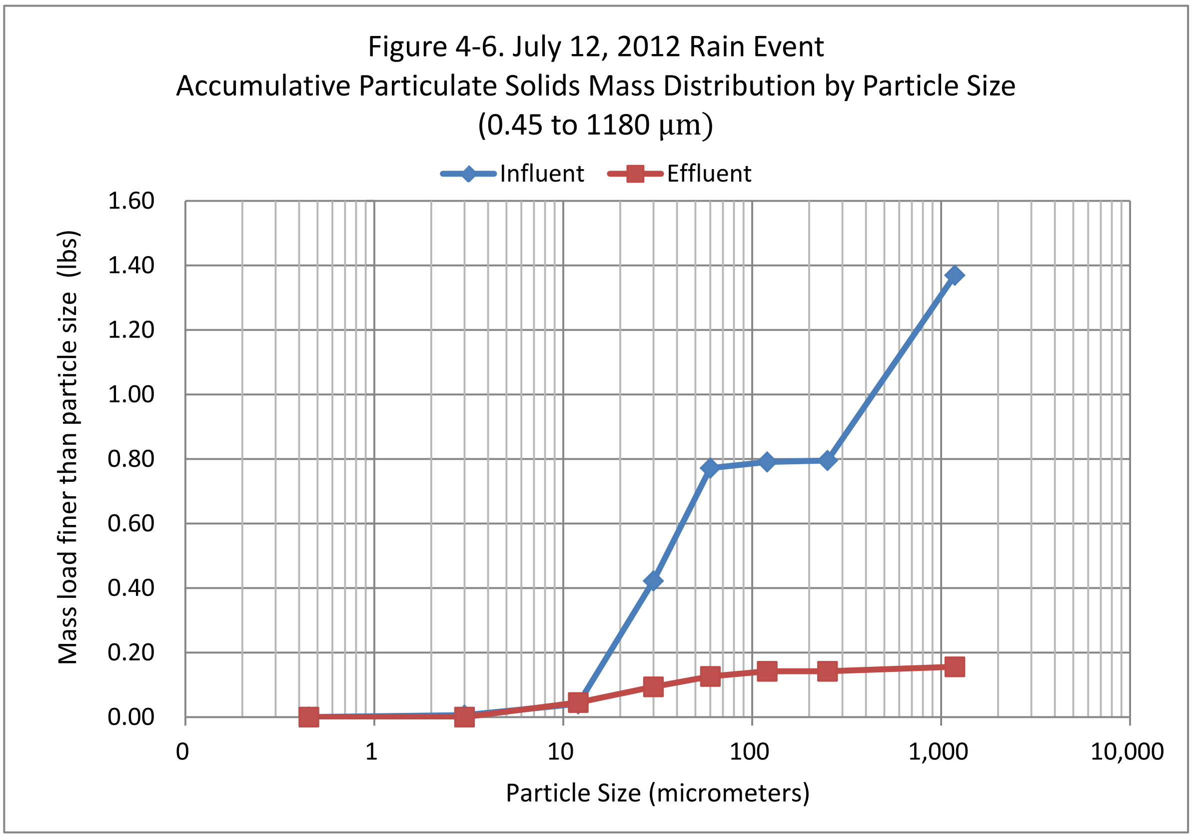


Figure 4-4. July 12, 2012 Rain Event
Flow-Duration Curve
100
10
1
Effluent Flowrate (GPM)
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Probability of Exceedance





Not shown: The influent sample had 0.08 lbs larger than 1180 µm and the effluent had <0.01 lbs larger than 1180 µm (5.55% and 2.45% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 4-10. July 12, 2012 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.14	0.00	0.44	0.00	0.01	0.00	0.01	100.00
3 to 12	0.75	1.32	2.37	28.37	0.03	0.05	-0.01	-32.06
12 to 30	8.33	1.42	26.29	30.43	0.38	0.05	0.33	87.22
30 to 60	7.65	0.93	24.15	19.92	0.35	0.03	0.32	90.89
60 to 120	0.41	0.46	1.29	9.96	0.02	0.02	0.00	14.85
120 to 250	0.09	0.00	0.30	0.00	0.00	0.00	0.00	100.00
250 to 1180	12.55	0.41	39.61	8.87	0.57	0.01	0.56	97.53
>1180	1.76	0.11	5.55	2.45	0.08	0.00	0.08	95.12
Total	32	5	100.00	100.00	1.45	0.16	1.29	88.95

Table 4-11. July 12, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.44	0.00	0.01	0.00
<12	2.81	28.37	0.04	0.05
<30	29.10	58.80	0.42	0.09
<60	53.26	78.73	0.77	0.13
<120	54.55	88.68	0.79	0.14
<250	54.84	88.68	0.80	0.14
<1180	94.45	97.55	1.37	0.16
>1180	100.00	100.00	1.45	0.16

Figure 4-7. July 12, 2012 Rain Event
Temperature vs. Rain Intensity

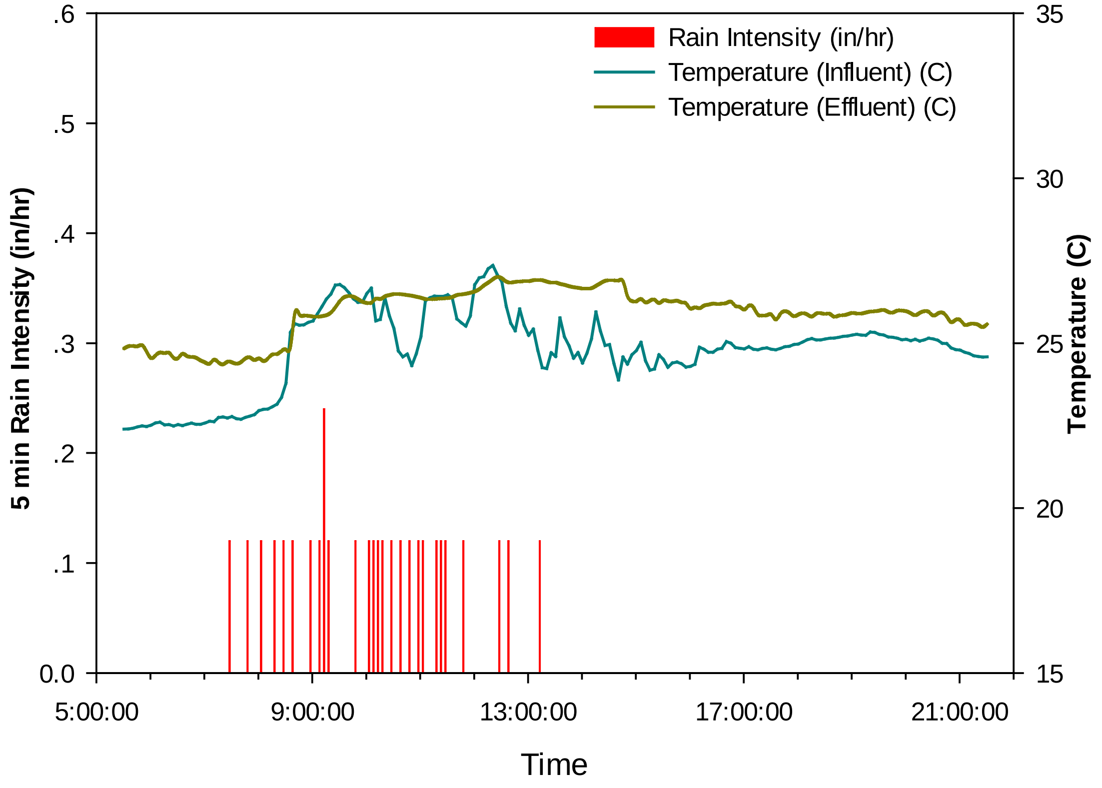
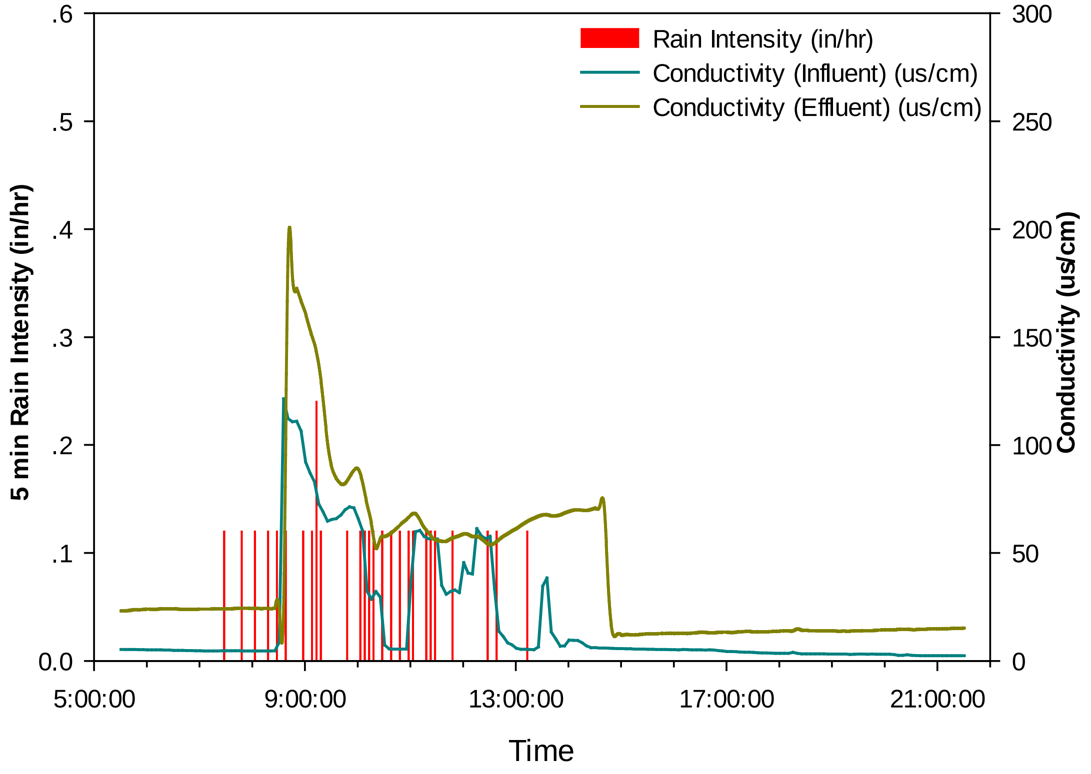


Figure 4-8. July 12, 2012 Rain Event
Conductivity vs. Rain Intensity



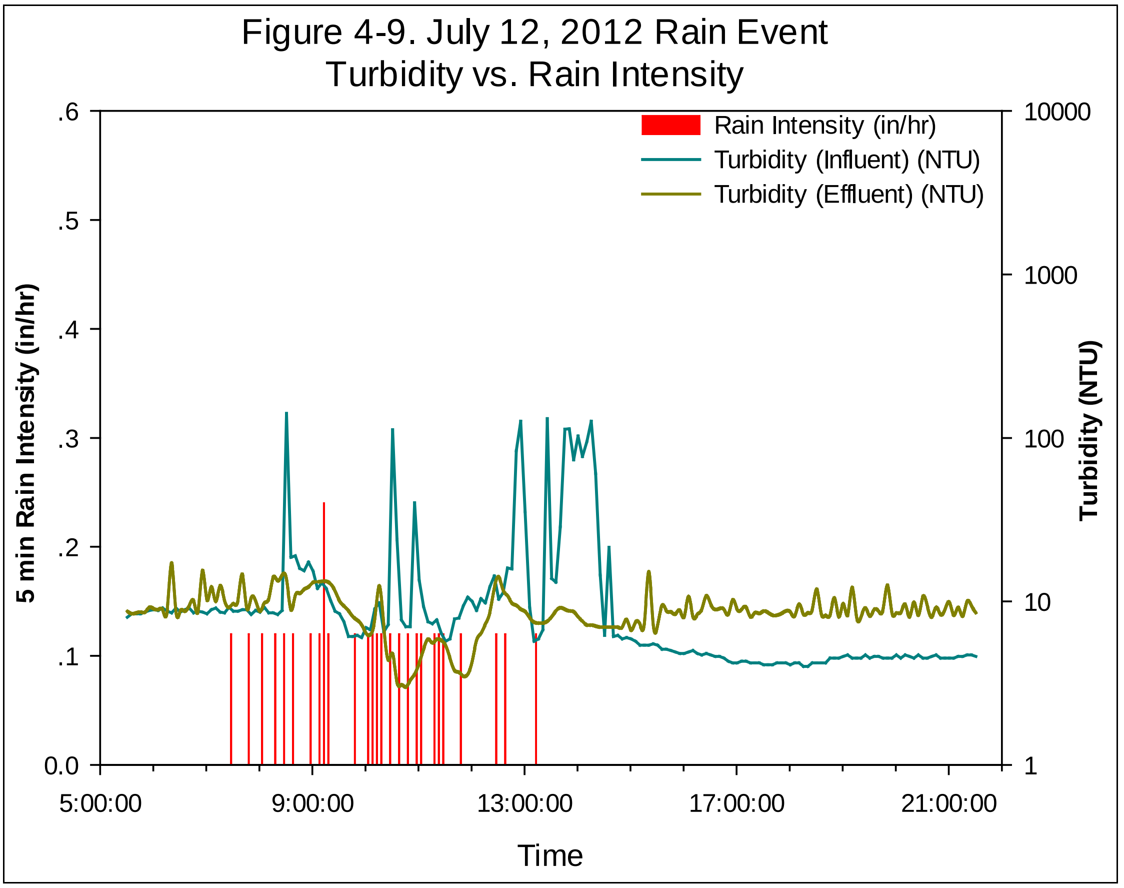
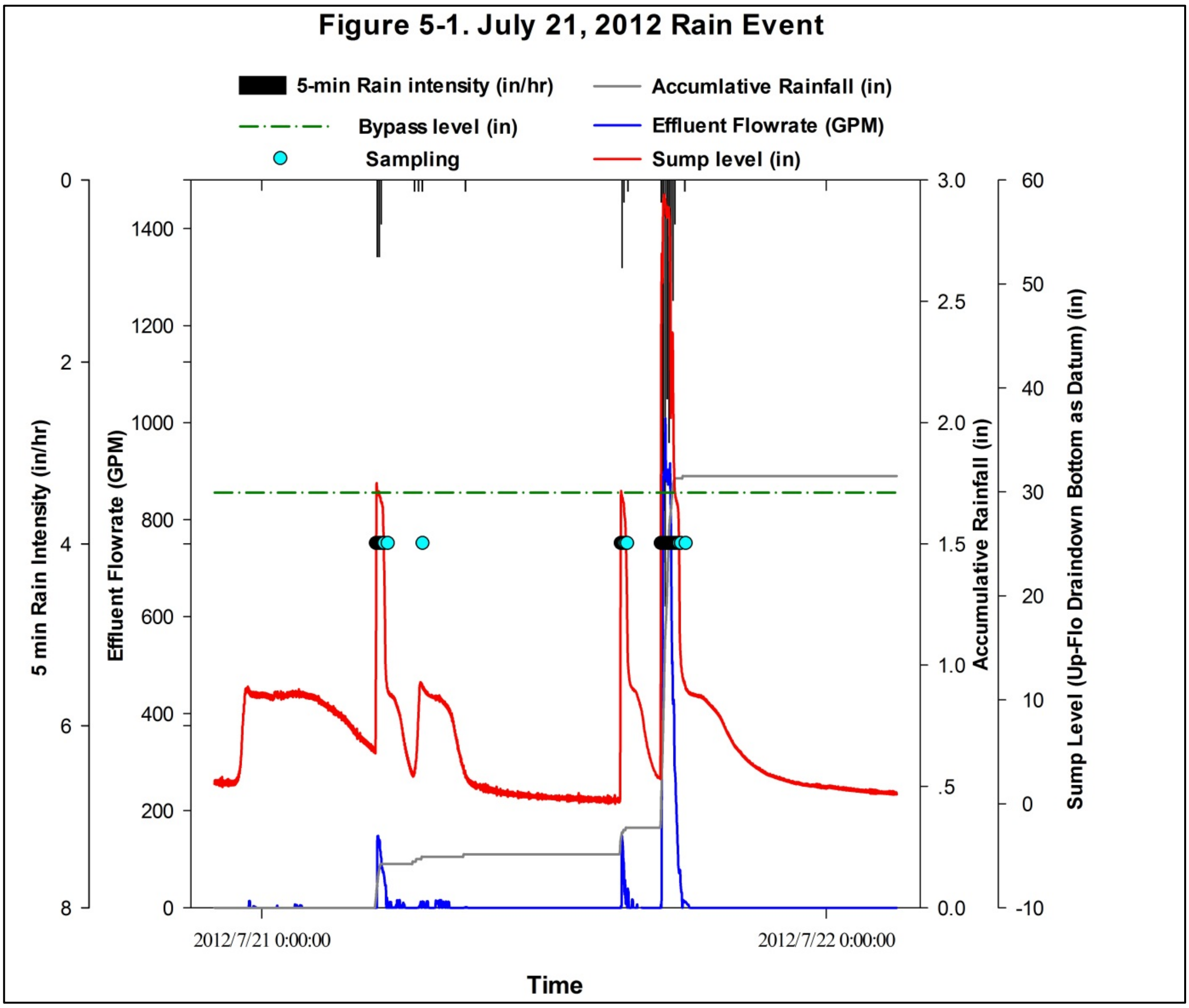


Figure 4-9. July 12, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
.6
.5
.4
.3
.2
.1
0.0
10000
1000
100
10
1
5:00:00
9:00:00
13:00:00
17:00:00
21:00:00
Time



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 5-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.54
Volumetric Runoff Coefficient (Rv)	0.50

Table 5-2. July 21, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/7/21 4:50
Rain Event End Date/Time:			2012/7/21 17:54
Total Precipitation (inch):	≥ 0.1	1.78	
Total Runoff Depth (inch):	NA	0.90	
Total Outflow (gallon):	NA	30906	
Rain Duration (hours):	≥ 1	13.07	
Flow Start Date/Time:			2012/7/20 23:28
Flow End Date/Time:			2012/7/21 18:11
Flow Duration (hours):	NA	18.72	
Average Rain Intensity (in/hr):	NA	0.14	
Average Runoff Rate (gallons/min):	NA	28	
Peak 5-min Rain Intensity (in/hr):	NA	4.68	
Peak Runoff Rate (gallons/min):	NA	1009	
Peak to Average Runoff Ratio:	NA	36.66	
Bypassed flow volume (gallon):	NA	14933	
Percentage of Bypassed Flow (%):	NA	48.32	
Inter-Event Time since prior rain (hours)	≥ 6.0	64.48	

Table 5-3. July 21, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	75	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	18.8	1) The 15 Liter sample bottles were changed to new ones during event; 2) The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Sample Coverage of total storm flow (%)	75.00	99.54	

Table 5-4. July 21, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	105	36	65.7	SM 2540D	1 mg/L	Stillbrook Lab
TSS	571	41	92.7	SM 2540D	1 mg/L	UA Lab
SSC	1850	41	97.8	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	2297	40	98.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	56	39	29.5	EPA 160.2	1 mg/L	UA Lab
VSS	124	15	87.5	SM 2540E	1 mg/L	UA Lab
Total N as N	1.6	1.0	37.5	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.8	0.4	50.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.22	0.20	9.1	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.67	0.74	-10.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.49	0.49	0.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.007	BDL	> 28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.009	BDL	> 44.4	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	0.006	BDL	> 16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.011	BDL	> 54.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.098	0.032	67.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.006	0.006	0.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	27629	665	97.6	IDEXX Method	<1	UA Lab
Enterococci	23297	372	98.4	IDEXX Method	<1	UA Lab
pH	6.52	6.65	-2.0	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	34.25	8.06	76.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	37.3	36.4	2.4	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	27.7	27.2	1.8	SM 212/ EPA 170.1	5 °C	UA Lab

Table 5-5. July 21, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	1850	NA*	NA*	41	NA*	NA*	97.8	NA*	NA*
UA Lab	1352	944	2297	39	2	40	97.1	99.8	98.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 5-6. July 21, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	53630	12099	195	31	3.6	2.6

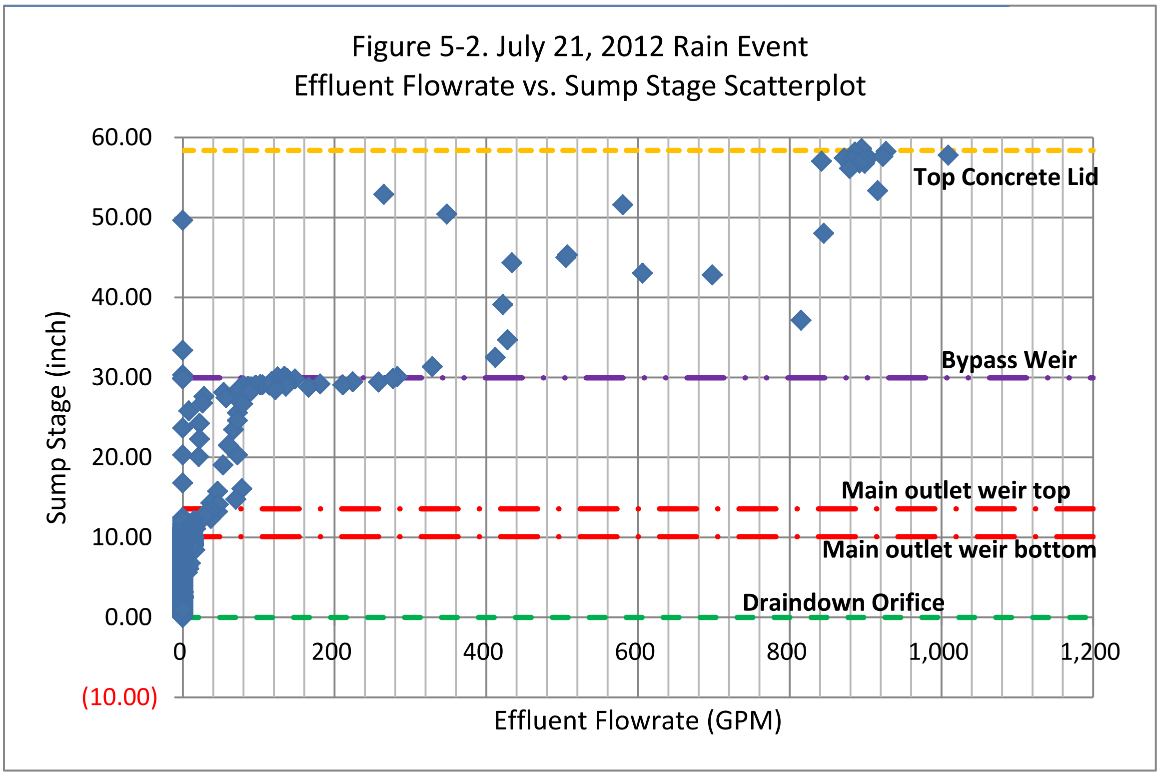
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 5-7. July 21, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	566	576	571	42	41	41
Millipore Membrane Filter, 0.45µm	474	484	479	40	43	41

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 5-8. July 21, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	24,196	31,062	27,629	602	728	665
Enterococci	24,196	22,398	23,297	214	530	372

Table 5-9. July 21, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH^{TM} Glass Microfiber Filters, 1.5µm	138	110	124	14	17	15



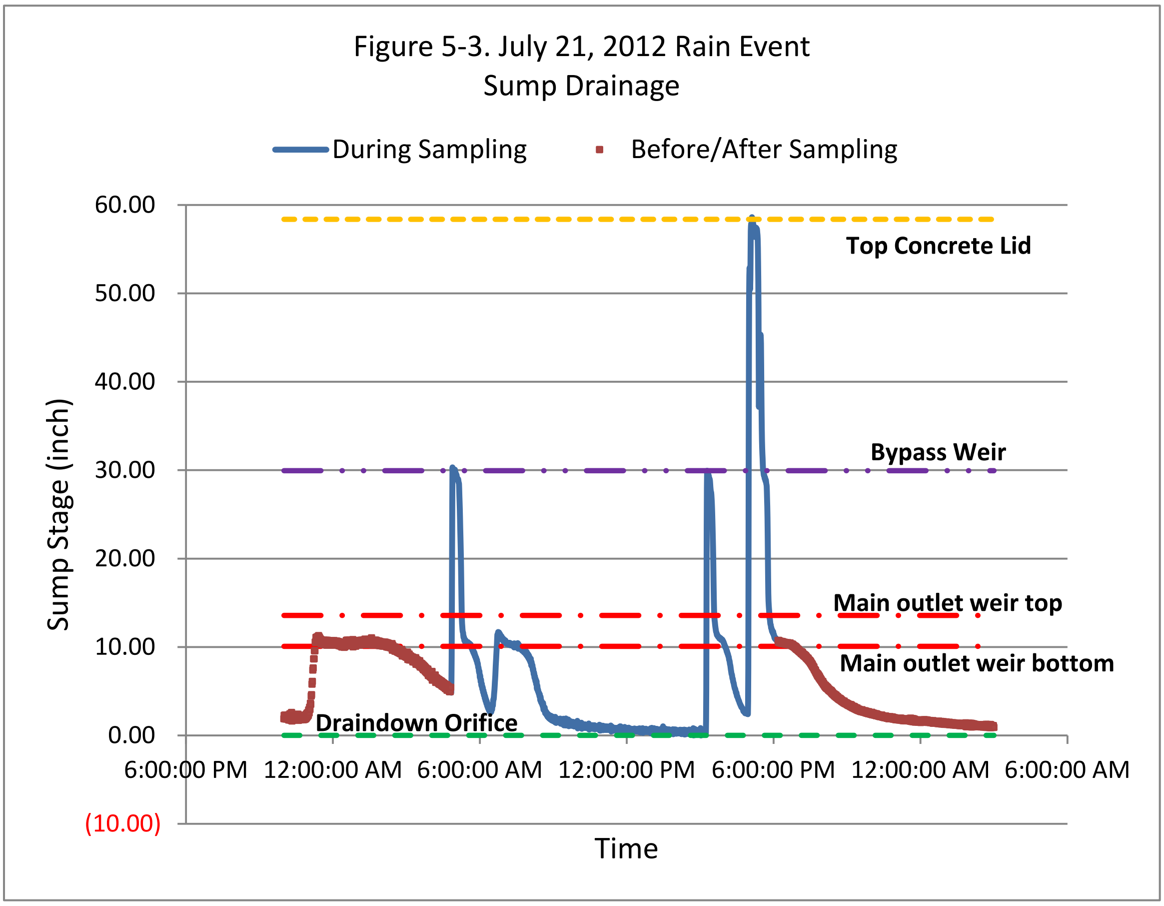


Figure 5-3. July 21, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
Time

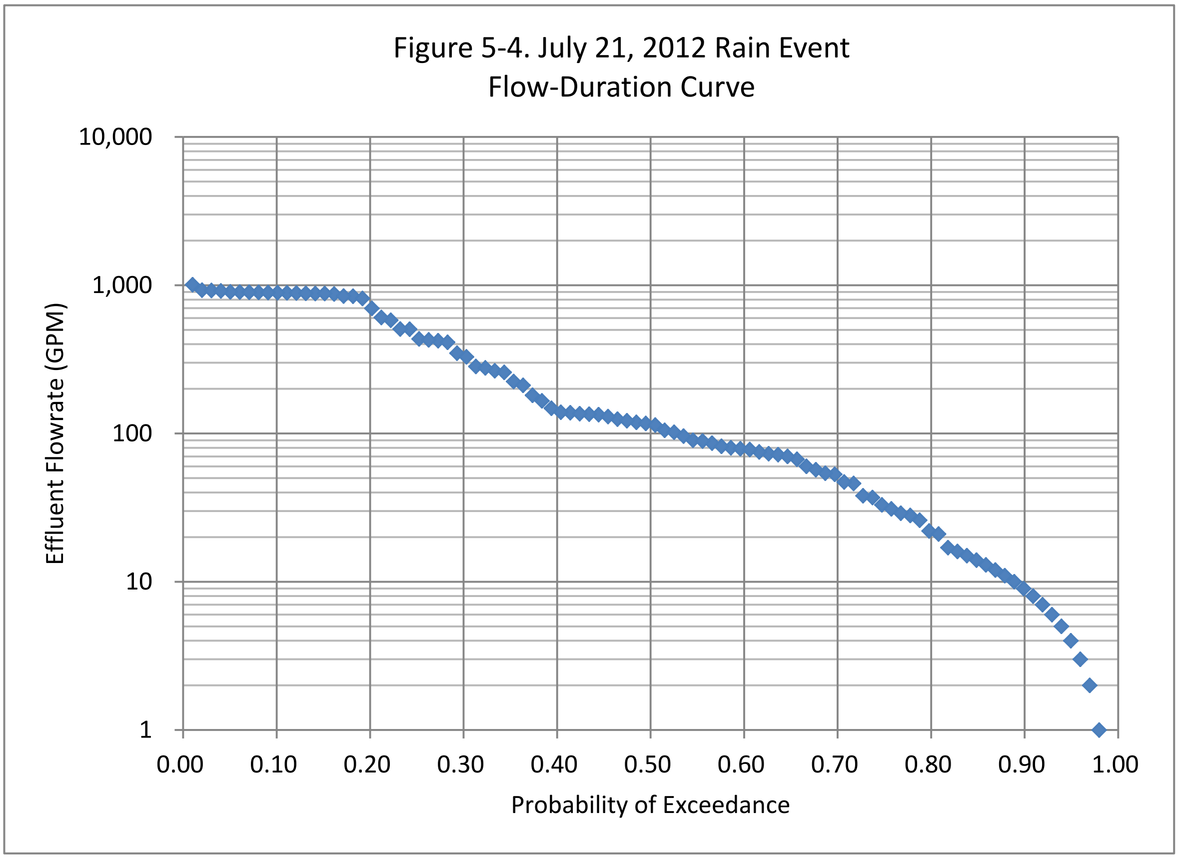
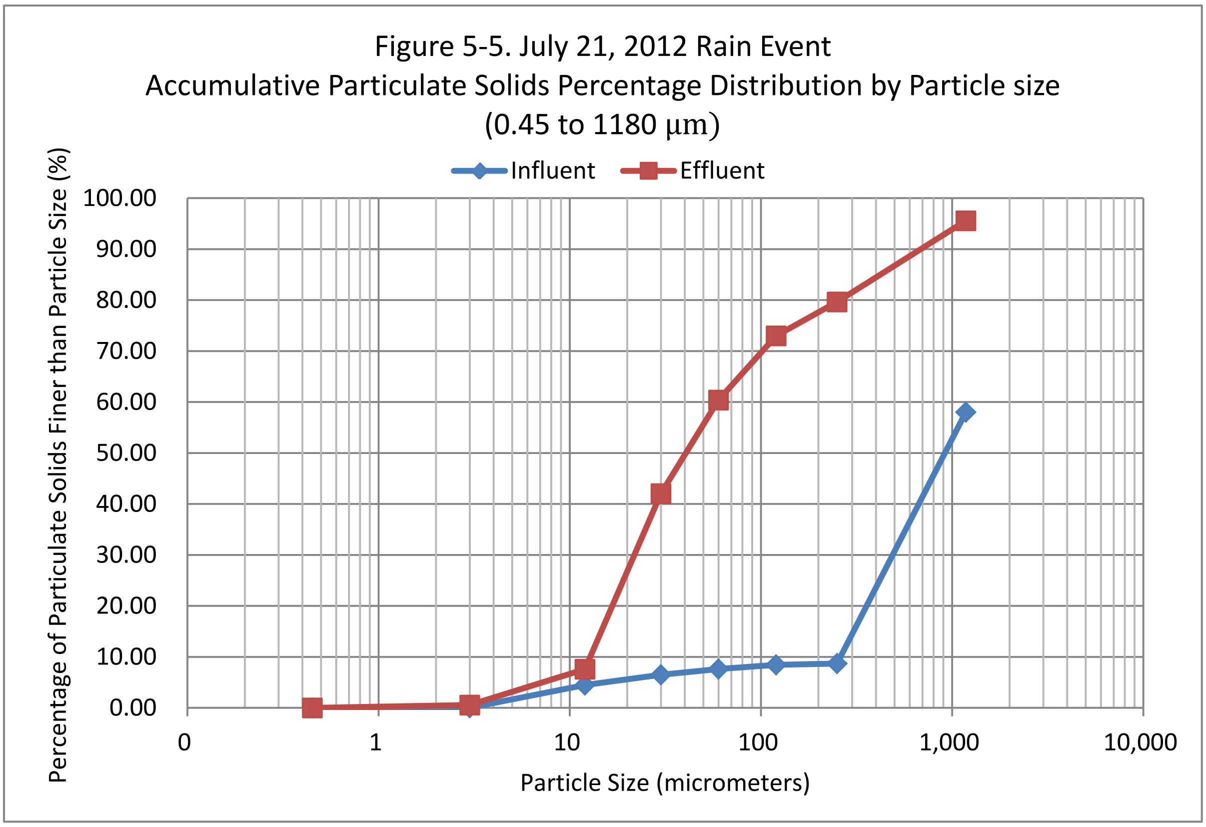
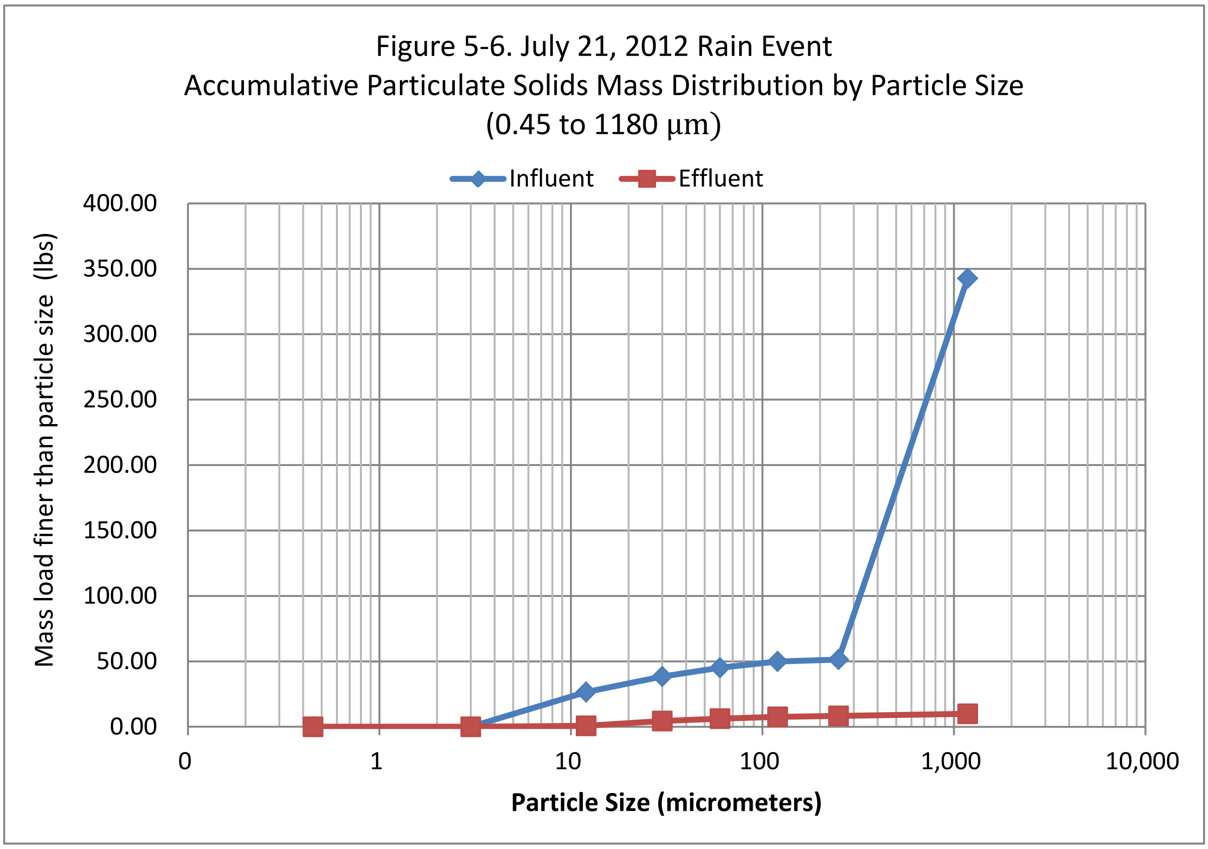


Figure 5-4. July 21, 2012 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
10,000
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 248.02 lbs larger than 1180 µm and the effluent had 0.46 lbs larger than 1180 µm (41.99% and 4.44% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 5-10. July 21, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.21	0.21	0.01	0.54	0.05	0.06	0.00	-2.40
3 to 12	100.69	2.77	4.48	7.06	26.44	0.73	25.71	97.23
12 to 30	45.21	13.52	2.01	34.44	11.87	3.57	8.30	69.89
30 to 60	25.58	7.21	1.14	18.36	6.72	1.91	4.81	71.63
60 to 120	18.24	4.94	0.81	12.59	4.79	1.31	3.49	72.74
120 to 250	5.50	2.61	0.24	6.65	1.44	0.69	0.75	52.22
250 to 1180	1109.38	6.25	49.32	15.93	291.37	1.65	289.71	99.43
>1180	944.33	1.74	41.99	4.44	248.02	0.46	247.56	99.81
Total	2249	39	100.00	100.00	590.71	10.38	580.33	98.24

Table 5-11. July 21, 2012 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.01	0.54	0.05	0.06
<12	4.49	7.60	26.50	0.79
<30	6.50	42.04	38.37	4.36
<60	7.63	60.40	45.09	6.27
<120	8.44	72.99	49.88	7.57
<250	8.69	79.63	51.32	8.26
<1180	58.01	95.56	342.69	9.92
>1180	100.00	100.00	590.71	10.38

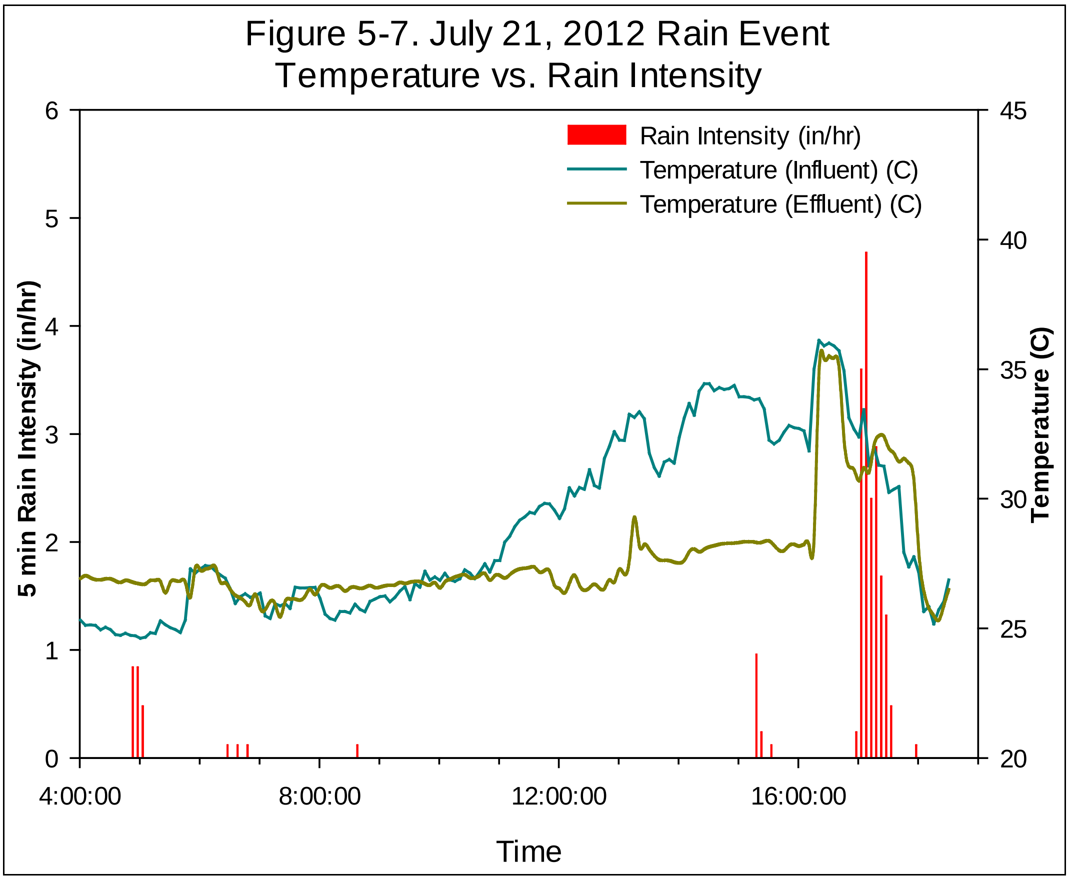


Figure 5-7. July 21, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
0
1
2
3
4
5
6
20
25
30
35
40
45
4:00:00
8:00:00
12:00:00
16:00:00
Time

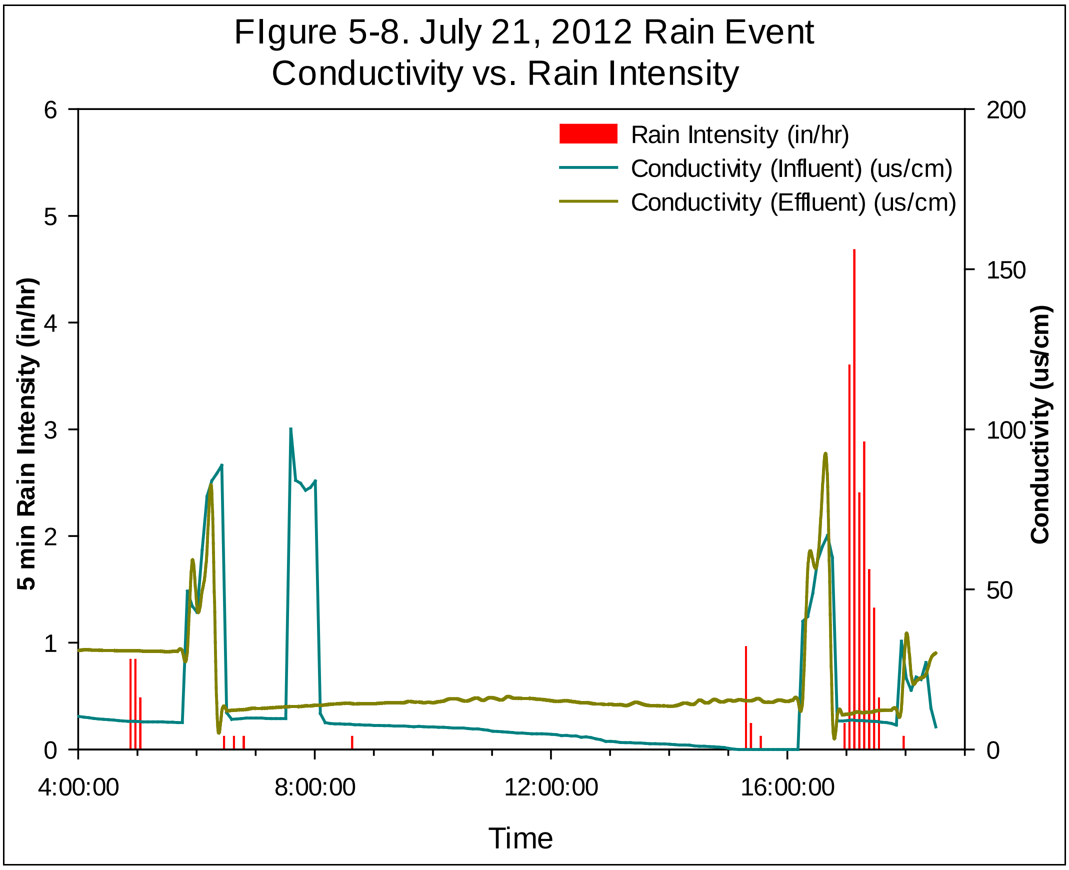


FIgure 5-8. July 21, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
0
1
2
3
4
5
6
0
50
100
150
200
4:00:00
8:00:00
12:00:00
16:00:00
Time

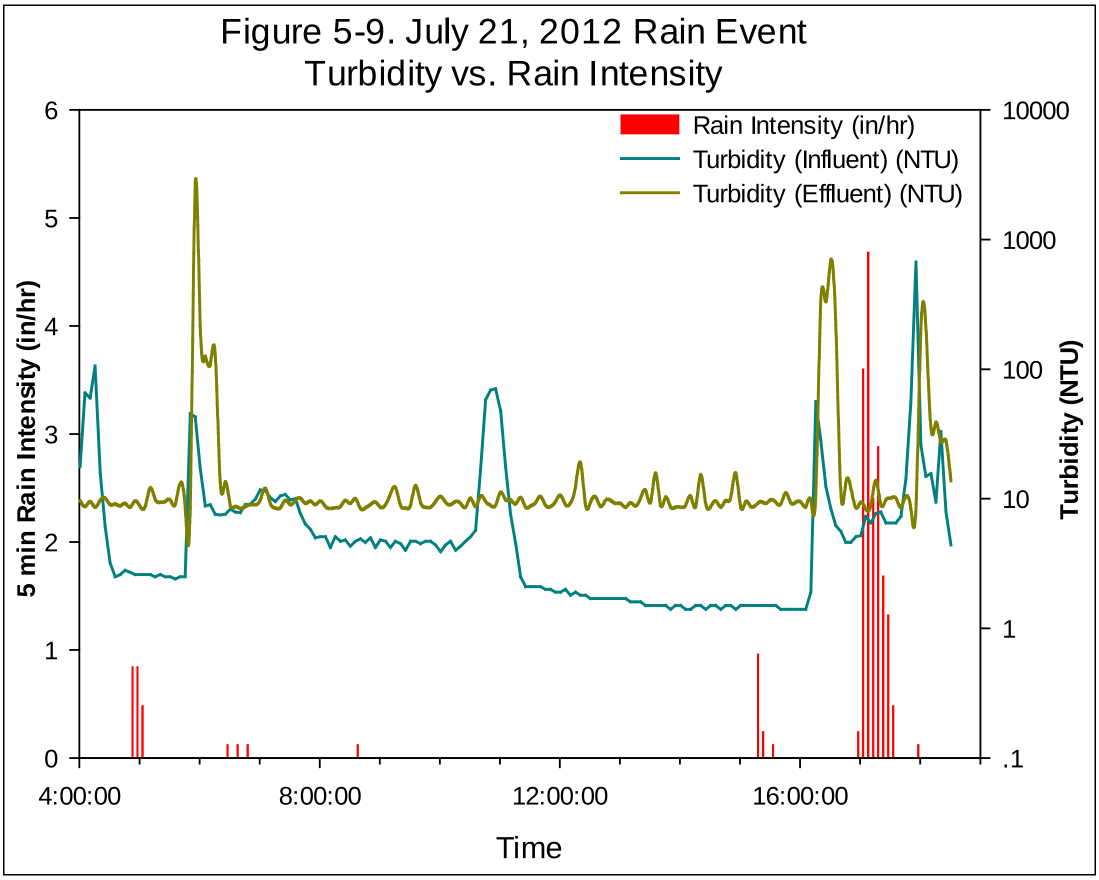
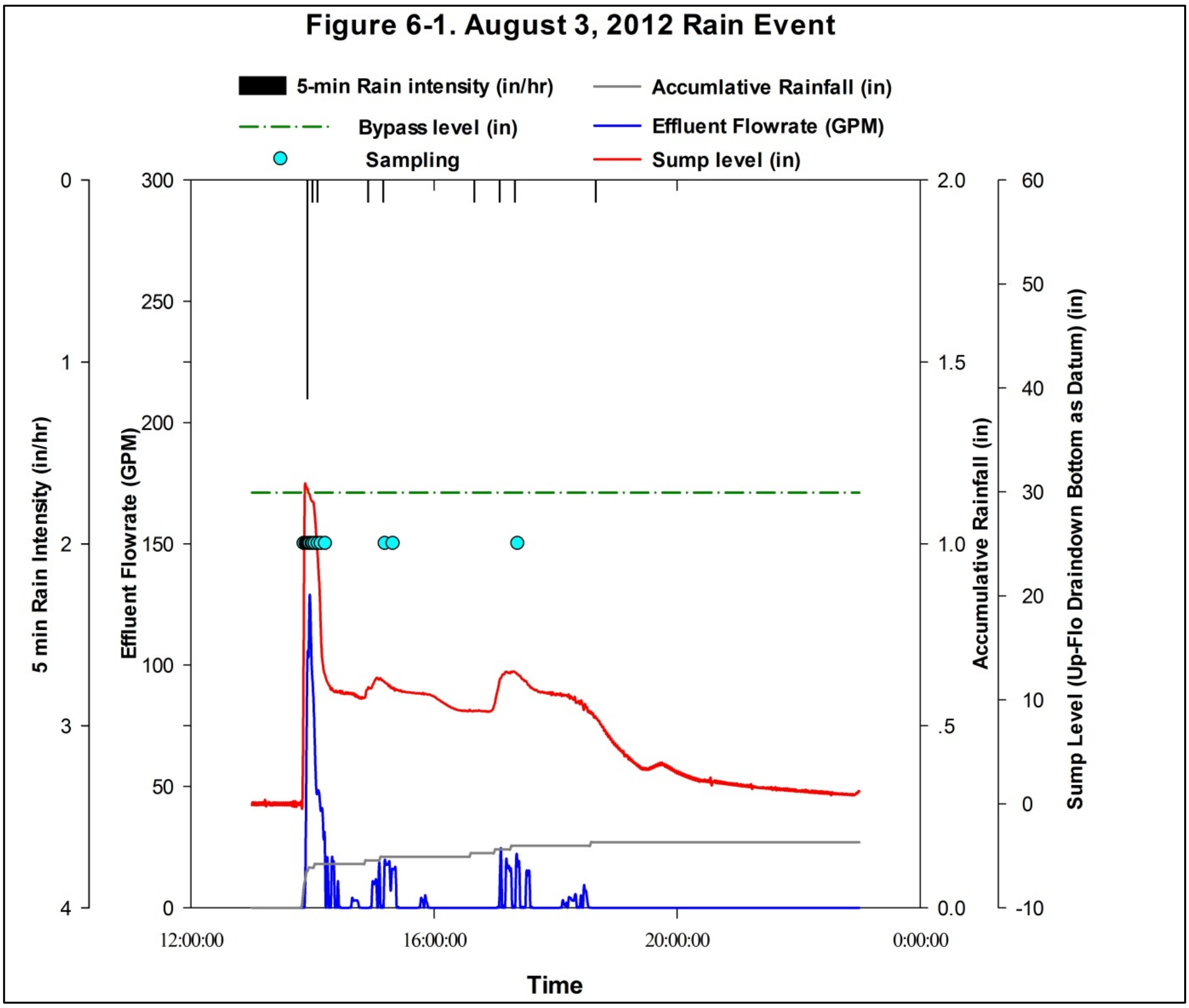


Figure 5-9. July 21, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Time
6
5
4
3
2
1
0
10000
1000
100
10
1
.1
4:00:00
8:00:00
12:00:00
16:00:00

Appendix F.6: August 3, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 6-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.27
Volumetric Runoff Coefficient (Rv)	0.49

Table 6-2. August 3, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/8/3 13:50
Rain Event End Date/Time:			2012/8/3 18:35
Total Precipitation (inch):	≥ 0.1	0.18	
Total Runoff Depth (inch):	NA	0.09	
Total Outflow (gallon):	NA	2065	
Rain Duration (hours):	≥ 1	4.75	
Flow Start Date/Time:			2012/8/3 13:53
Flow End Date/Time:			2012/8/3 18:33
Flow Duration (hours):	NA	4.67	
Average Rain Intensity (in/hr):	NA	0.04	
Average Runoff Rate (gallons/min):	NA	7	
Peak 5-min Rain Intensity (in/hr):	NA	1.20	
Peak Runoff Rate (gallons/min):	NA	128	
Peak to Average Runoff Ratio:	NA	17.36	
Bypassed flow volume (gallon):	NA	13	
Percentage of Bypassed Flow (%):	NA	0.64	
Inter-Event Time since prior rain (hours)	≥ 6.0	84.25	

Table 6-3. August 3, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	15	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	3.8	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	92.78	

Table 6-4. August 3, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	117	53	54.7	SM 2540D	1 mg/L	Stillbrook Lab
TSS	116	54	54.1	SM 2540D	1 mg/L	UA Lab
SSC	97	50	48.5	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	116	54	53.0	ASTM D3977-97B	1 mg/L	UA Lab
TDS	98	92	6.1	EPA 160.2	1 mg/L	UA Lab
VSS	49	25	50.0	SM 2540E	1 mg/L	UA Lab
Total N as N	1.7	1.9	-11.8	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	1.3	1.6	-23.1	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.86	0.79	8.1	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.86	0.74	14.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.71	0.61	14.1	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.52	0.46	11.5	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.007	BDL	> 28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.007	BDL	> 28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.094	0.055	41.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.011	0.008	27.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	48,392	39,726	17.9	IDEXX Method	<1	UA Lab
Enterococci	18,416	4,312	76.6	IDEXX Method	<1	UA Lab
pH	6.24	6.53	-4.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	40.00	24.20	39.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	88.5	94.5	-6.8	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	28.7	28.6	0.3	SM 212/ EPA 170.1	5 °C	UA Lab

Table 6-5. August 3, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	97	NA*	NA*	50	NA*	NA*	48.5	NA*	NA*
UA Lab	97	19	116	50	4	54	48.0	78.7	53.0

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 6-6. August 3, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	39193	12977	84	35	2.1	2.7

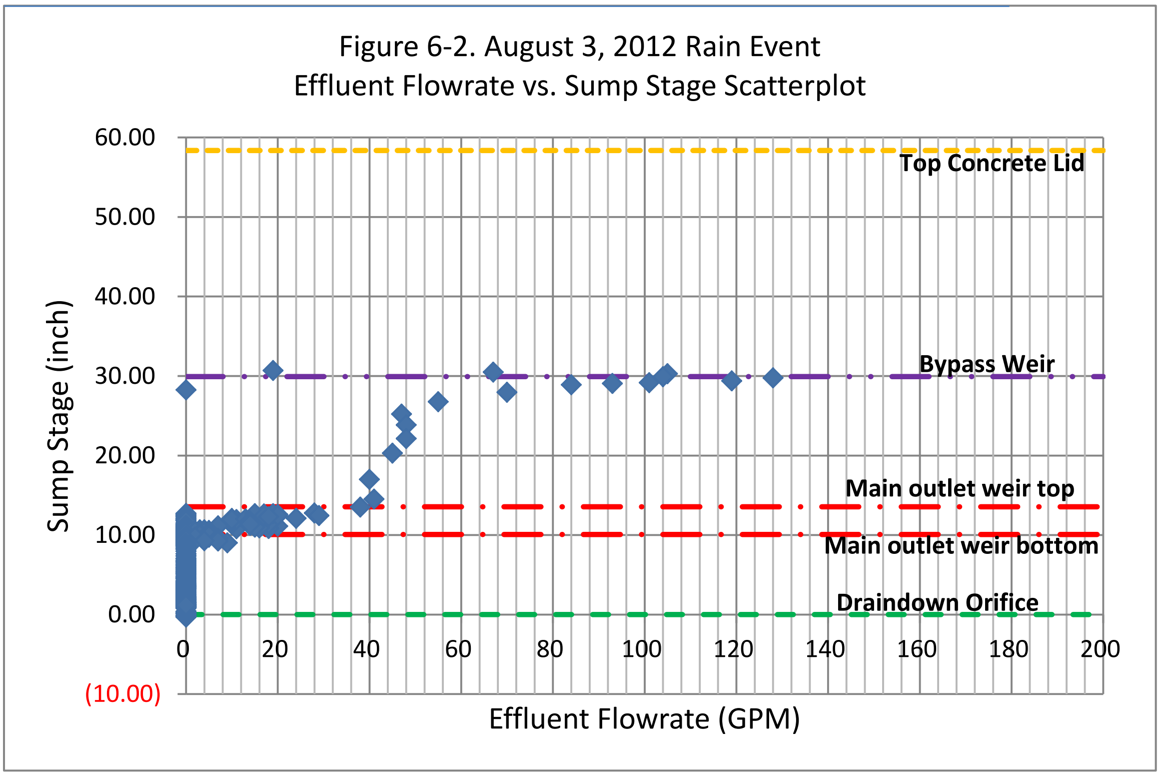
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 6-7. August 3, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	114	119	116	57	50	54
Millipore Membrane Filter, 0.45µm	109	107	108	50	41	45

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 6-8. August 3, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	> 24,196	48,392	48,392	> 24,196	39,726	39,726
Enterococci	> 24,196	18,416	18,416	5,172	3,452	4,312

Table 6-9. August 3, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	47	51	49	26	23	25



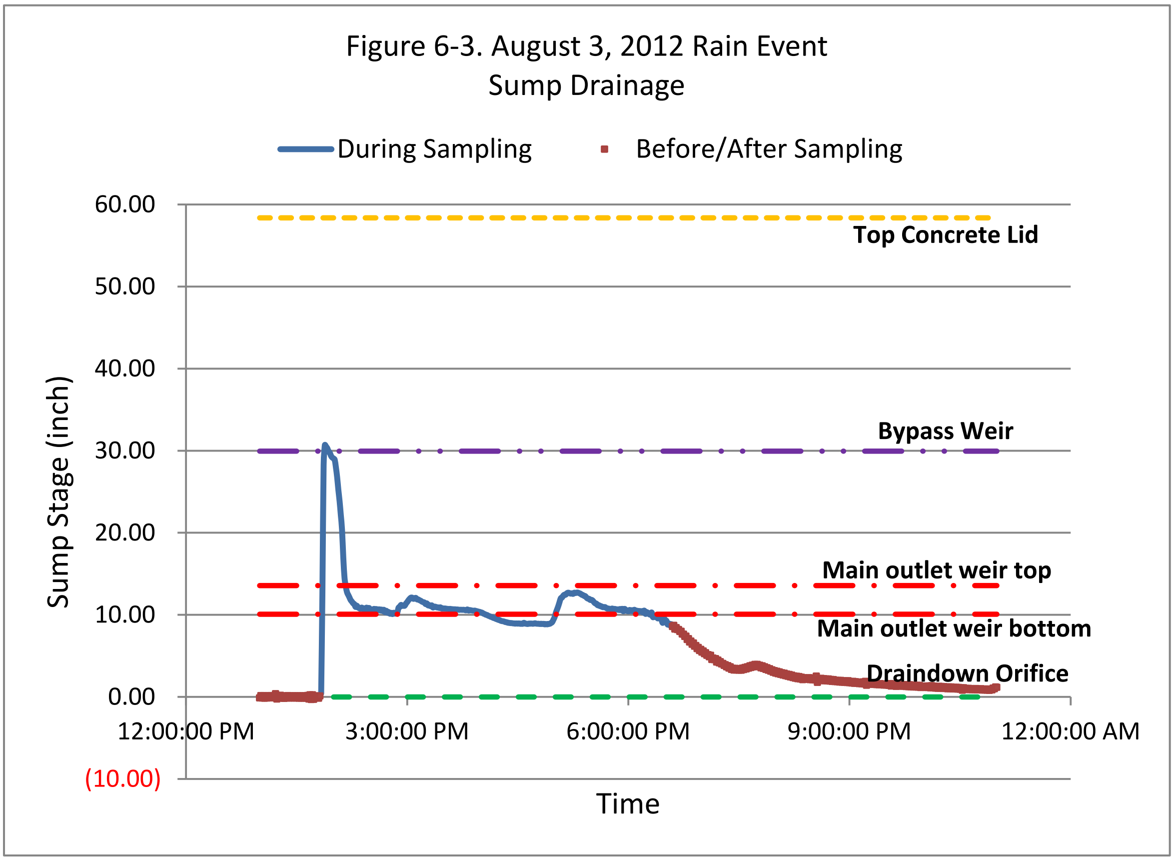


Figure 6-3. August 3, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
12:00:00 PM
3:00:00 PM
6:00:00 PM
9:00:00 PM
12:00:00 AM
Time

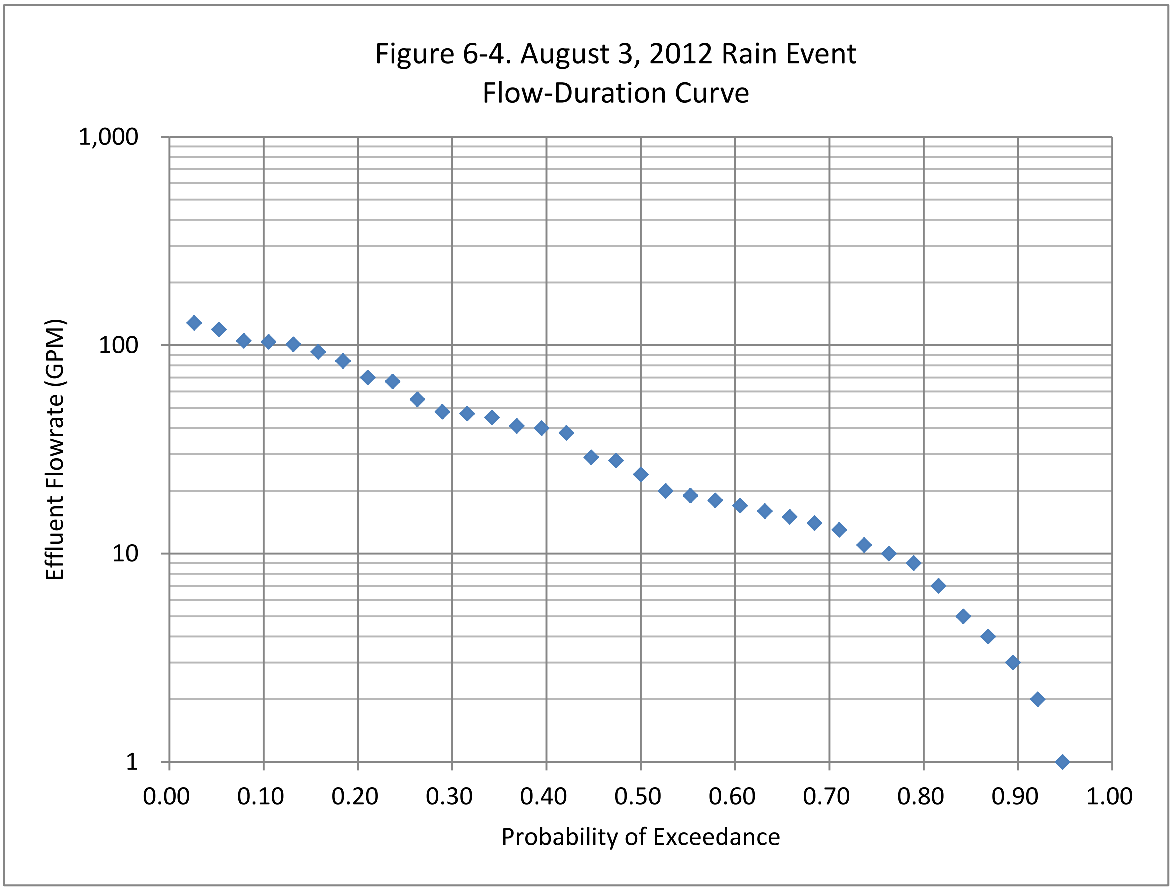


Figure 6-4. August 3, 2012 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 6-5. August 3, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

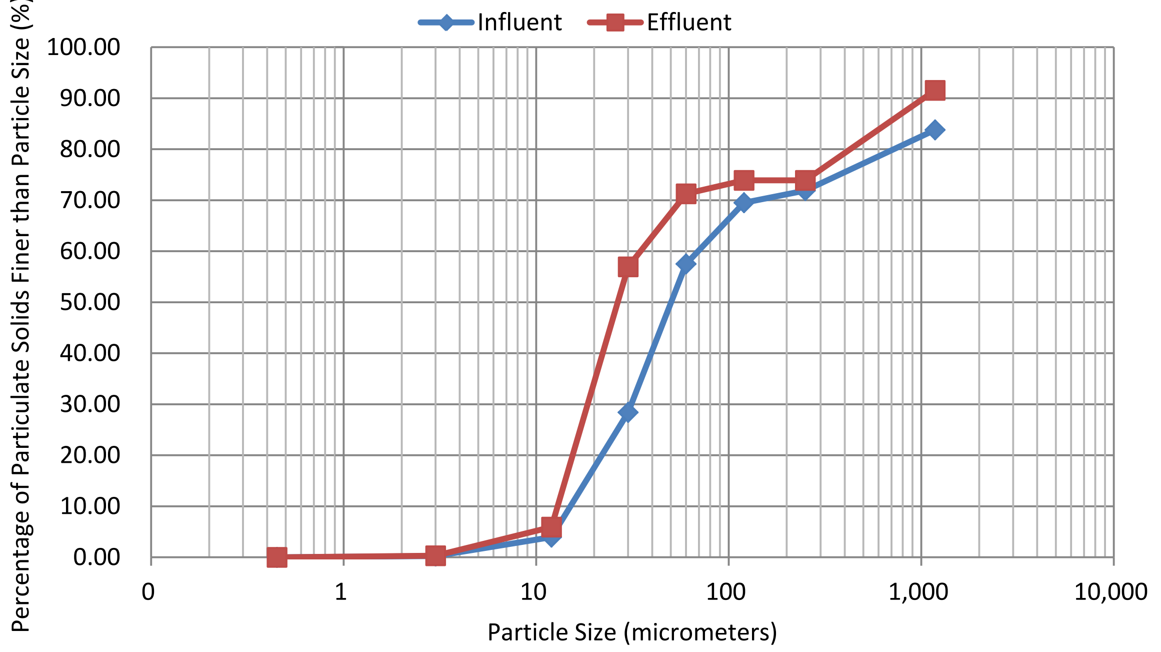
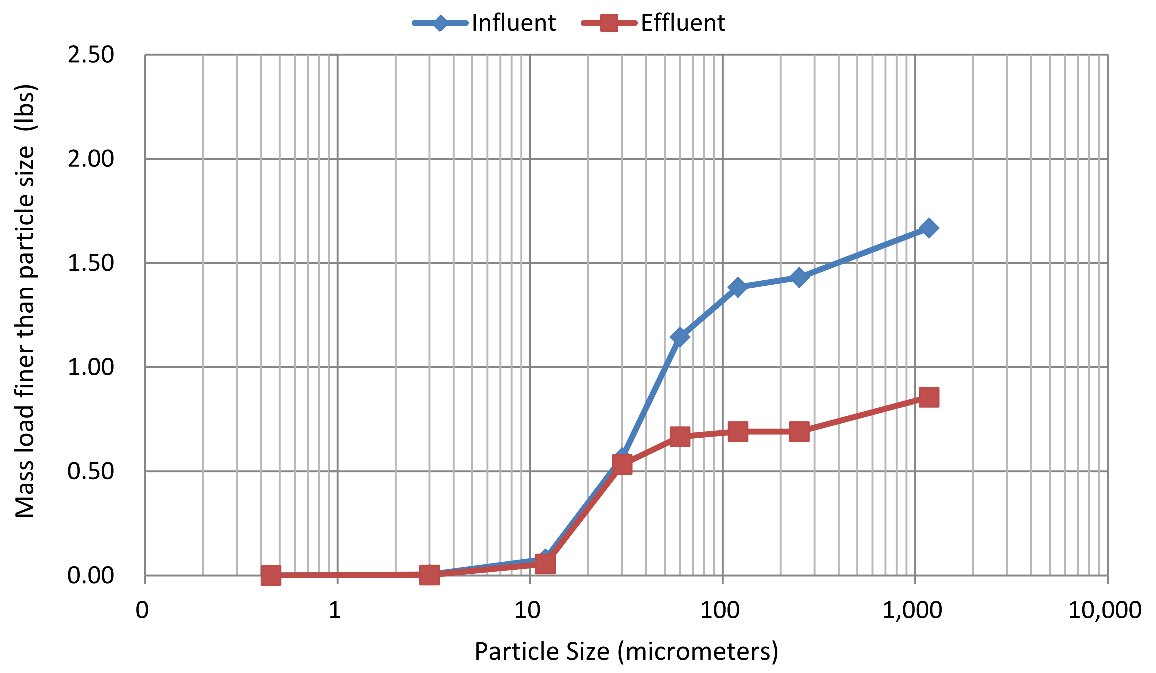


Figure 6-6. August 3, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 0.32 lbs larger than 1180 µm and the effluent had 0.08 lbs larger than 1180 µm (16.22% and 8.45% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 6-10. August 3, 2012 Rain Event
Particle Size Distribution Information

	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass of the event for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.29	0.14	0.25	0.30	0.00	0.00	0.00	43.88
3 to 12	4.33	2.71	3.69	5.64	0.07	0.05	0.02	28.24
12 to 30	28.71	24.54	24.45	51.02	0.49	0.48	0.01	1.97
30 to 60	34.18	6.88	29.11	14.31	0.58	0.13	0.45	76.90
60 to 120	14.11	1.27	12.01	2.63	0.24	0.02	0.21	89.70
120 to 250	2.79	0.00	2.37	0.00	0.05	0.00	0.05	100.00
250 to 1180	13.97	8.49	11.90	17.65	0.24	0.17	0.07	30.30
>1180	19.05	4.06	16.22	8.45	0.32	0.08	0.24	75.53
Total	117	48	100.00	100.00	1.99	0.94	1.06	53.02

Table 6-11. August 3, 2012 Rain Event
Particle Size Distribution Information

Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.25	0.30	0.00	0.00
<12	3.94	5.93	0.08	0.06
<30	28.39	56.95	0.57	0.53
<60	57.50	71.27	1.14	0.67
<120	69.51	73.90	1.38	0.69
<250	71.88	73.90	1.43	0.69
<1180	83.78	91.55	1.67	0.86
>1180	100.00	100.00	1.99	0.94

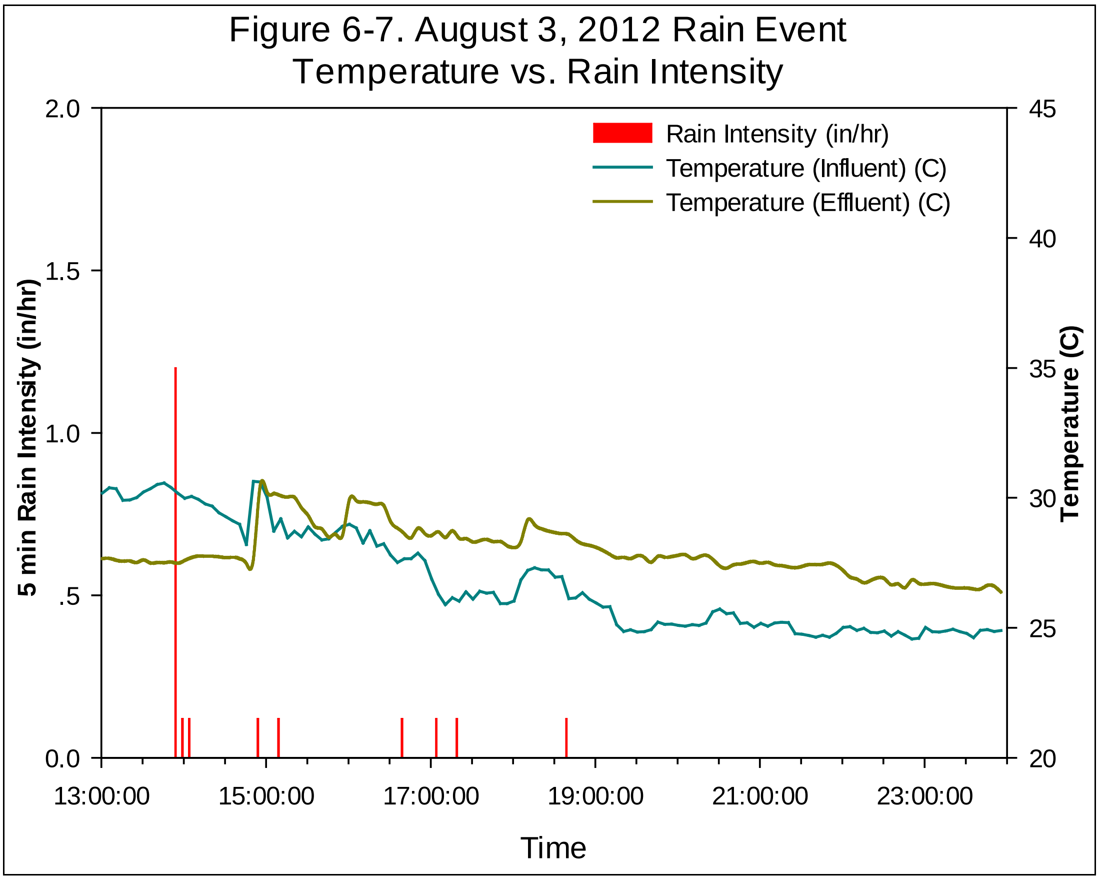


Figure 6-7. August 3, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
2.0
1.5
1.0
.5
0.0
45
40
35
30
25
20
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

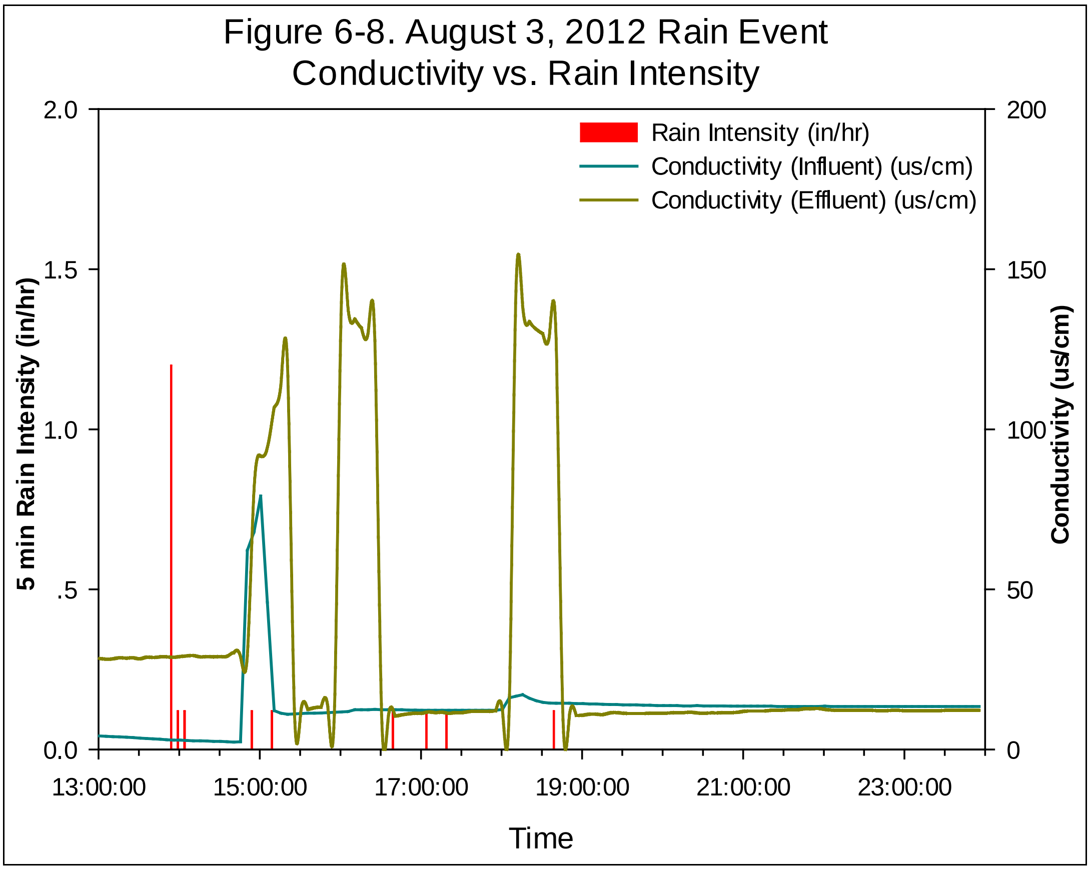


Figure 6-8. August 3, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

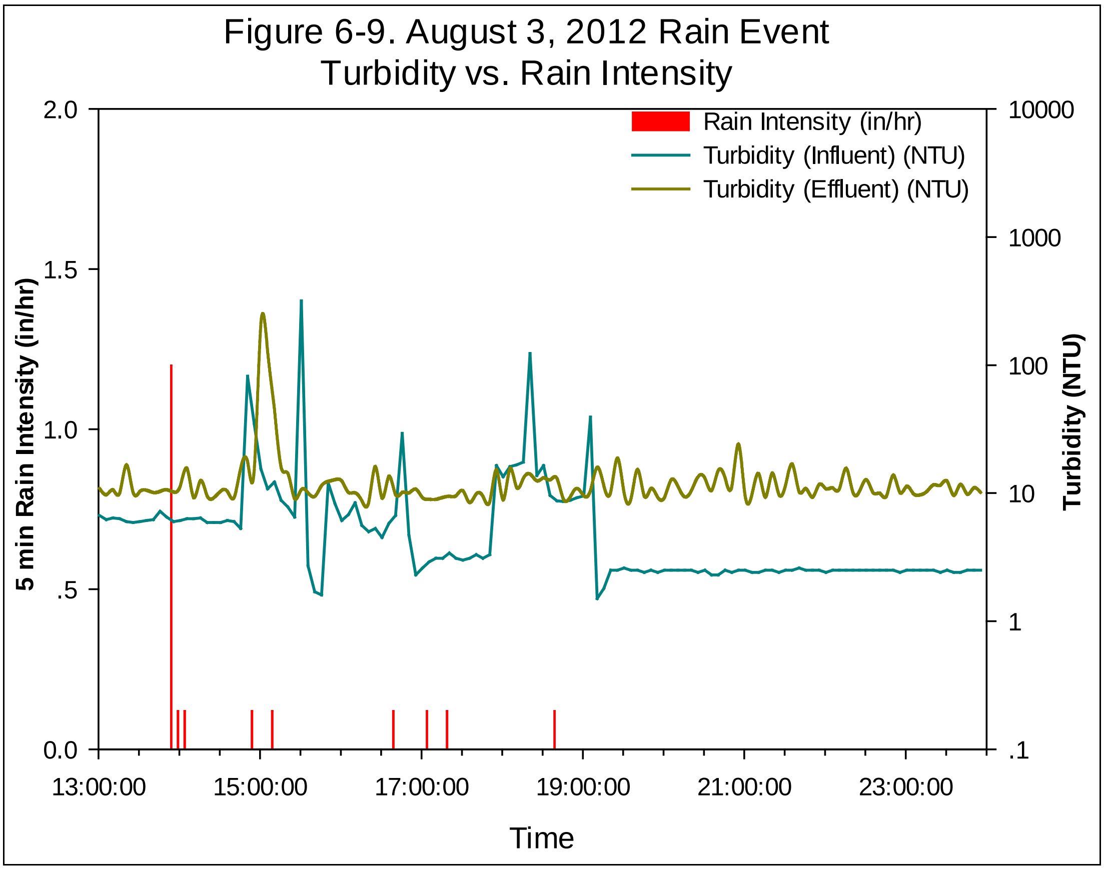
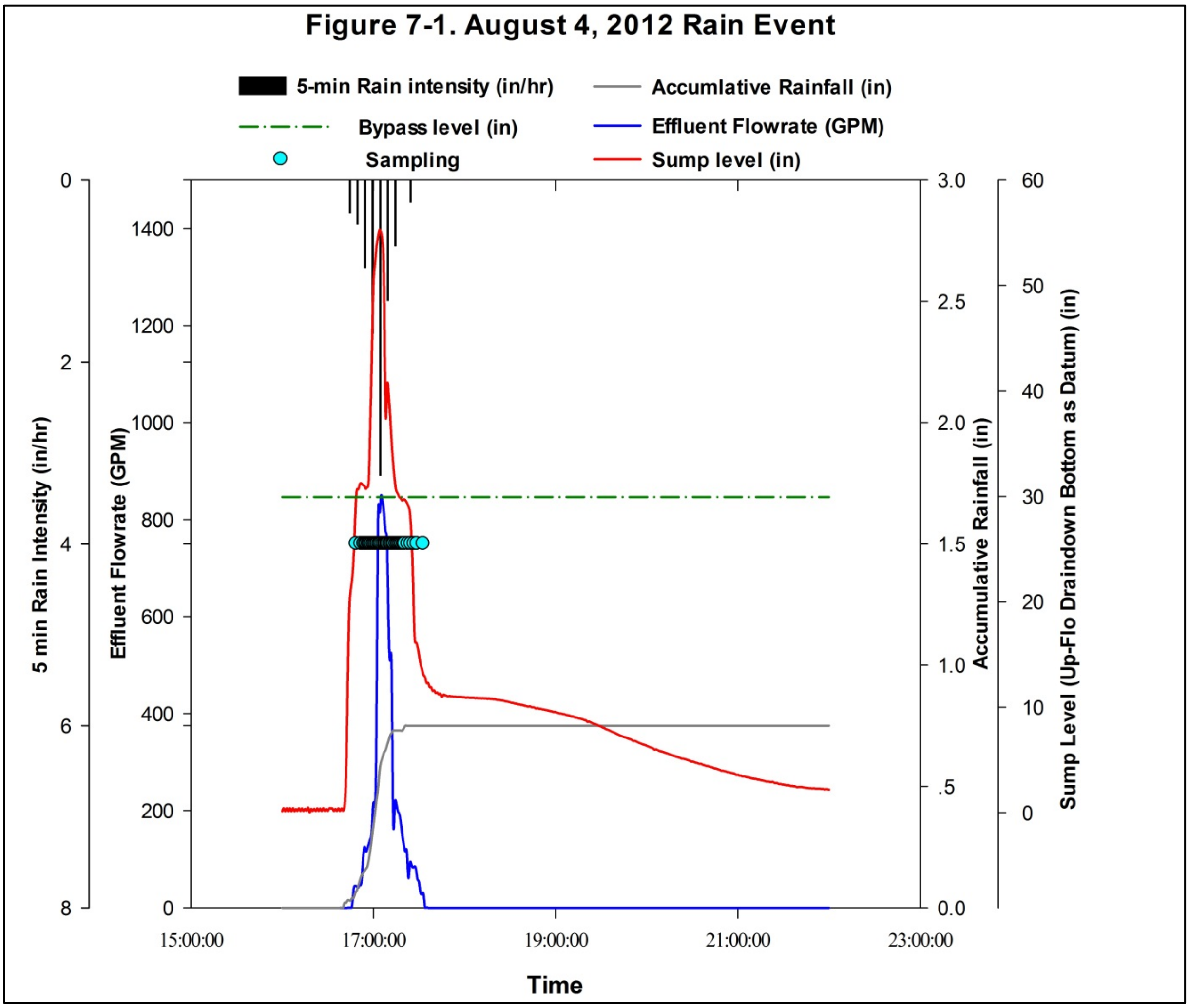


Figure 6-9. August 3, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
.1
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

Appendix F.7: August 4, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 7-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.66
Volumetric Runoff Coefficient (Rv)	0.54

Table 7-2. August 4, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/8/4 16:41
Rain Event End Date/Time:			2012/8/4 17:21
Total Precipitation (inch):	≥ 0.1	0.75	
Total Runoff Depth (inch):	NA	0.40	
Total Outflow (gallon):	NA	11535	
Rain Duration (hours):	≥ 1	0.67	
Flow Start Date/Time:			2012/8/4 16:46
Flow End Date/Time:			2012/8/4 17:34
Flow Duration (hours):	NA	0.80	
Average Rain Intensity (in/hr):	NA	1.12	
Average Runoff Rate (gallons/min):	NA	240	
Peak 5-min Rain Intensity (in/hr):	NA	3.24	
Peak Runoff Rate (gallons/min):	NA	850	
Peak to Average Runoff Ratio:	NA	3.54	
Bypassed flow volume (gallon):	NA	5518	
Percentage of Bypassed Flow (%):	NA	47.84	
Inter-Event Time since prior rain (hours)	≥ 6.0	26.85	

Table 7-3. August 4, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	35	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	8.8	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	100.00	

Table 7-4. August 4, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	95	26	72.6	SM 2540D	1 mg/L	Stillbrook Lab
TSS	126	55	56.3	SM 2540D	1 mg/L	UA Lab
SSC	100	64	36.0	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	133	57	57.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	48	49	-2.1	EPA 160.2	1 mg/L	UA Lab
VSS	41	7	82.7	SM 2540E	1 mg/L	UA Lab
Total N as N	1.2	1.2	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	1.0	0.7	30.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.35	0.37	-5.7	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.74	0.67	9.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.58	0.55	5.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.37	0.31	16.2	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	0.028	BDL	> 82.1	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	0.014	BDL	> 64.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.105	0.010	90.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.068	BDL	> 92.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	3939	4868	-23.6	IDEXX Method	<1	UA Lab
Enterococci	2497	648	74.1	IDEXX Method	<1	UA Lab
pH	6.37	6.62	-3.9	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	17.45	3.60	79.4	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	46.0	50.3	-9.3	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	26.9	26.9	0.0	SM 212/ EPA 170.1	5 °C	UA Lab

Table 7-5. August 4, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	100	NA*	NA*	64	NA*	NA*	36.0	NA*	NA*
UA Lab	103	30	133	55	2	57	46.4	94.7	57.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 7-6. August 4, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	8372	8363	67	20	8.0	2.4

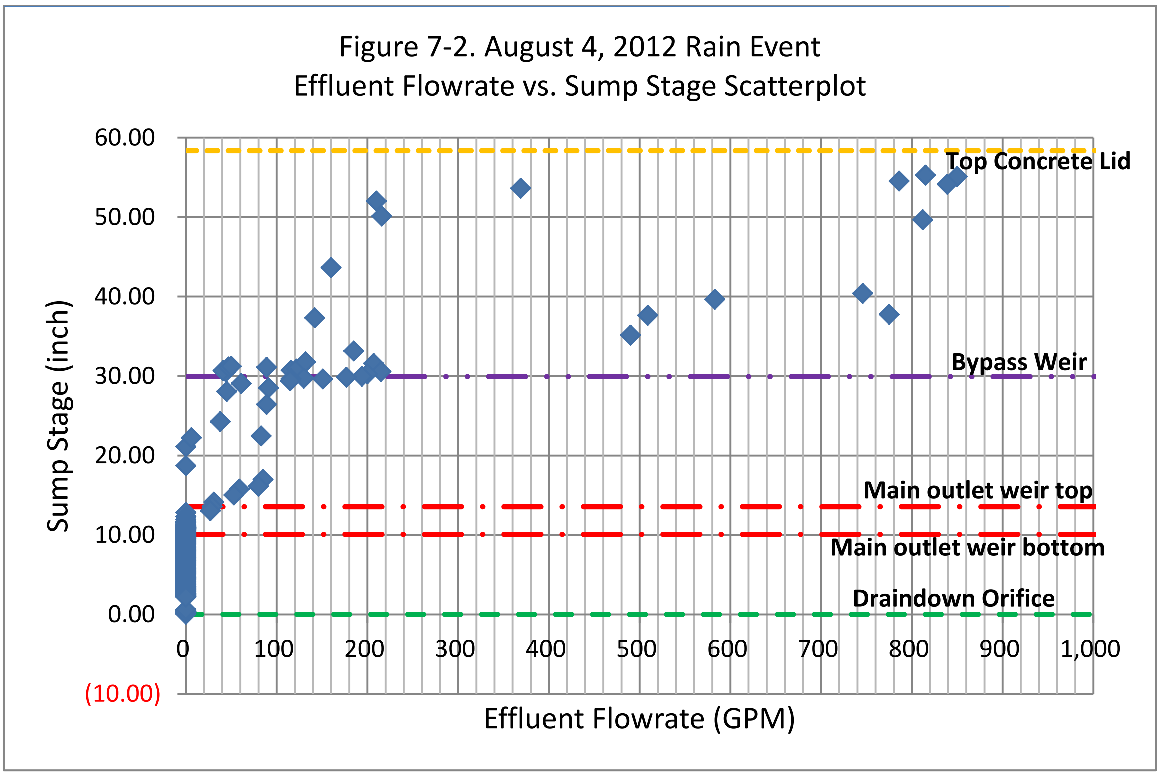
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 7-7. August 4, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	132	120	126	60	50	55
Millipore Membrane Filter, 0.45µm	106	104	105	52	44	48

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 7-8. August 4, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	4,884	2,994	3,939	5,172	4,564	4,868
Enterococci	3,076	1,918	2,497	613	682	648

Table 7-9. August 4, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5μm	43	38	41	7	7	7



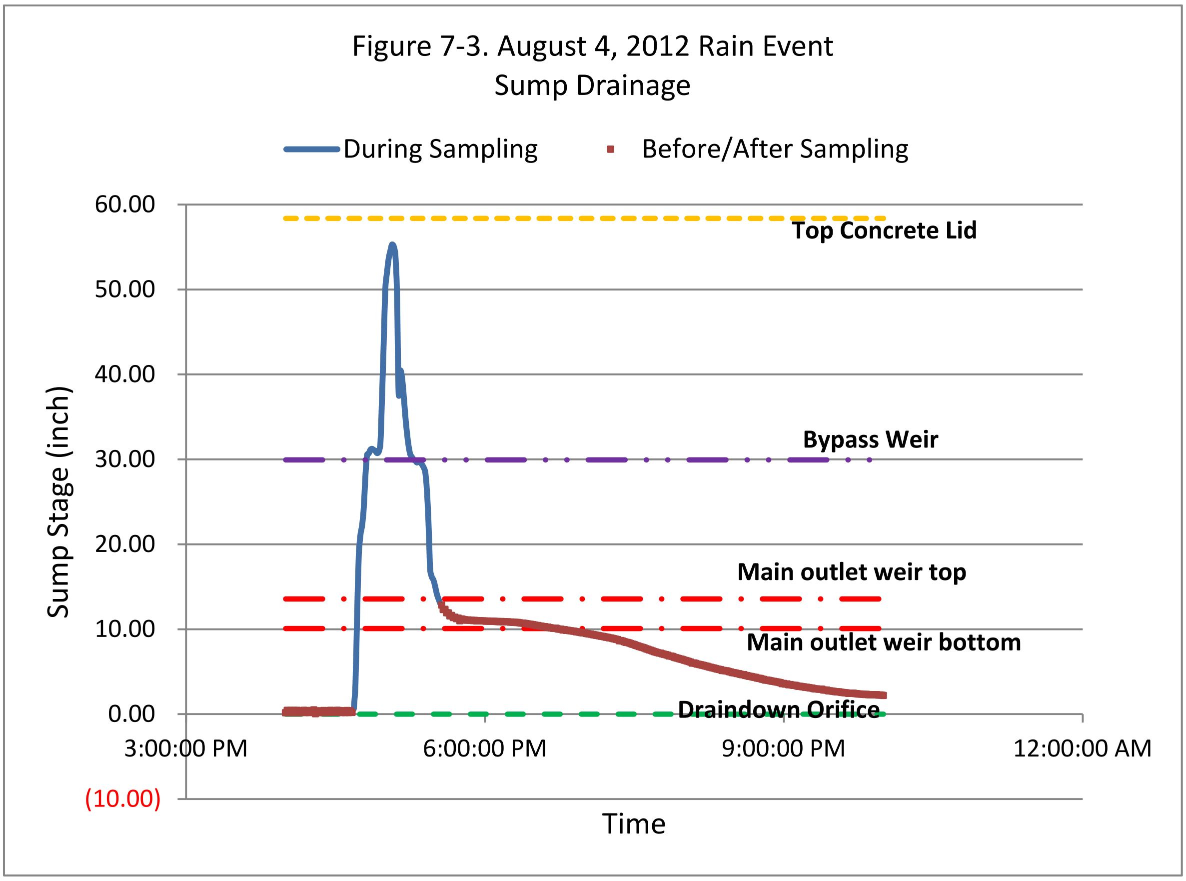


Figure 7-3. August 4, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
3:00:00 PM
6:00:00 PM
9:00:00 PM
12:00:00 AM
Time

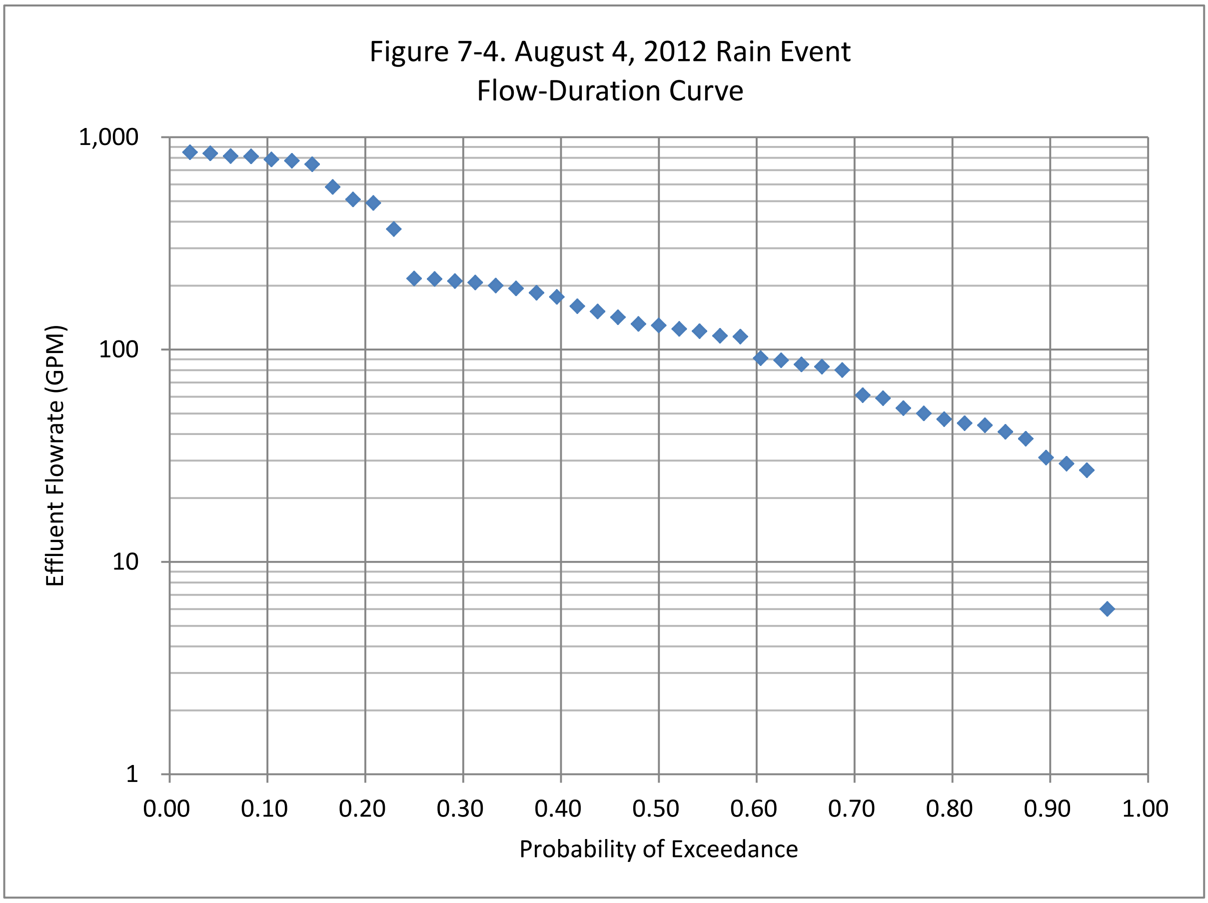
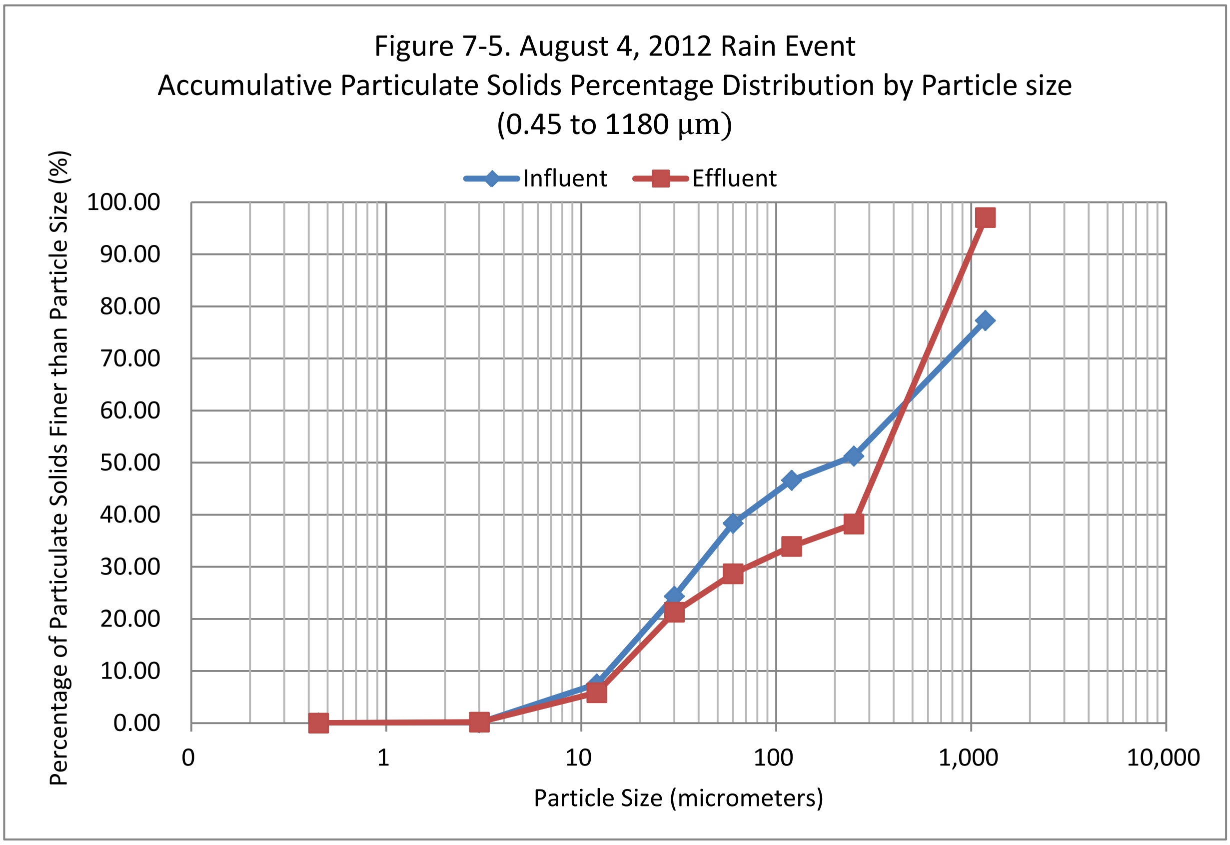
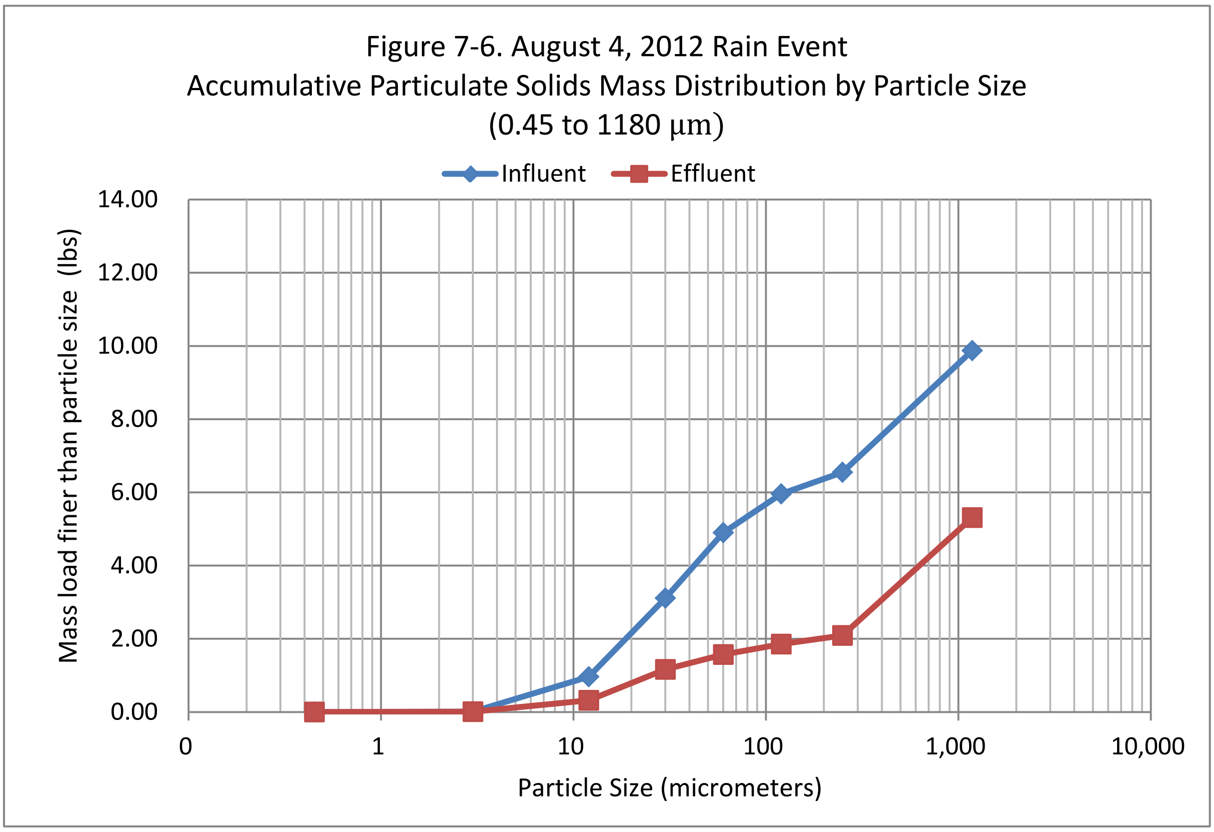


Figure 7-4. August 4, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 2.91 lbs larger than 1180 µm and the effluent had 0.16 lbs larger than 1180 µm (22.73% and 2.94% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 7-10. August 4, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.10	0.08	0.18	0.01	0.01	0.00	2.02
3 to 12	9.72	3.05	7.44	5.68	0.95	0.31	0.64	67.30
12 to 30	21.96	8.28	16.81	15.43	2.15	0.84	1.30	60.71
30 to 60	18.32	3.97	14.02	7.38	1.79	0.40	1.39	77.46
60 to 120	10.80	2.81	8.26	5.24	1.06	0.29	0.77	72.85
120 to 250	6.05	2.32	4.63	4.32	0.59	0.24	0.36	60.04
250 to 1180	34.00	31.59	26.02	58.82	3.33	3.22	0.11	3.23
>1180	29.70	1.58	22.73	2.94	2.91	0.16	2.74	94.46
Total	131	54	100.00	100.00	12.78	5.47	7.31	57.19

Table 7-11. August 4, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.08	0.18	0.01	0.01
<12	7.52	5.87	0.96	0.32
<30	24.33	21.29	3.11	1.17
<60	38.35	28.68	4.90	1.57
<120	46.62	33.92	5.96	1.86
<250	51.24	38.23	6.55	2.09
<1180	77.27	97.06	9.87	5.31
>1180	100.00	100.00	12.78	5.47

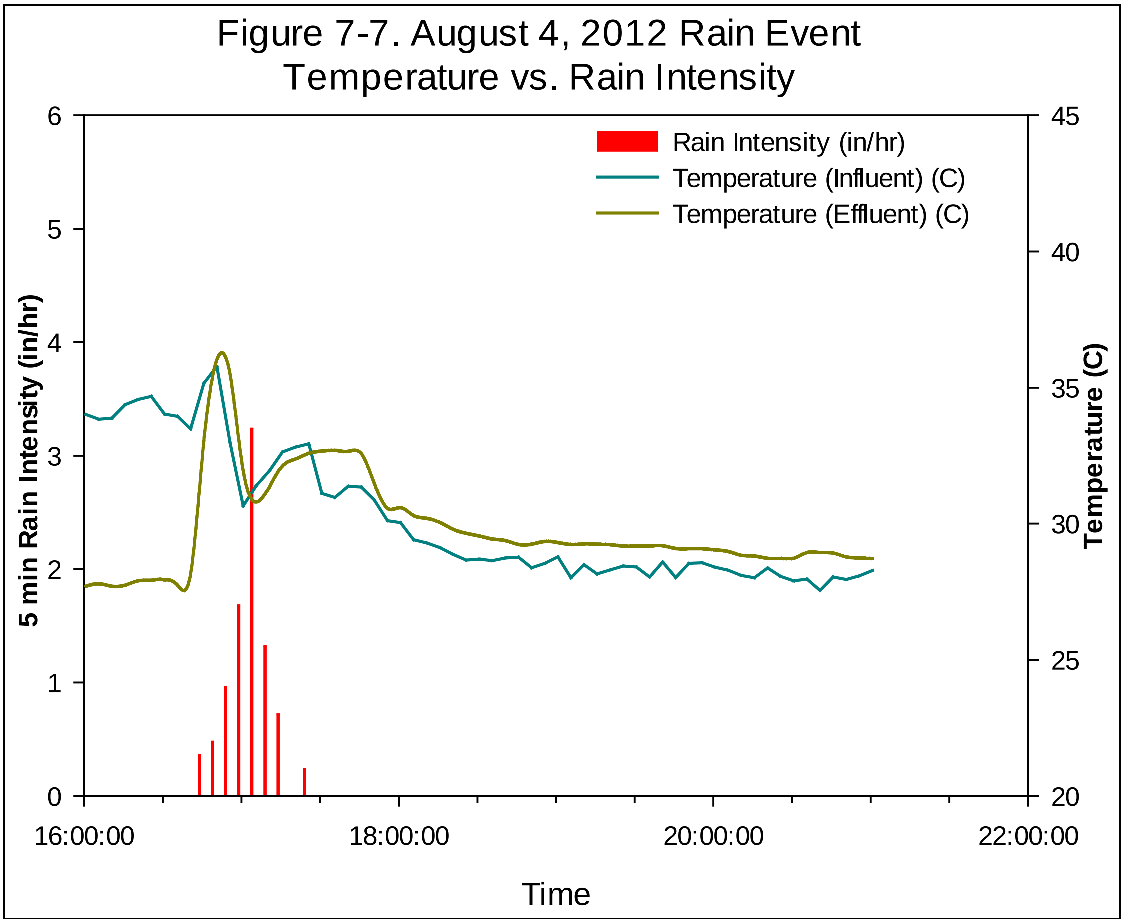


Figure 7-7. August 4, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
0
1
2
3
4
5
6
20
25
30
35
40
45
16:00:00
18:00:00
20:00:00
22:00:00
Time

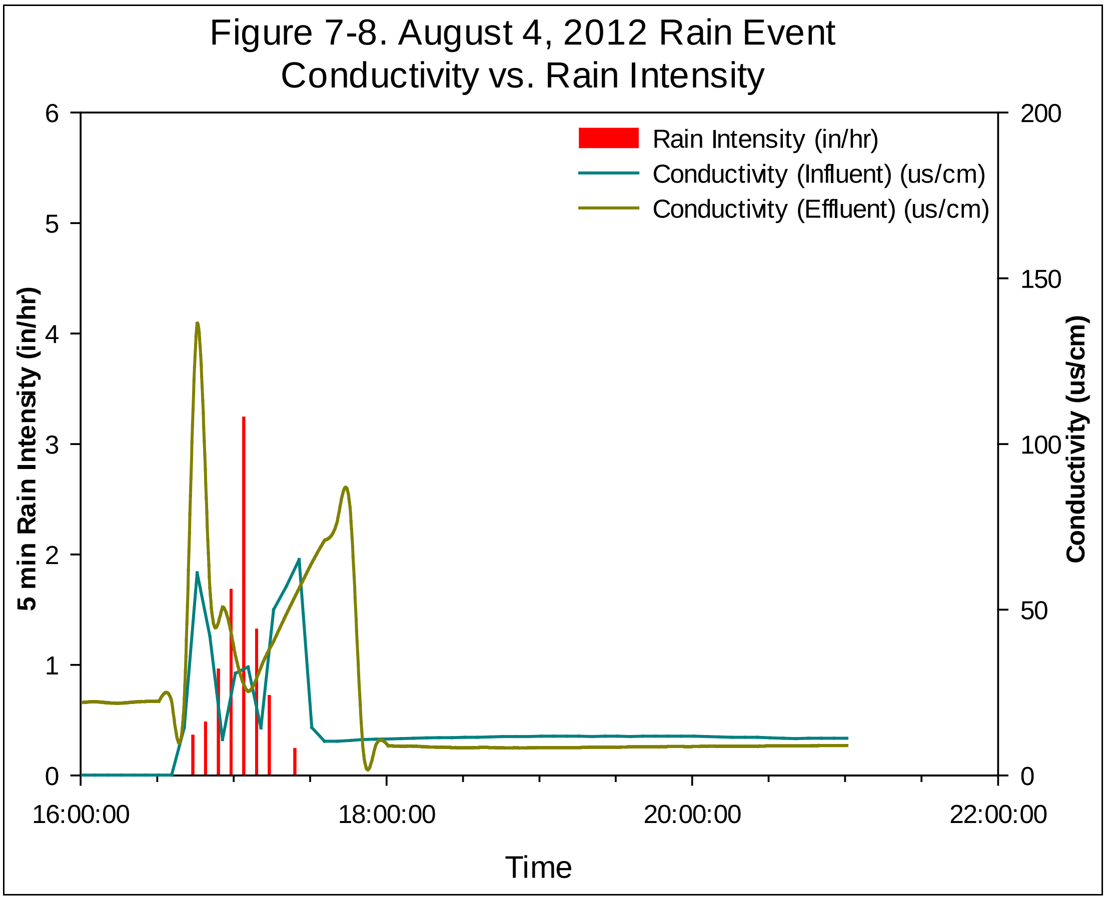


Figure 7-8. August 4, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
0
1
2
3
4
5
6
0
50
100
150
200
16:00:00
18:00:00
20:00:00
22:00:00
Time

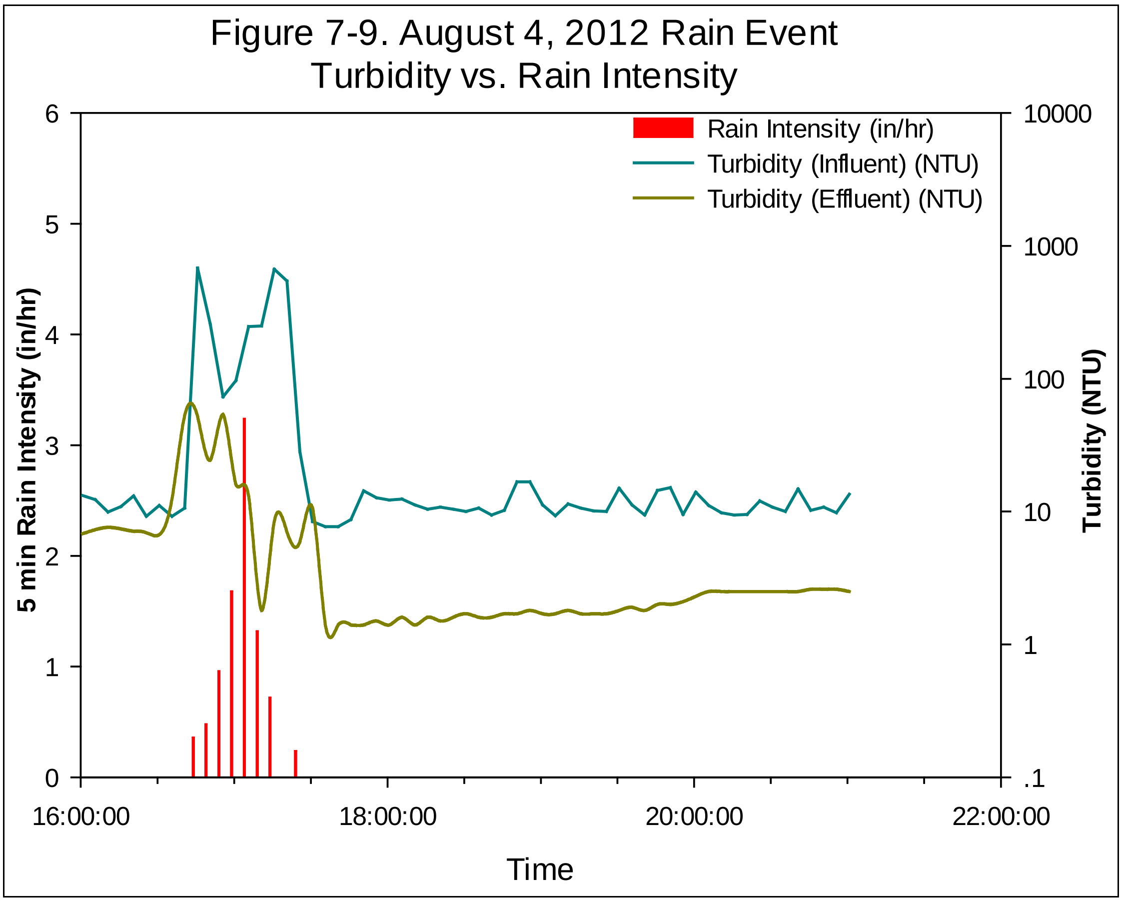
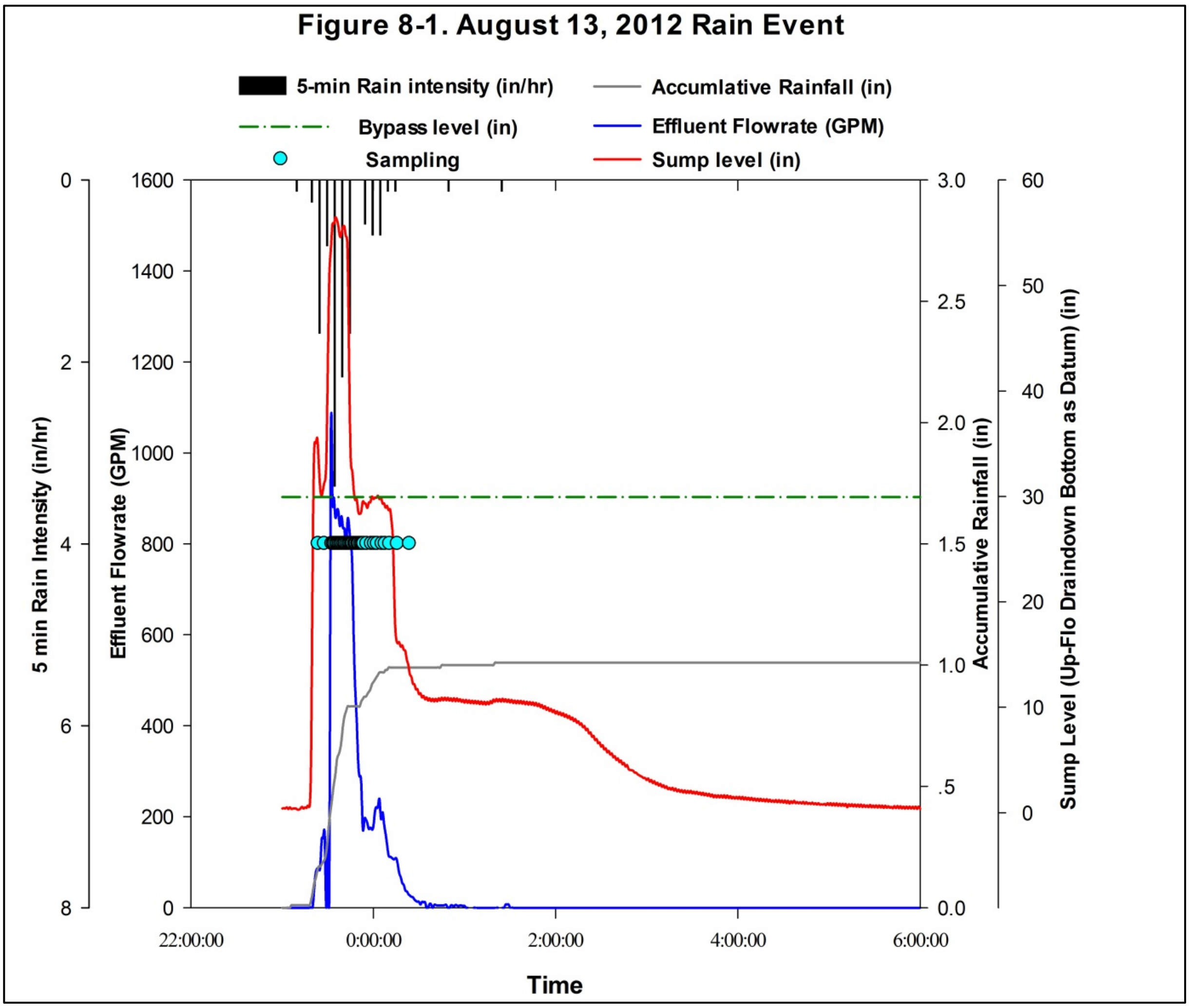


Figure 7-9. August 4, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Time
0
1
2
3
4
5
6
.1
1
10
100
1000
10000
16:00:00
18:00:00
20:00:00
22:00:00

Appendix F.8: August 13, 2012 Storm Event Summary



Note: The level Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 8-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.76
Volumetric Runoff Coefficient (Rv)	0.89

Table 8-2. August 13, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/8/13 23:06
Rain Event End Date/Time:			2012/8/14 1:19
Total Precipitation (inch):	≥ 0.1	1.01	
Total Runoff Depth (inch):	NA	0.90	
Total Outflow (gallon):	NA	20903	
Rain Duration (hours):	≥ 1	2.22	
Flow Start Date/Time:			2012/8/13 23:21
Flow End Date/Time:			2012/8/14 1:29
Flow Duration (hours):	NA	2.13	
Average Rain Intensity (in/hr):	NA	0.45	
Average Runoff Rate (gallons/min):	NA	162	
Peak 5-min Rain Intensity (in/hr):	NA	3.36	
Peak Runoff Rate (gallons/min):	NA	1023	
Peak to Average Runoff Ratio:	NA	6.31	
Bypassed flow volume (gallon):	NA	10571	
Percentage of Bypassed Flow (%):	NA	50.57	
Inter-Event Time since prior rain (hours)	≥ 6.0	154.85	

Table 8-3. August 13, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	42	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	10.5	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	97.87	

Table 8-4. August 13, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	35	14	60.0	SM 2540D	1 mg/L	Stillbrook Lab
TSS	93	14	85.4	SM 2540D	1 mg/L	UA Lab
SSC	50	20	60.0	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	93	16	82.4	ASTM D3977-97B	1 mg/L	UA Lab
TDS	33	26	21.2	EPA 160.2	1 mg/L	UA Lab
VSS	15	6	60.0	SM 2540E	1 mg/L	UA Lab
Total N as N	1.0	0.9	10.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.18	0.19	-5.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	1.13	0.86	23.9	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.95	0.77	18.9	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.006	BDL	> 16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.047	0.016	66.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	0.010	0.006	40.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.022	BDL	> 77.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.050	0.017	66.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.014	0.008	42.9	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	3077	1887	38.7	IDEXX Method	<1	UA Lab
Enterococci	13769	2847	79.3	IDEXX Method	<1	UA Lab
pH	6.85	6.93	-1.2	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	11.15	8.59	23.0	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	24.5	23.9	2.4	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	24.0	24.2	-0.8	SM 212/ EPA 170.1	5 °C	UA Lab

Table 8-5. August 13, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	50	NA*	NA*	20	NA*	NA*	60.0	NA*	NA*
UA Lab	86	7	93	15	1	16	82.6	79.8	82.4

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 8-6. August 13, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	13845	6124	34	10	2.5	1.7

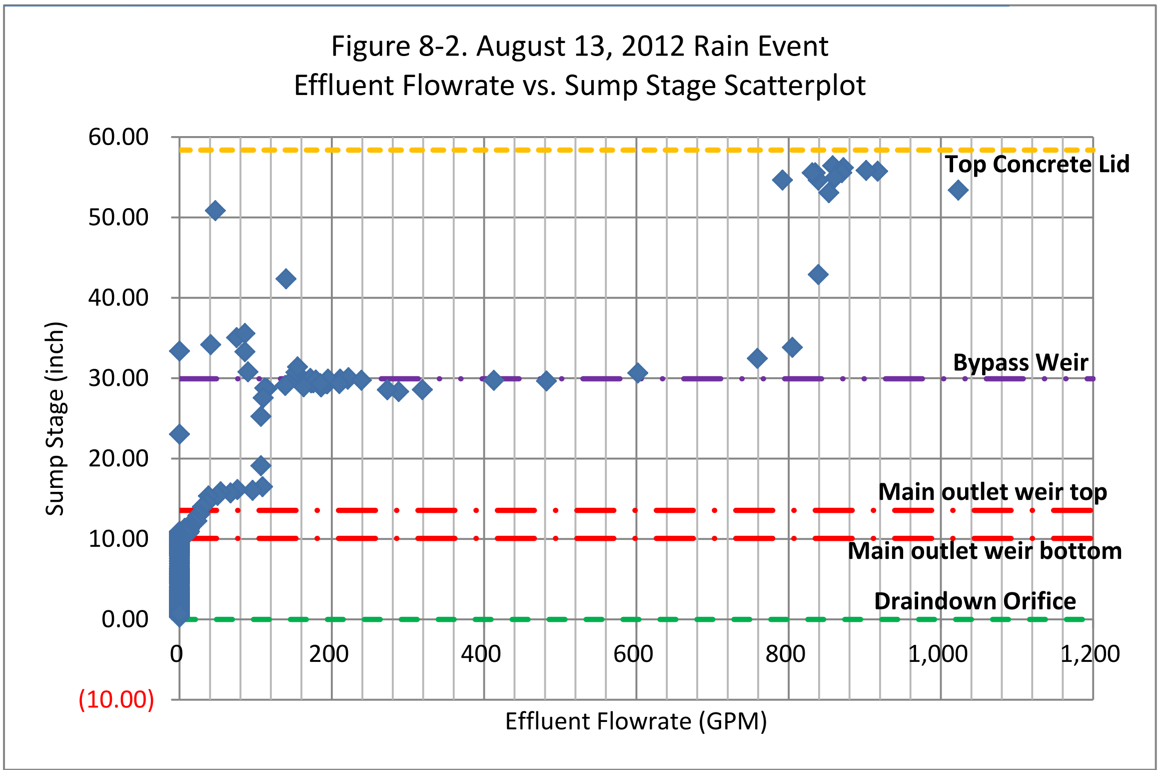
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 8-7. August 13, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	94	91	93	13	14	14
Millipore Membrane Filter, 0.45µm	91	93	92	18	16	17

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 8-8. August 13, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	3,654	2,500	3,077	2,014	1,760	1,887
Enterococci	12,997	14,540	13,769	3,076	2,618	2,847

Table 8-9. August 13, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	14	16	15	7	5	6



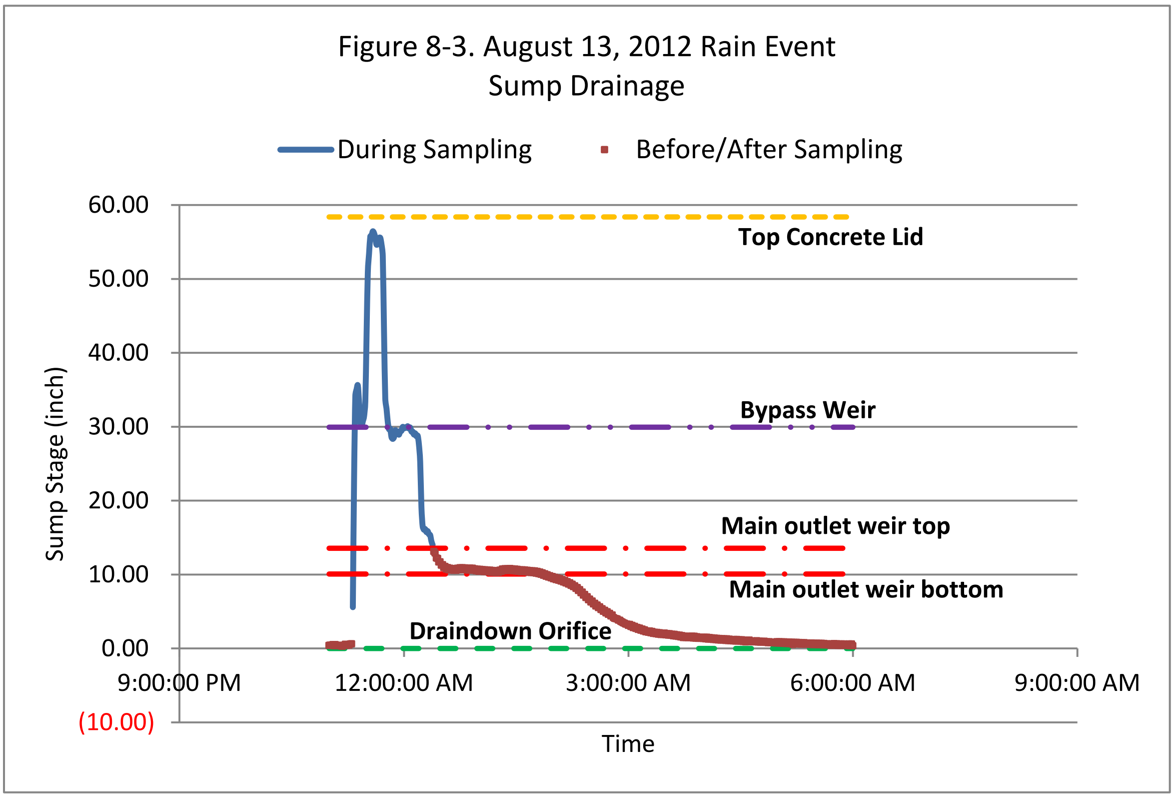


Figure 8-3. August 13, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
9:00:00 PM
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
Time

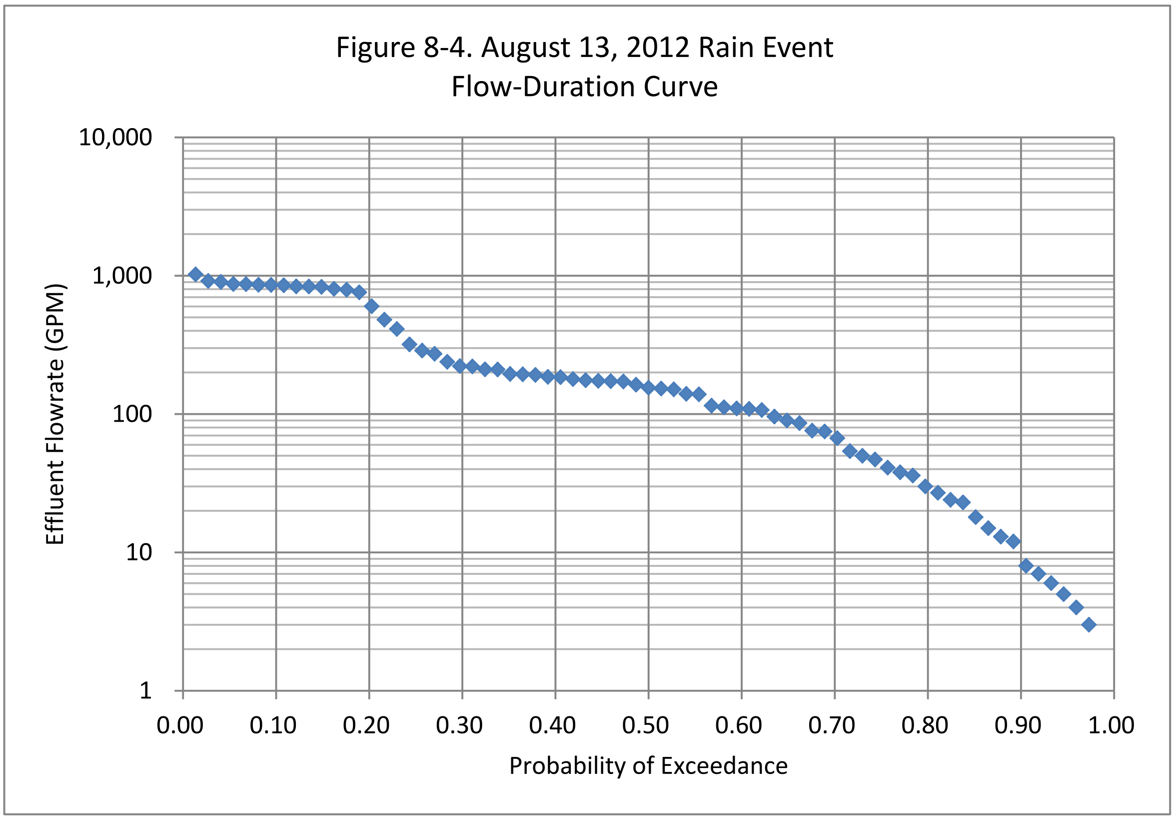
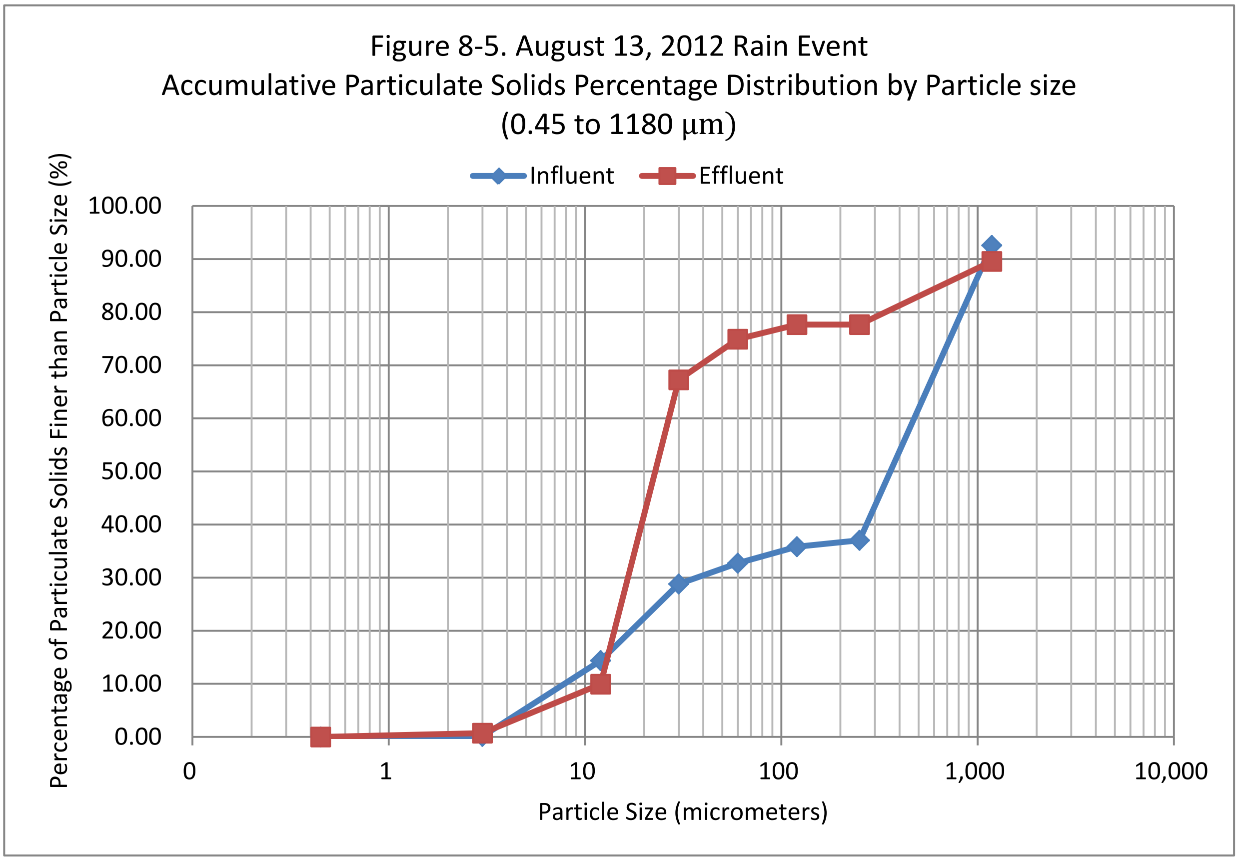
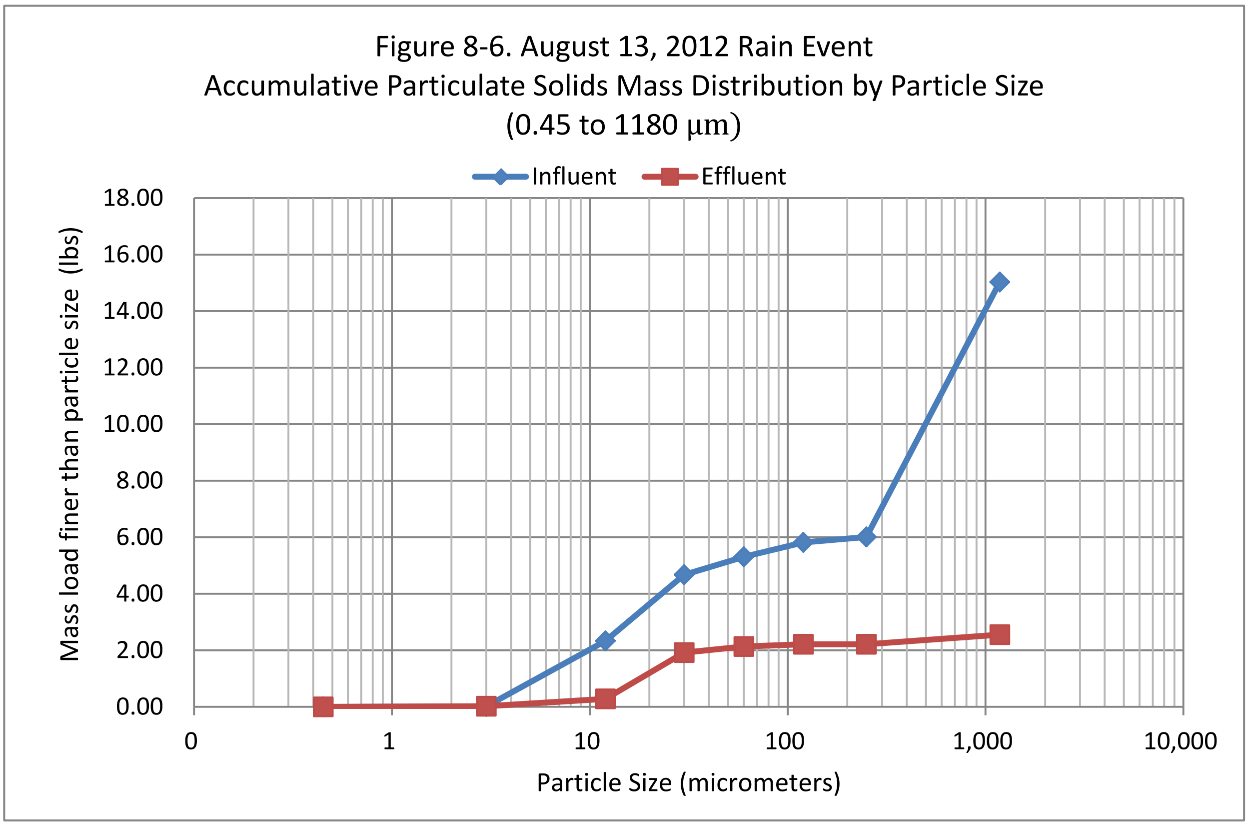


Figure 8-4. August 13, 2012 Rain Event
Flow-Duration Curve
10,000
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 1.21 lbs larger than 1180 µm and the effluent had 0.30 lbs larger than 1180 µm (7.43% and 10.43% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 8-10. August 13, 2012 Rain Event
Particle Size Distribution Information

	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.09	0.11	0.70	0.02	0.02	0.00	-12.90
3 to 12	13.14	1.22	14.27	9.24	2.32	0.26	2.05	88.62
12 to 30	13.28	7.59	14.42	57.33	2.34	1.64	0.71	30.15
30 to 60	3.60	1.01	3.91	7.66	0.63	0.22	0.42	65.57
60 to 120	2.86	0.36	3.11	2.75	0.50	0.08	0.43	84.46
120 to 250	1.12	0.00	1.21	0.00	0.20	0.00	0.20	100.00
250 to 1180	51.15	1.57	55.54	11.90	9.02	0.34	8.68	96.24
>1180	6.84	1.38	7.43	10.43	1.21	0.30	0.91	75.33
Total	92	13	100.00	100.00	16.24	2.85	13.38	82.43

Table 8-11. August 13, 2012 Rain Event
Particle Size Distribution Information

Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.11	0.70	0.02	0.02
<12	14.38	9.94	2.33	0.28
<30	28.80	67.27	4.68	1.92
<60	32.71	74.93	5.31	2.14
<120	35.81	77.67	5.82	2.22
<250	37.03	77.67	6.01	2.22
<1180	92.57	89.57	15.03	2.56
>1180	100.00	100.00	16.24	2.85

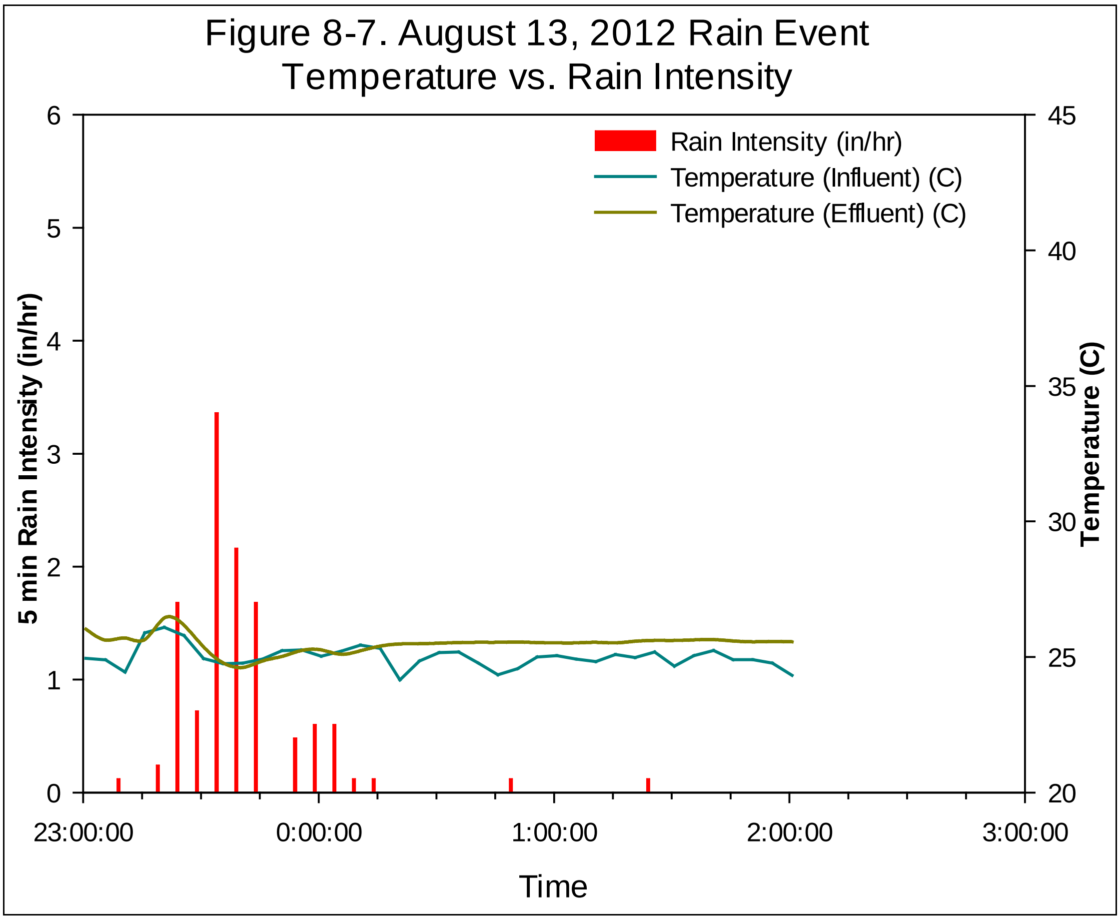


Figure 8-7. August 13, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
0
1
2
3
4
5
6
20
25
30
35
40
45
23:00:00
0:00:00
1:00:00
2:00:00
3:00:00
Time

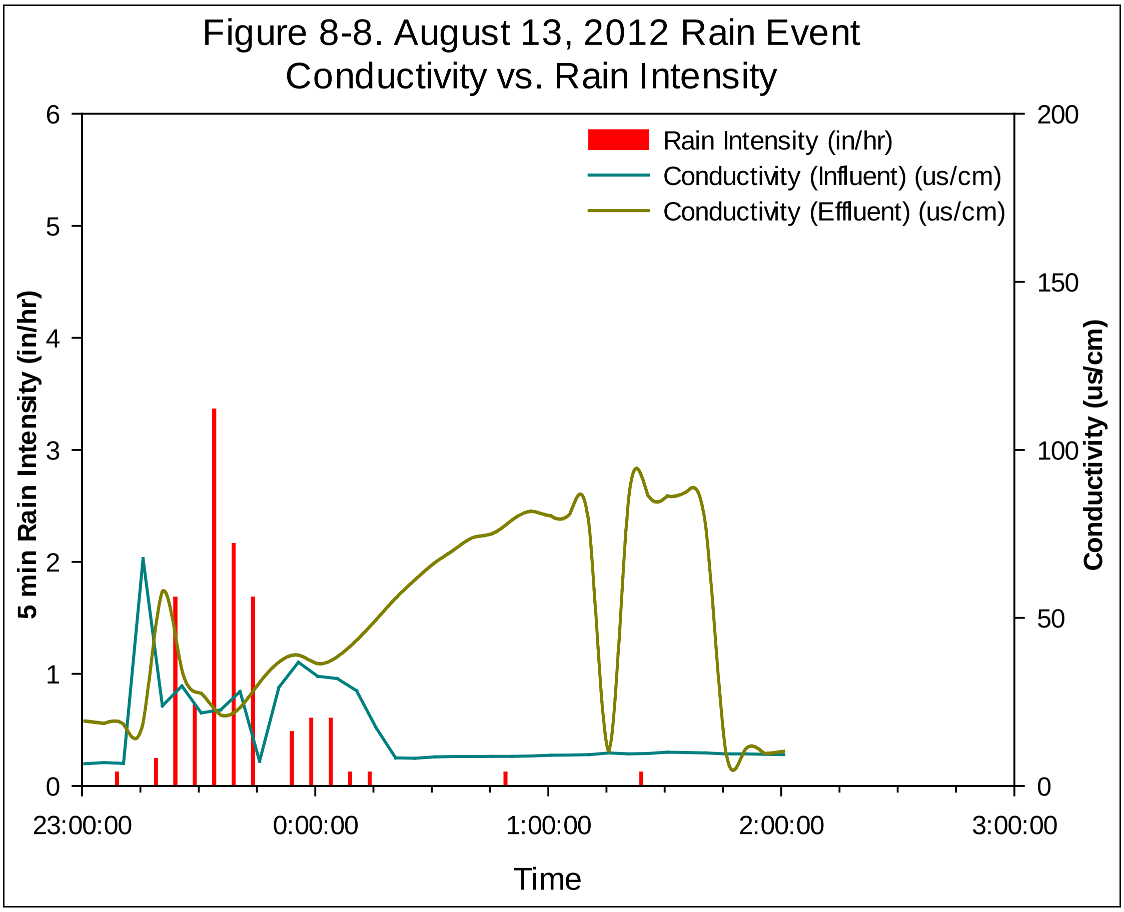
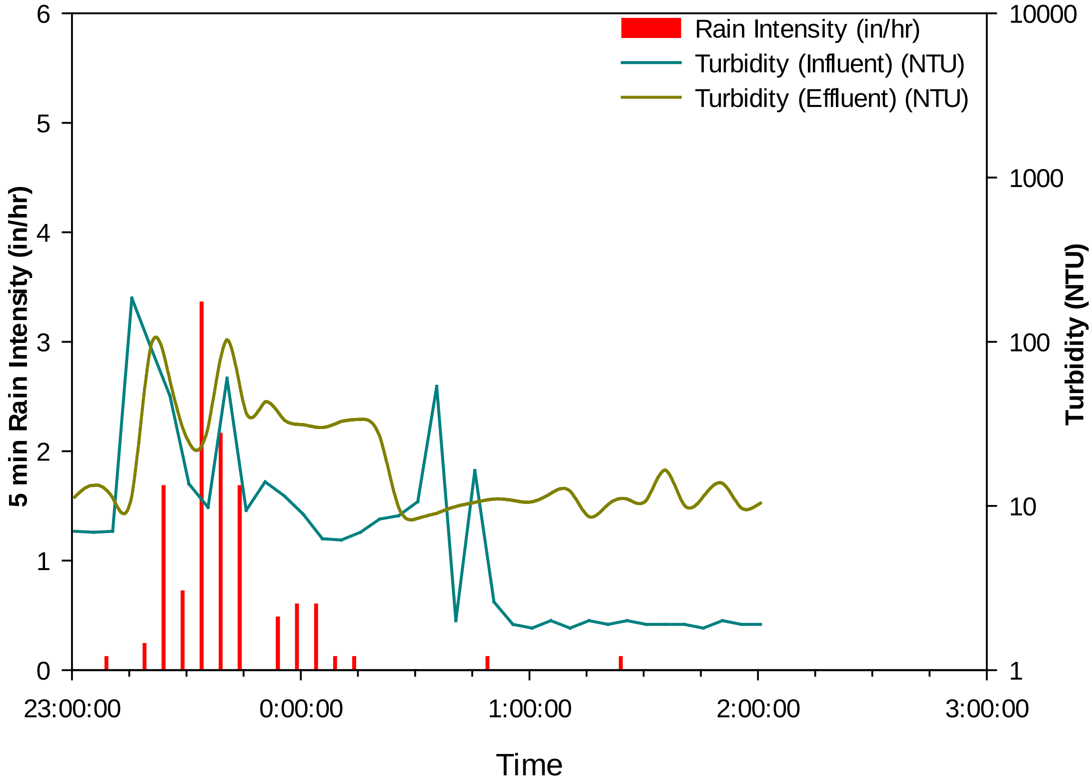
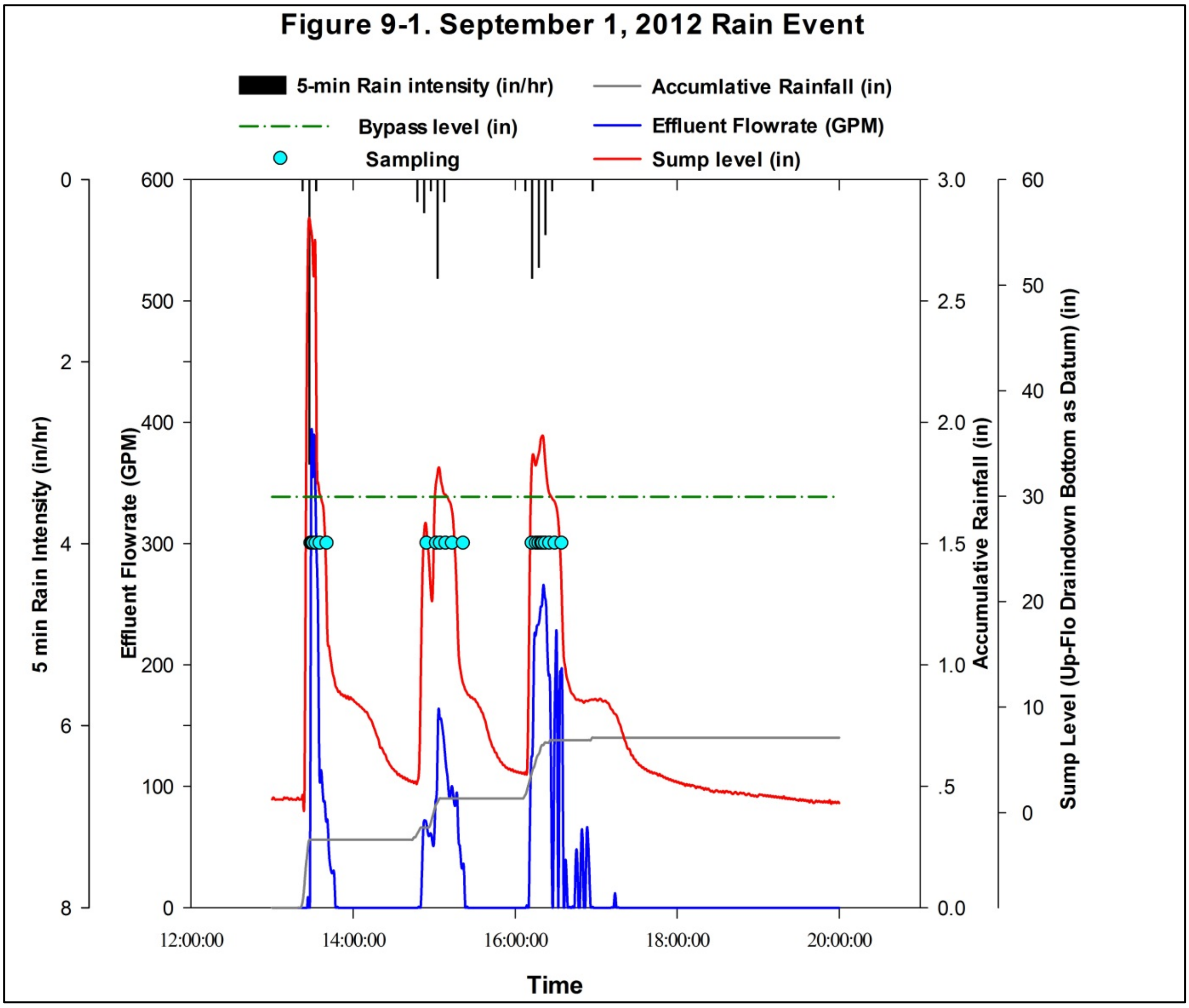


Figure 8-8. August 13, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
0
1
2
3
4
5
6
0
50
100
150
200
23:00:00
0:00:00
1:00:00
2:00:00
3:00:00
Time

Figure 8-9. August 13, 2012 Rain Event
Turbidity vs. Rain Intensity



Appendix F.9: September 1, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 9-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.31
Volumetric Runoff Coefficient (Rv)	0.59

Table 9-2. September 1, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/9/1 13:22
Rain Event End Date/Time:			2012/9/1 16:57
Total Precipitation (inch):	≥ 0.1	0.70	
Total Runoff Depth (inch):	NA	0.41	
Total Outflow (gallon):	NA	10402	
Rain Duration (hours):	≥ 1	3.58	
Flow Start Date/Time:			2012/9/1 13:29
Flow End Date/Time:			2012/9/1 17:15
Flow Duration (hours):	NA	3.77	
Average Rain Intensity (in/hr):	NA	0.20	
Average Runoff Rate (gallons/min):	NA	46	
Peak 5-min Rain Intensity (in/hr):	NA	3.12	
Peak Runoff Rate (gallons/min):	NA	390	
Peak to Average Runoff Ratio:	NA	8.47	
Bypassed flow volume (gallon):	NA	2507	
Percentage of Bypassed Flow (%):	NA	24.10	
Inter-Event Time since prior rain (hours)	≥ 6.0	52.07	

Table 9-3. September 1, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	21	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	5.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.09	

Table 9-4. September 1, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	55	15	72.7	SM 2540D	1 mg/L	Stillbrook Lab
TSS	162	10	93.8	SM 2540D	1 mg/L	UA Lab
SSC	237	29	87.8	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	304	22	92.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	57	46	20.2	EPA 160.2	1 mg/L	UA Lab
VSS	39	6	84.4	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.6	0.5	16.7	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.07	0.09	-28.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.71	0.92	-29.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.55	0.64	-16.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.49	0.31	36.7	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.010	0.010	0.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	2579	2061	20.1	IDEXX Method	<1	UA Lab
Enterococci	12098	3340	72.4	IDEXX Method	<1	UA Lab
pH	6.74	6.97	-3.4	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	45.80	9.15	80.0	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	46.9	49.2	-4.9	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	26.3	25.6	2.7	SM 212/ EPA 170.1	5 °C	UA Lab

Table 9-5. September 1, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	237	NA*	NA*	29	NA*	NA*	87.8	NA*	NA*
UA Lab	255	49	304	21	2	22	91.9	96.5	92.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 9-6. September 1, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	18634	8870	73	8	3.9	0.9

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

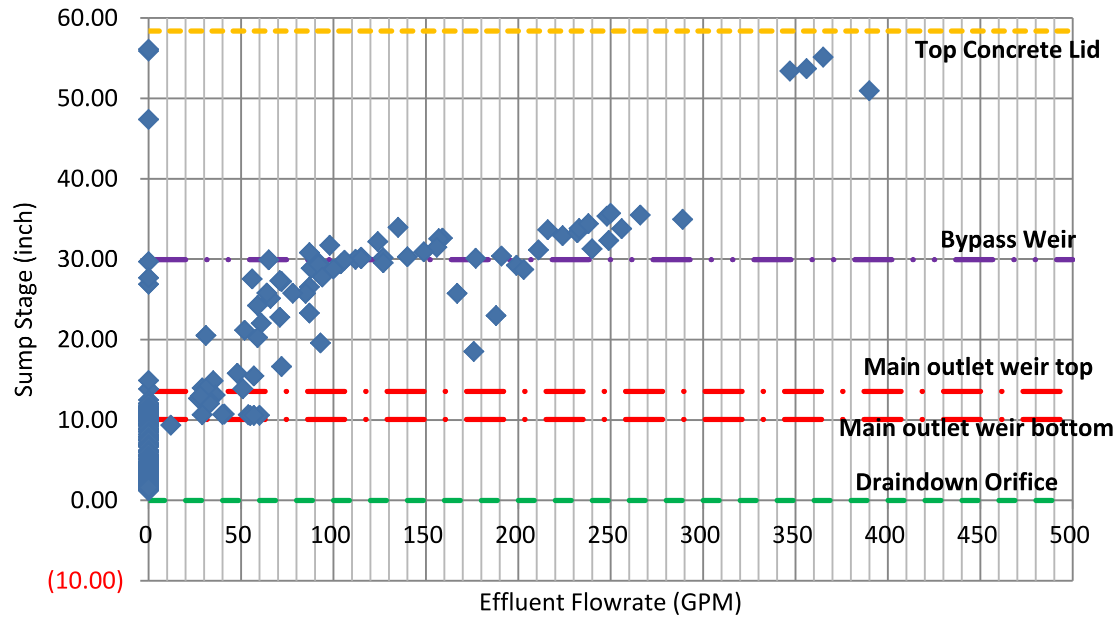
Table 9-7. September 1, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	154	169	162	10	10	10
Millipore Membrane Filter, 0.45µm	182	205	194	9	10	9

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 9-8. September 1, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	2,755	2,402	2,579	2,254	1,868	2,061
Enterococci	10,462	13,734	12,098	3,448	3,232	3,340

Table 9-9. September 1, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	31	46	39	6	6	6

Figure 9-2. September 1, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



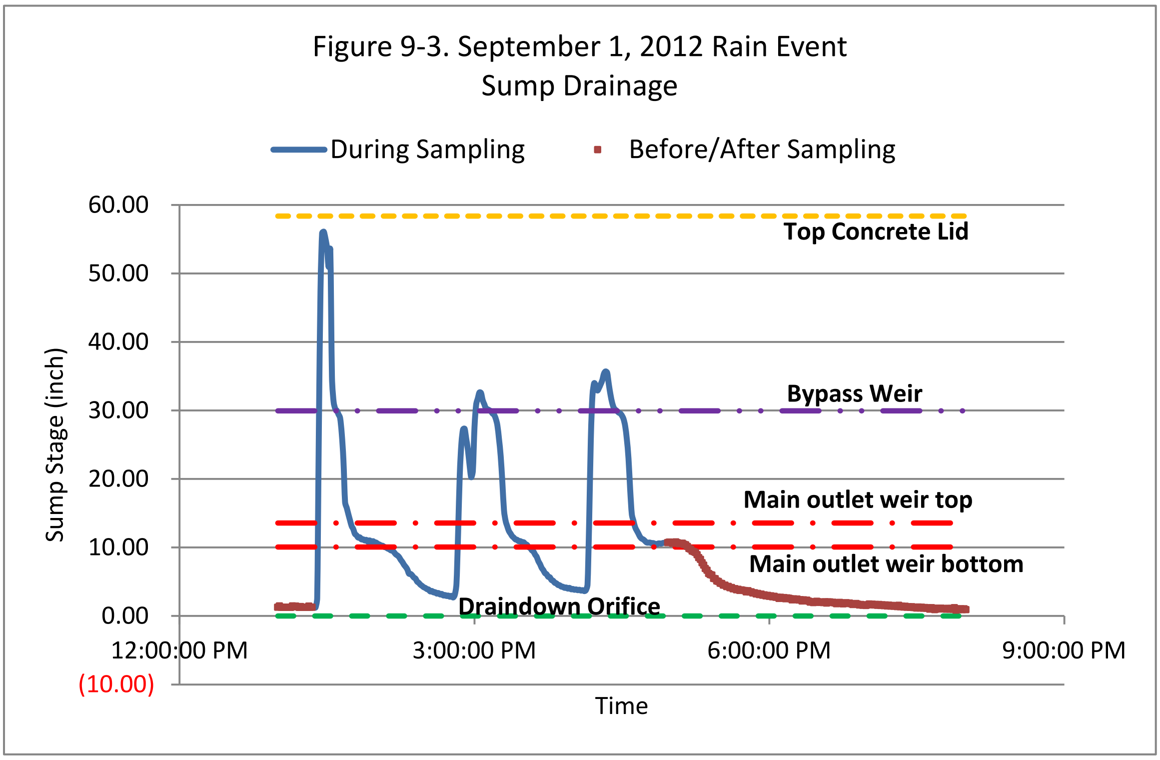


Figure 9-3. September 1, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
12:00:00 PM
3:00:00 PM
6:00:00 PM
9:00:00 PM
Time

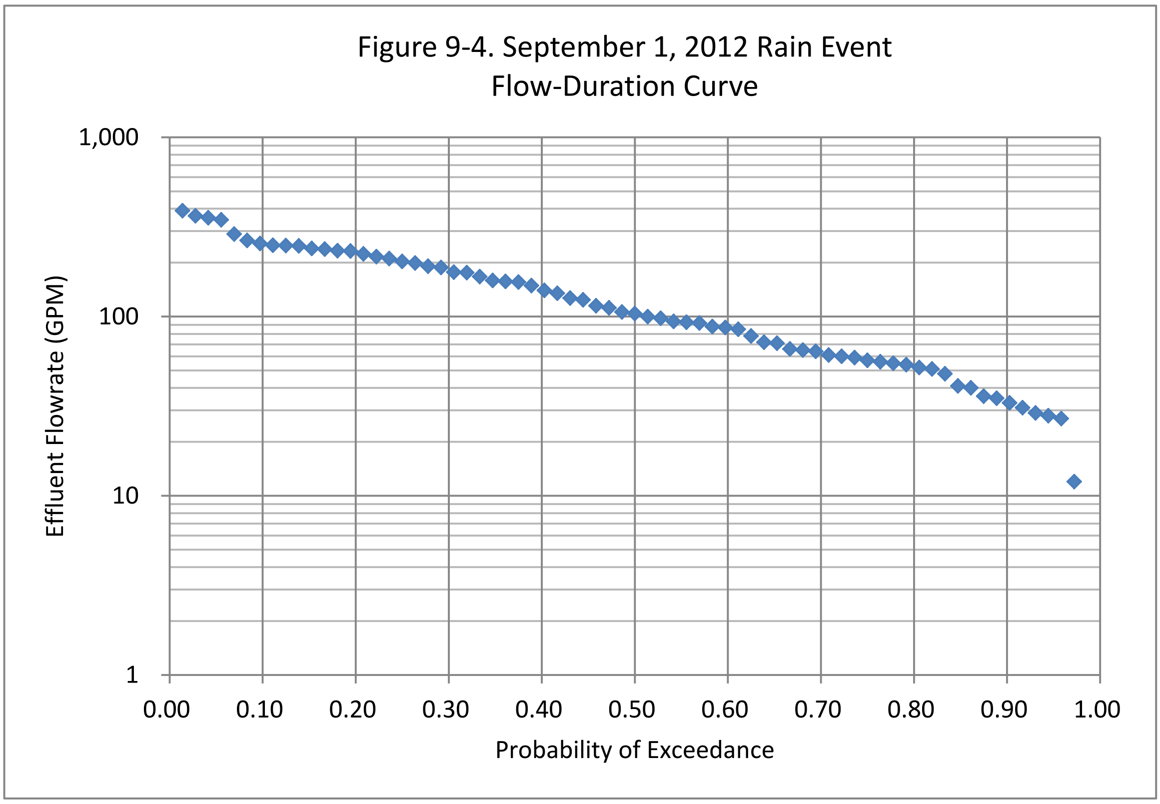


Figure 9-4. September 1, 2012 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 9-5. September 1, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

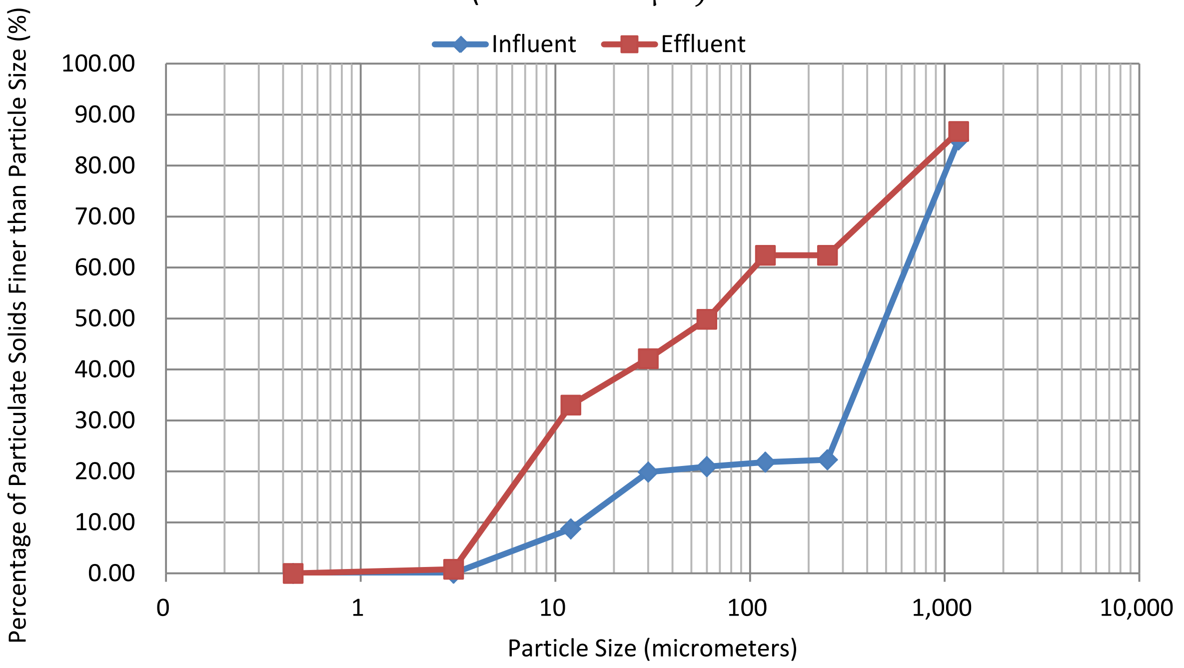
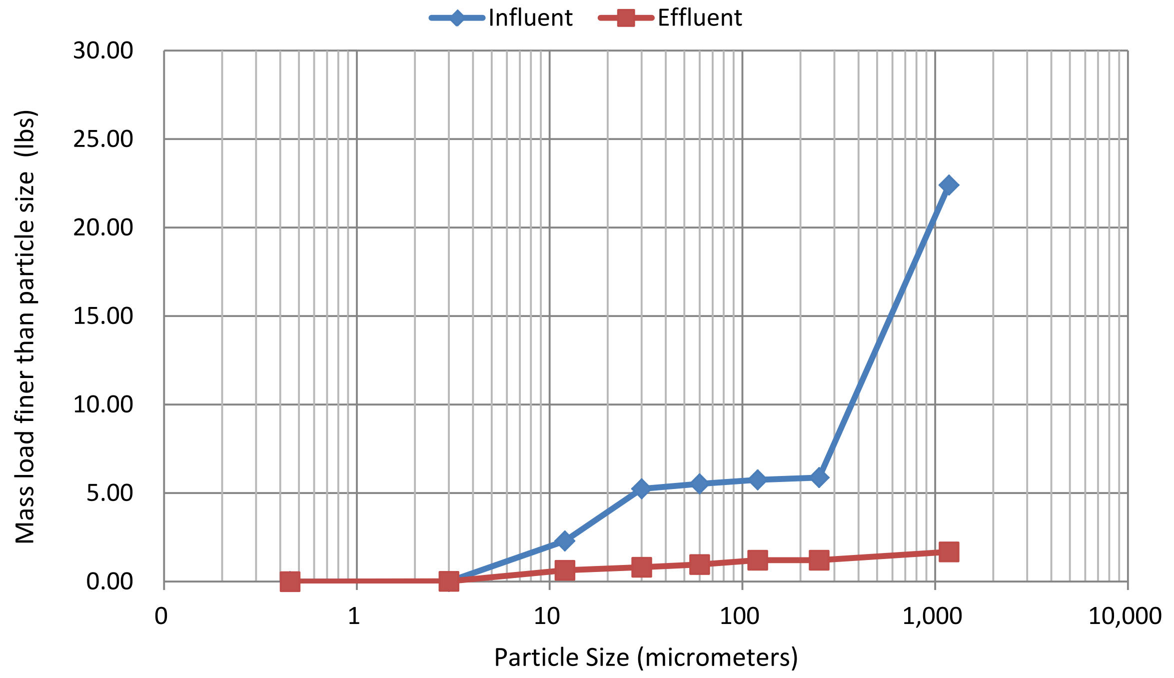


Figure 9-6. September 1, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 3.94 lbs larger than 1180 µm and the effluent had 0.26 lbs larger than 1180 µm (14.96% and 13.30% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 9-10. September 1, 2012 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.10	0.03	0.81	0.01	0.02	-0.01	-86.56
3 to 12	28.48	4.17	8.67	32.20	2.29	0.62	1.66	72.80
12 to 30	36.67	1.18	11.17	9.13	2.94	0.18	2.77	94.01
30 to 60	3.51	1.00	1.07	7.72	0.28	0.15	0.13	47.02
60 to 120	2.84	1.62	0.87	12.53	0.23	0.24	-0.01	-5.99
120 to 250	1.53	0.00	0.47	0.00	0.12	0.00	0.12	100.00
250 to 1180	206.06	3.14	62.76	24.31	16.54	0.47	16.07	97.16
>1180	49.12	1.72	14.96	13.30	3.94	0.26	3.69	93.49
Total	328	13	100.00	100.00	26.35	1.93	24.42	92.67

Table 9-11. September 1, 2012 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.03	0.81	0.01	0.02
<12	8.71	33.01	2.29	0.64
<30	19.88	42.14	5.24	0.81
<60	20.94	49.86	5.52	0.96
<120	21.81	62.39	5.75	1.20
<250	22.28	62.39	5.87	1.20
<1180	85.04	86.70	22.41	1.67
>1180	100.00	100.00	26.35	1.93

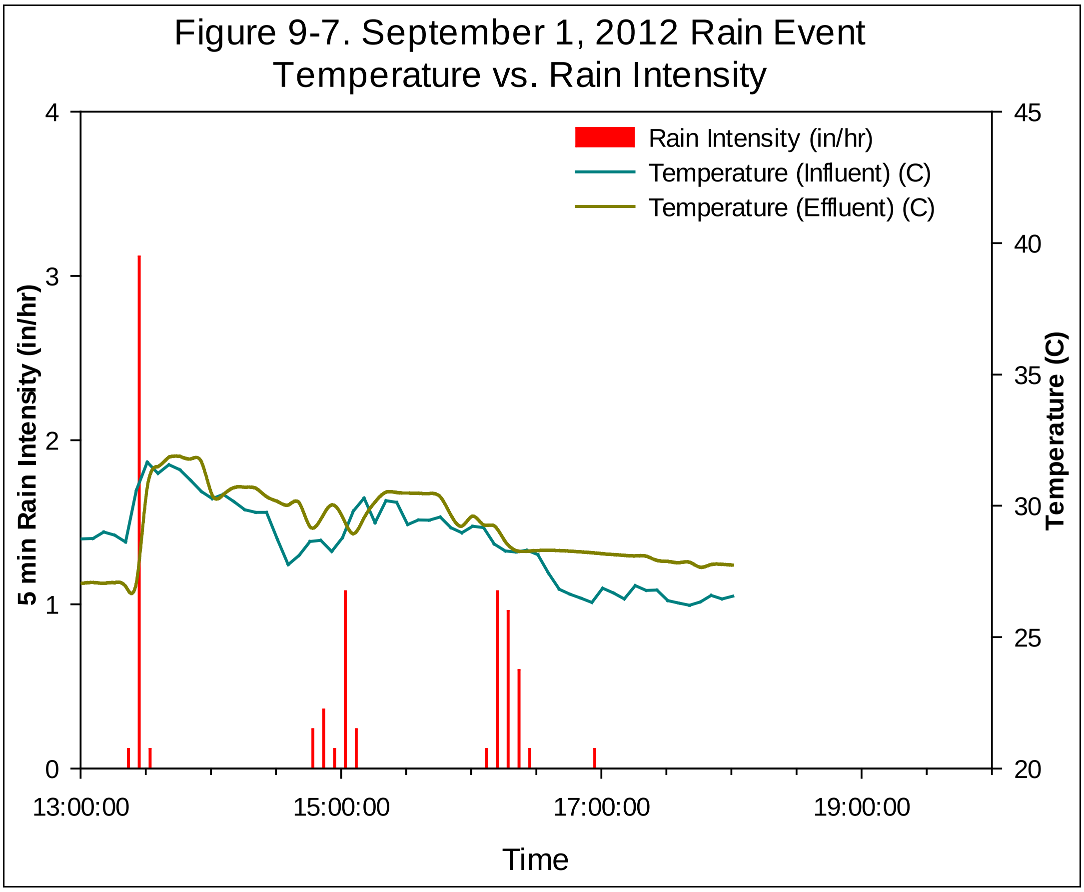


Figure 9-7. September 1, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
Time
4
3
2
1
0
45
40
35
30
25
20
13:00:00
15:00:00
17:00:00
19:00:00

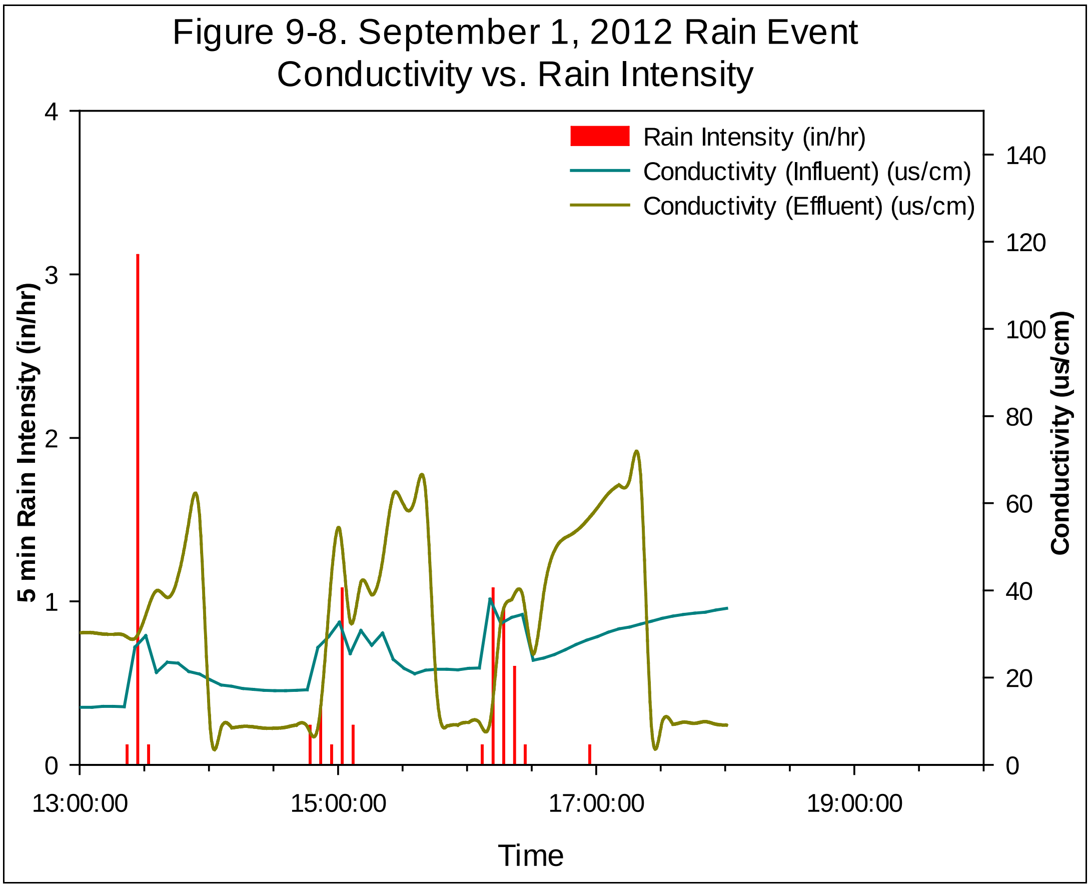


Figure 9-8. September 1, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
Time
4
3
2
1
0
140
120
100
80
60
40
20
0
13:00:00
15:00:00
17:00:00
19:00:00

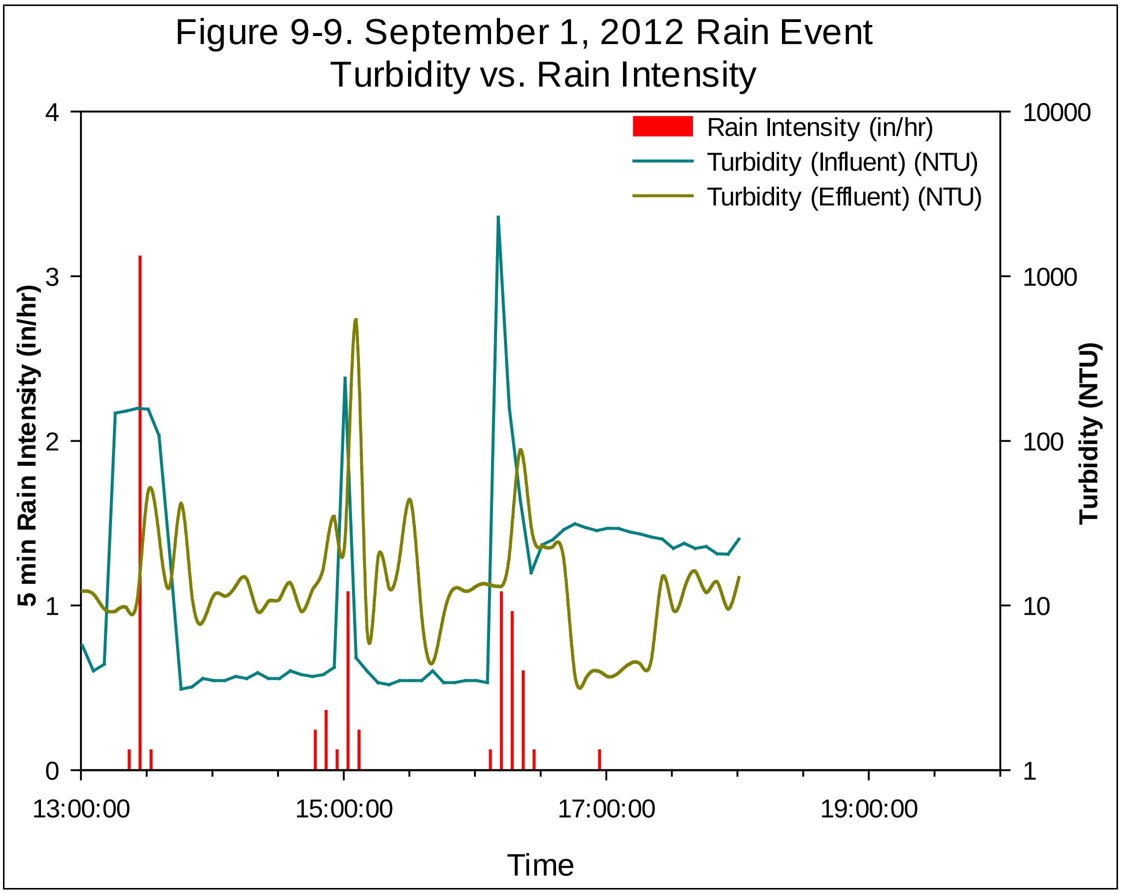
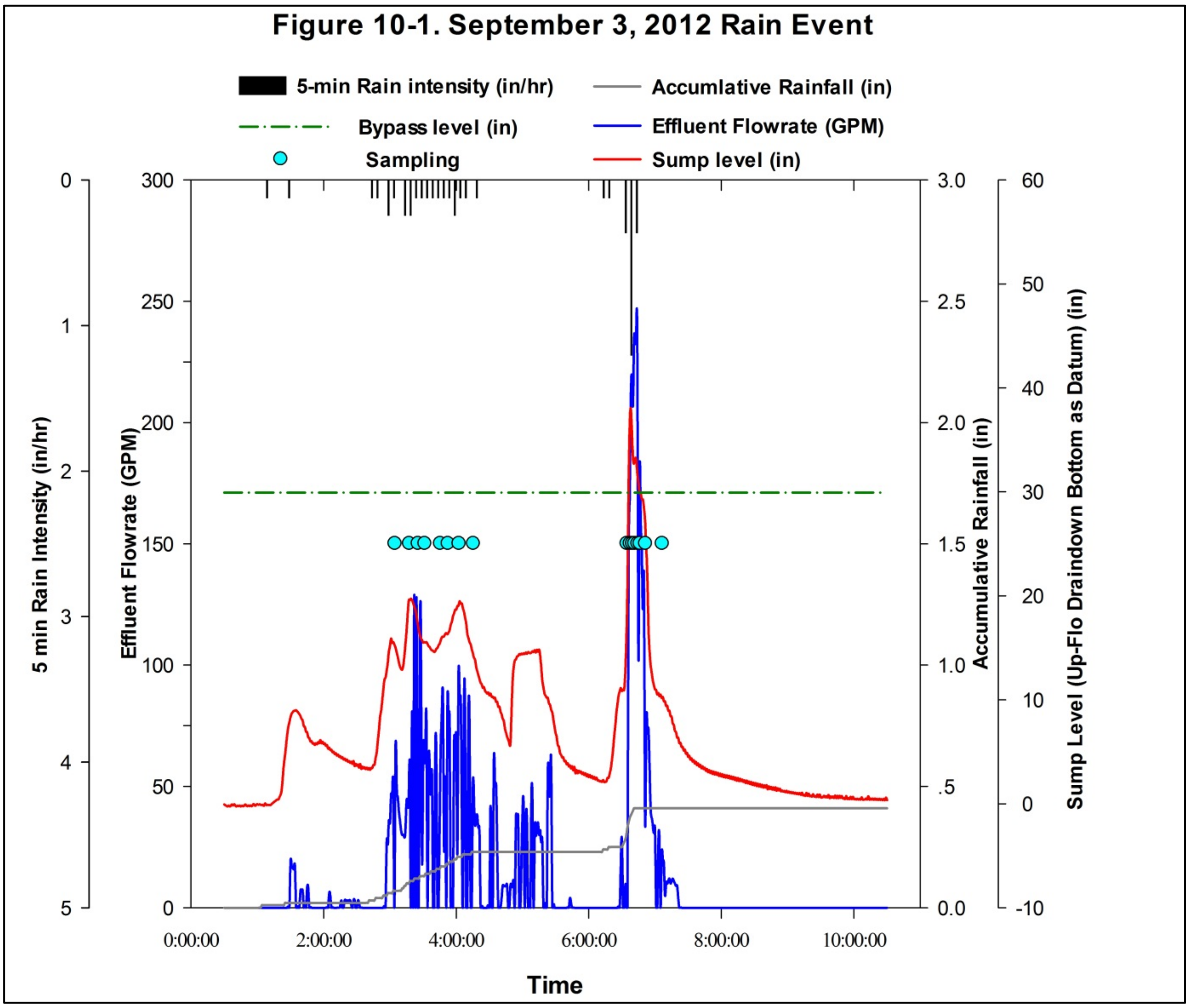


Figure 9-9. September 1, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
0
1
2
3
4
1
10
100
1000
10000
13:00:00
15:00:00
17:00:00
19:00:00
Time



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 10-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.50
Volumetric Runoff Coefficient (Rv)	0.83

Table 10-2. September 3, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/9/3 1:04
Rain Event End Date/Time:			2012/9/3 6:41
Total Precipitation (inch):	≥ 0.1	0.41	
Total Runoff Depth (inch):	NA	0.34	
Total Outflow (gallon):	NA	8509	
Rain Duration (hours):	≥ 1	5.62	
Flow Start Date/Time:			2012/9/3 1:30
Flow End Date/Time:			2012/9/3 7:22
Flow Duration (hours):	NA	5.87	
Average Rain Intensity (in/hr):	NA	0.07	
Average Runoff Rate (gallons/min):	NA	24	
Peak 5-min Rain Intensity (in/hr):	NA	1.20	
Peak Runoff Rate (gallons/min):	NA	239	
Peak to Average Runoff Ratio:	NA	9.89	
Bypassed flow volume (gallon):	NA	315	
Percentage of Bypassed Flow (%):	NA	3.70	
Inter-Event Time since prior rain (hours)	≥ 6.0	36.3	

Table 10-3. September 3, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	16	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	4.0	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	93.23	

Table 10-4. September 3, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	41	14	65.9	SM 2540D	1 mg/L	Stillbrook Lab
TSS	156	11	92.6	SM 2540D	1 mg/L	UA Lab
SSC	157	15	90.4	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	290	13	95.6	ASTM D3977-97B	1 mg/L	UA Lab
TDS	54	50	7.4	EPA 160.2	1 mg/L	UA Lab
VSS	22	6	72.7	SM 2540E	1 mg/L	UA Lab
Total N as N	0.5	0.5	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.4	20.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.13	0.13	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.52	0.46	11.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.37	0.34	8.1	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.007	BDL	> 28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	1582	457	71.1	IDEXX Method	<1	UA Lab
Enterococci	4193	241	94.3	IDEXX Method	<1	UA Lab
pH	6.66	6.97	-4.7	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	42.90	9.11	78.8	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	43.6	47.1	-8.0	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	24.2	24.0	0.8	SM 212/ EPA 170.1	5 °C	UA Lab

Table 10-5. September 3, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	157	NA*	NA*	15	NA*	NA*	90.4	NA*	NA*
UA Lab	217	73	290	10	2	13	95.3	96.6	95.6

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 10-6. September 3, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	9088	8389	28	8	3.1	0.9

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

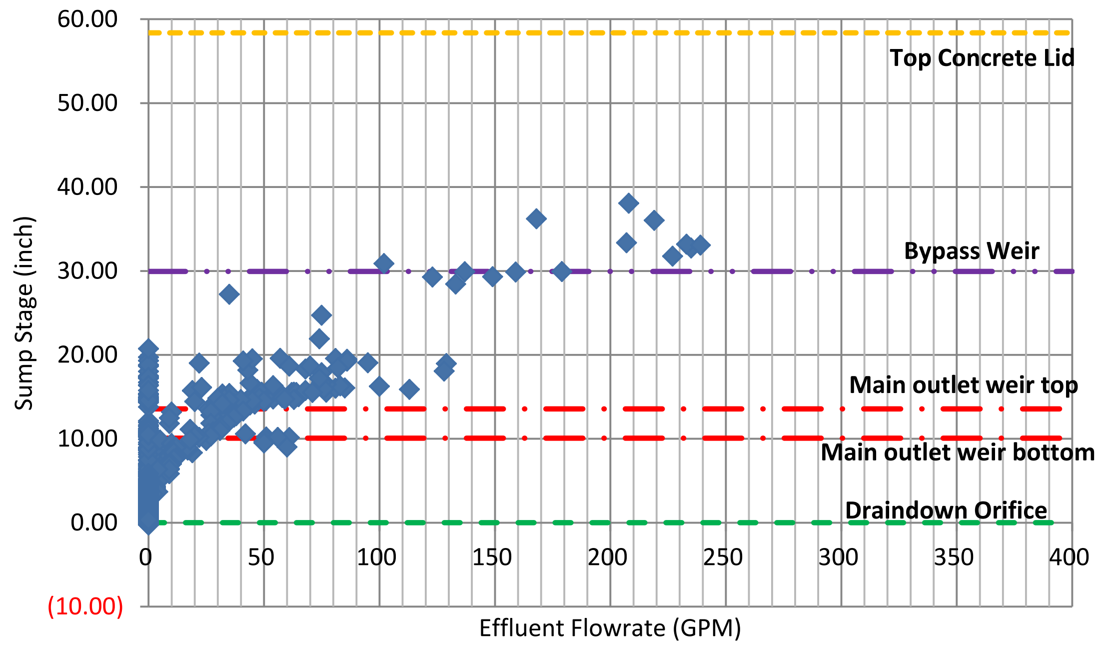
Table 10-7. September 3, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	154	157	156	11	12	11
Millipore Membrane Filter, 0.45µm	157	166	162	11	14	13

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 10-8. September 3, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	1,725	1,438	1,582	487	426	457
Enterococci	5,172	3,214	4,193	309	172	241

Table 10-9. September 3, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	23	21	22	7	5	6

Figure 10-2. September 3, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



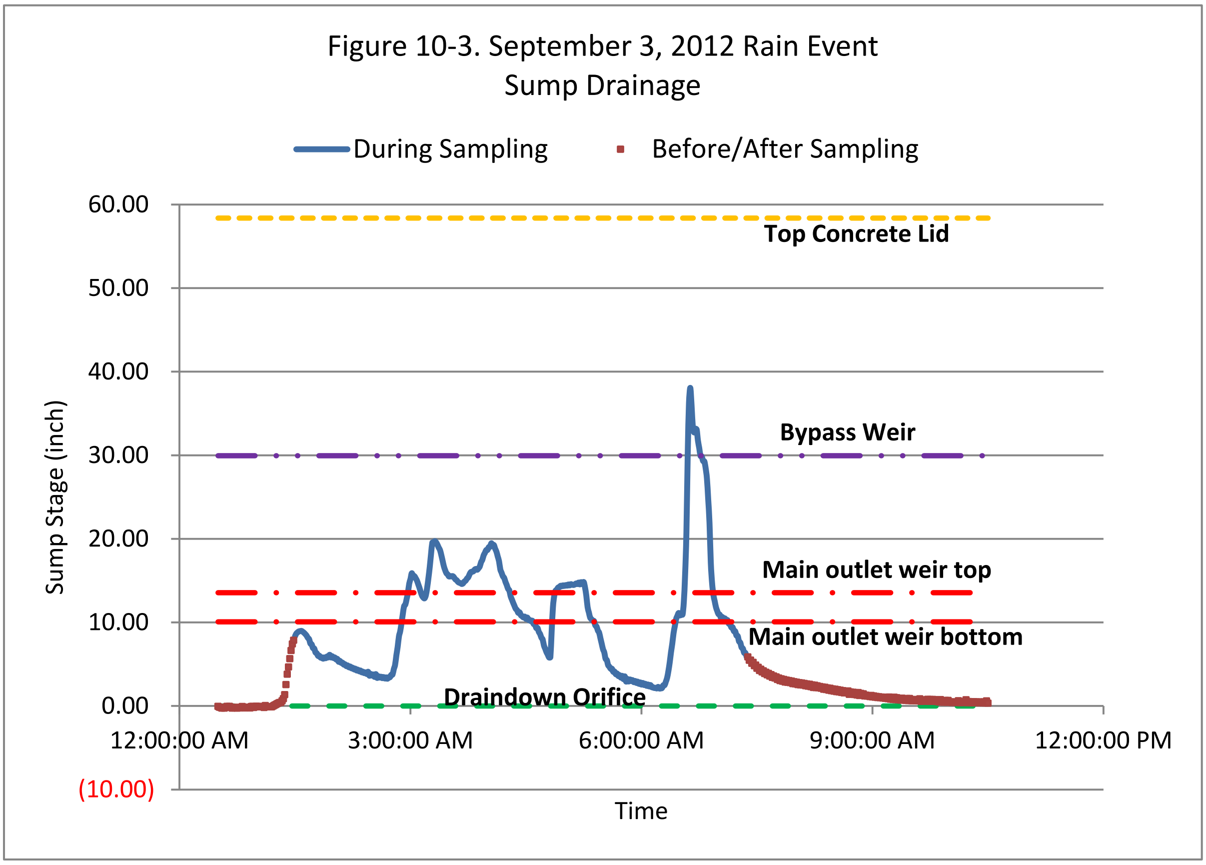


Figure 10-3. September 3, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
12:00:00 PM
Time

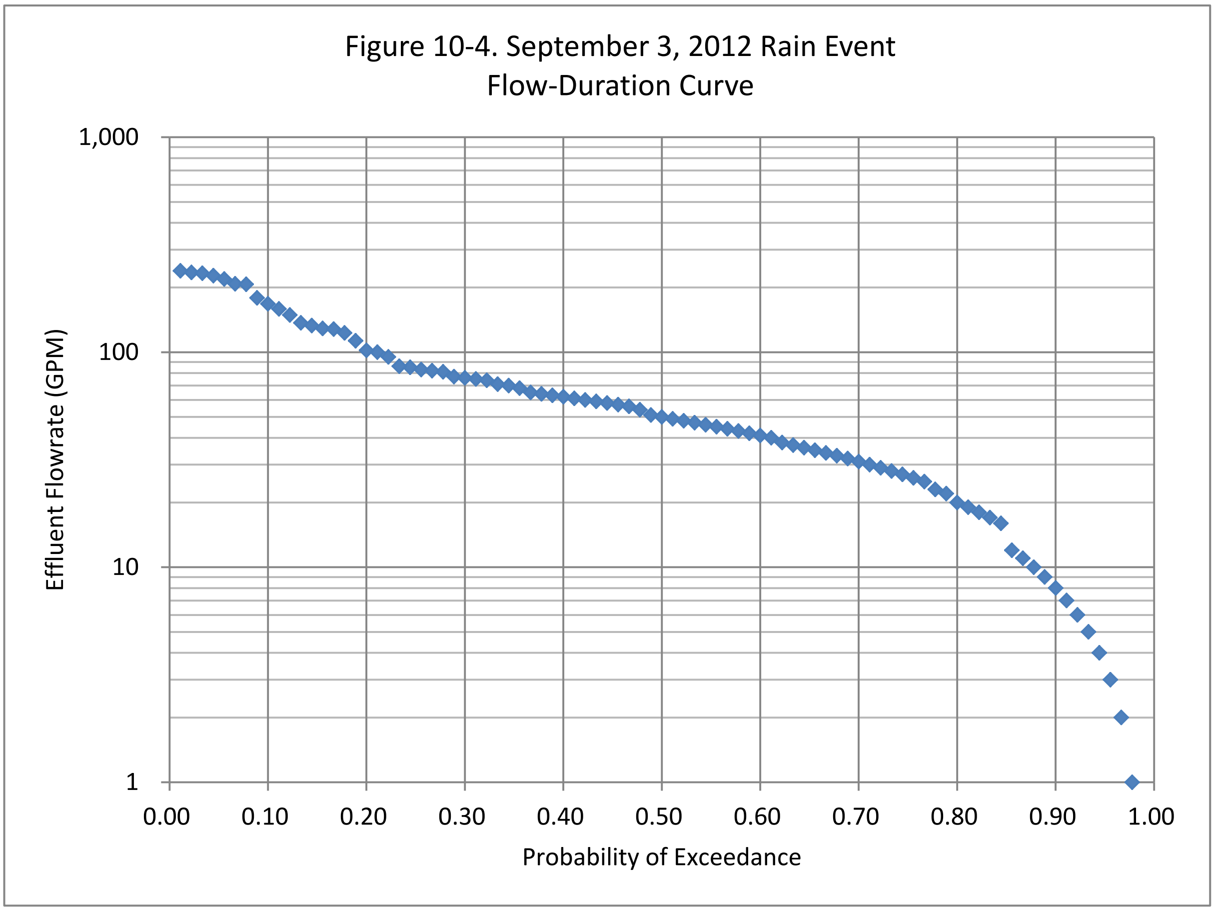
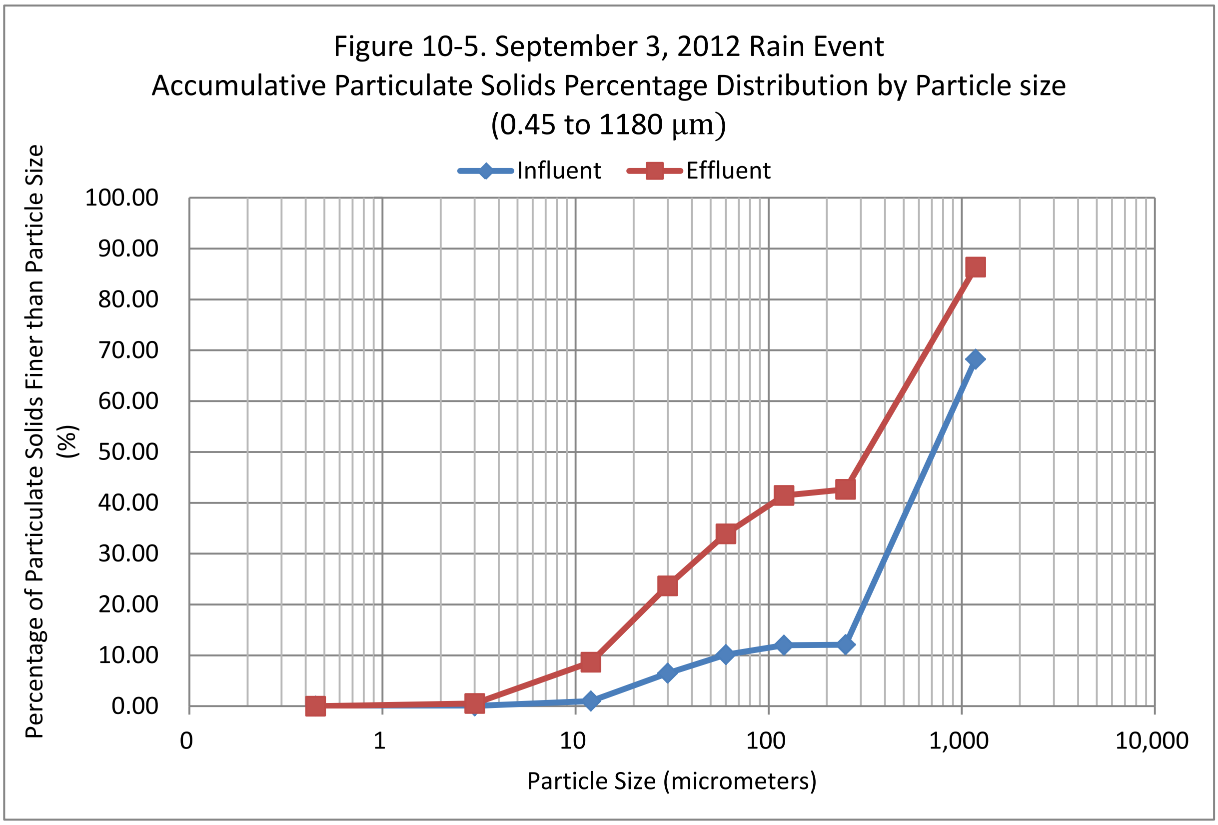
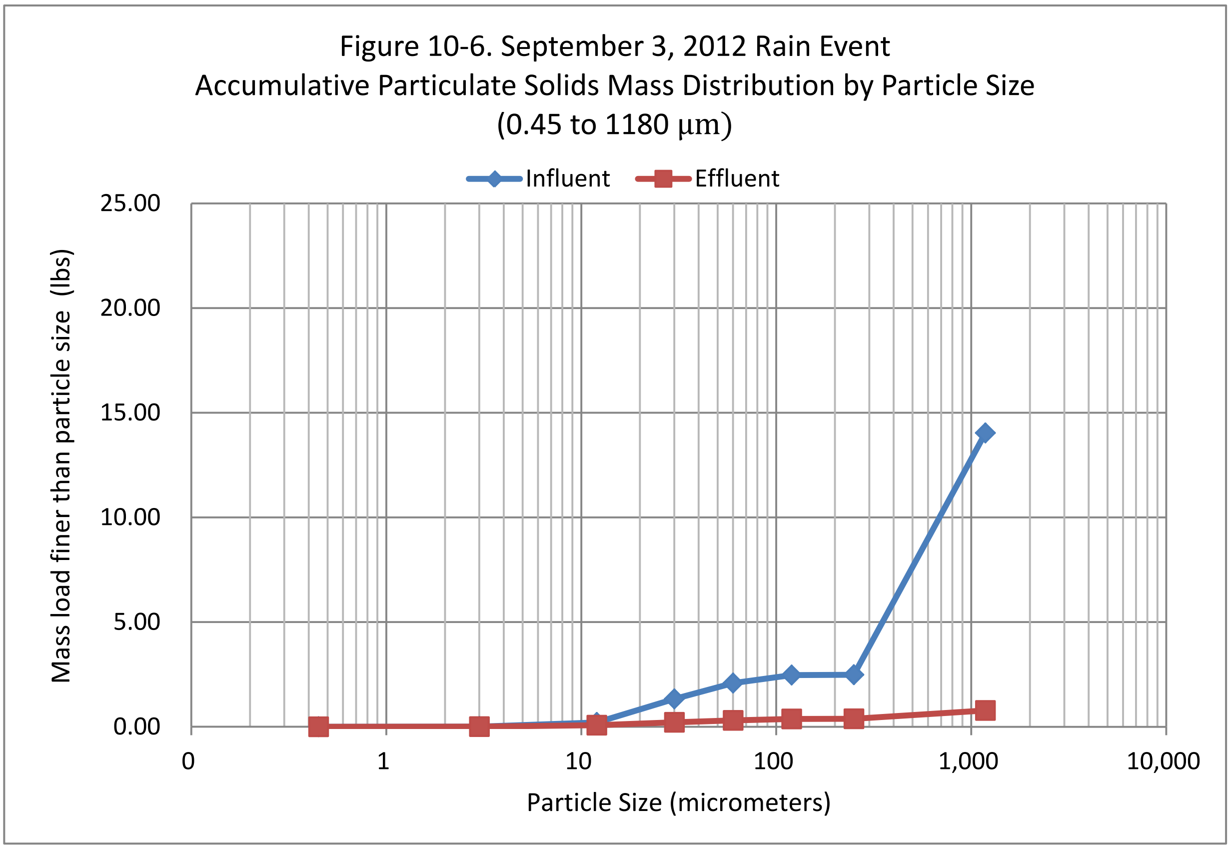


Figure 10-4. September 3, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 6.53 lbs larger than 1180 µm and the effluent had 0.12 lbs larger than 1180 µm (31.77% and 13.64% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 10-10. September 3, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.12	0.10	0.05	0.54	0.01	0.00	0.01	54.27
3 to 12	2.17	1.47	0.94	8.10	0.19	0.07	0.12	62.27
12 to 30	12.70	2.73	5.49	15.01	1.13	0.13	0.99	88.05
30 to 60	8.45	1.86	3.65	10.23	0.75	0.09	0.66	87.75
60 to 120	4.28	1.37	1.85	7.56	0.38	0.07	0.31	82.15
120 to 250	0.20	0.22	0.09	1.20	0.02	0.01	0.01	40.08
250 to 1180	129.83	7.94	56.15	43.72	11.55	0.39	11.15	96.60
>1180	73.45	2.48	31.77	13.64	6.53	0.12	6.41	98.12
Total	231	18	100.00	100.00	20.56	0.90	19.66	95.63

Table 10-11. September 3, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.05	0.54	0.01	0.00
<12	0.99	8.64	0.20	0.08
<30	6.49	23.65	1.33	0.21
<60	10.14	33.88	2.08	0.30
<120	11.99	41.44	2.47	0.37
<250	12.08	42.64	2.48	0.38
<1180	68.23	86.36	14.03	0.78
>1180	100.00	100.00	20.56	0.90

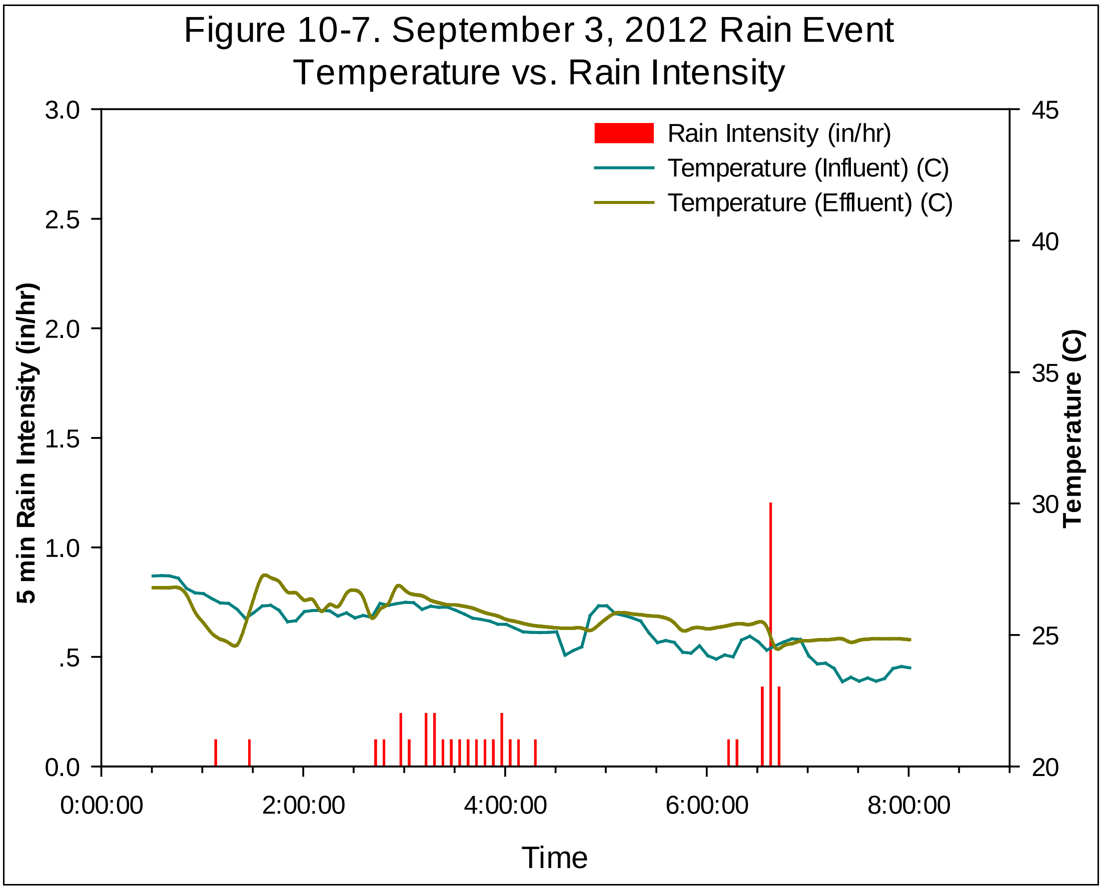


Figure 10-7. September 3, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
45
40
35
30
25
20
0:00:00
2:00:00
4:00:00
6:00:00
8:00:00

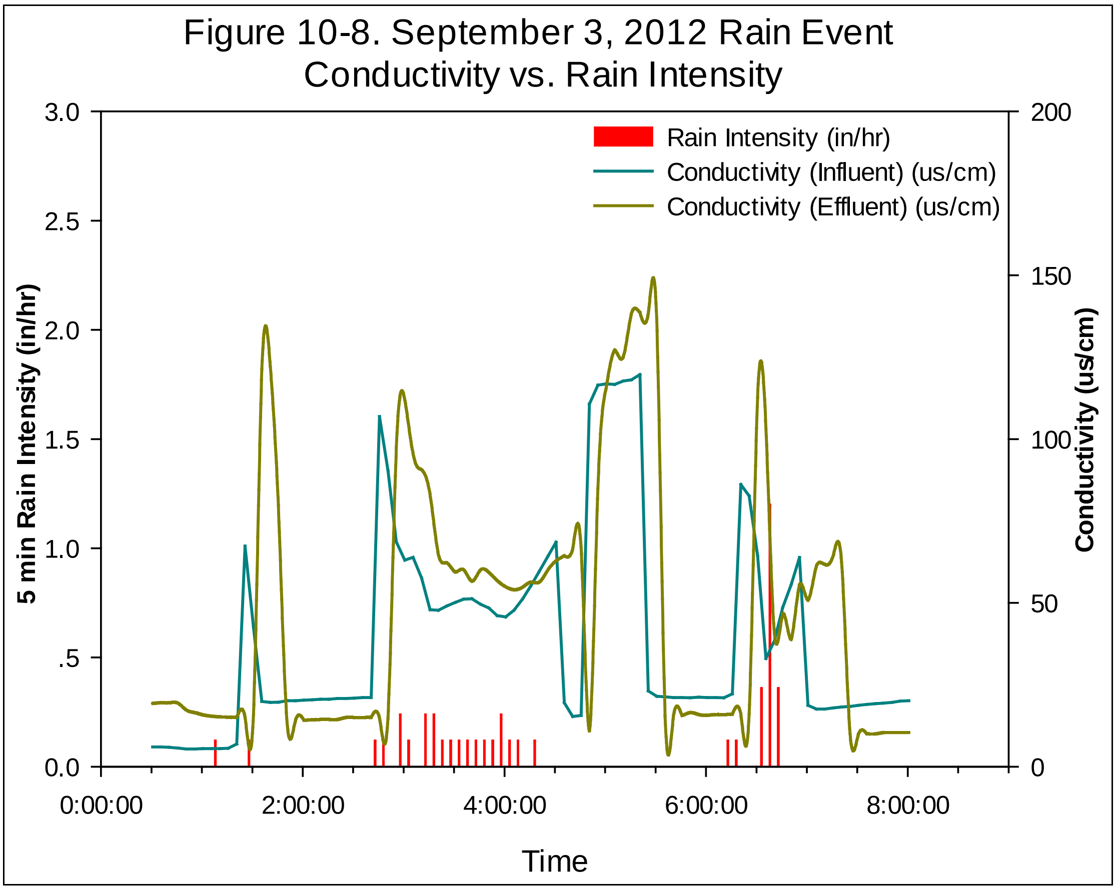


Figure 10-8. September 3, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
0:00:00
2:00:00
4:00:00
6:00:00
8:00:00

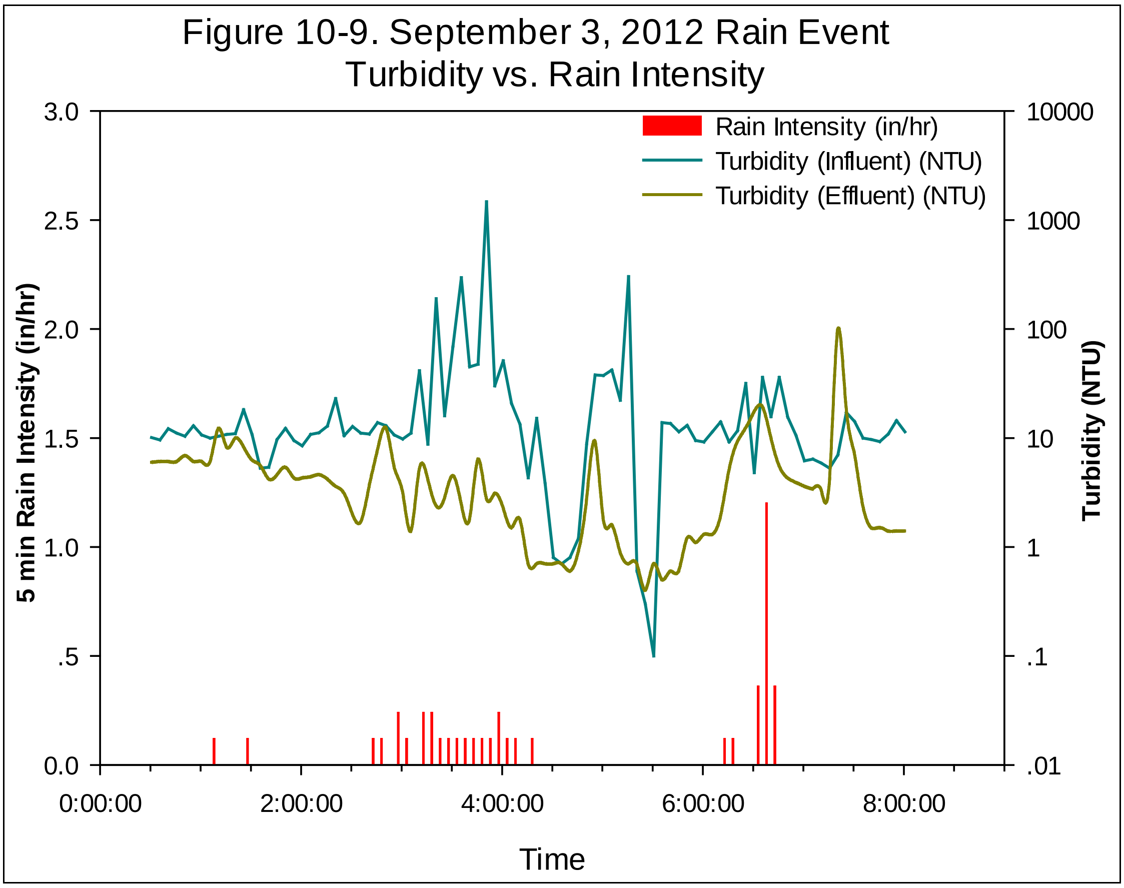
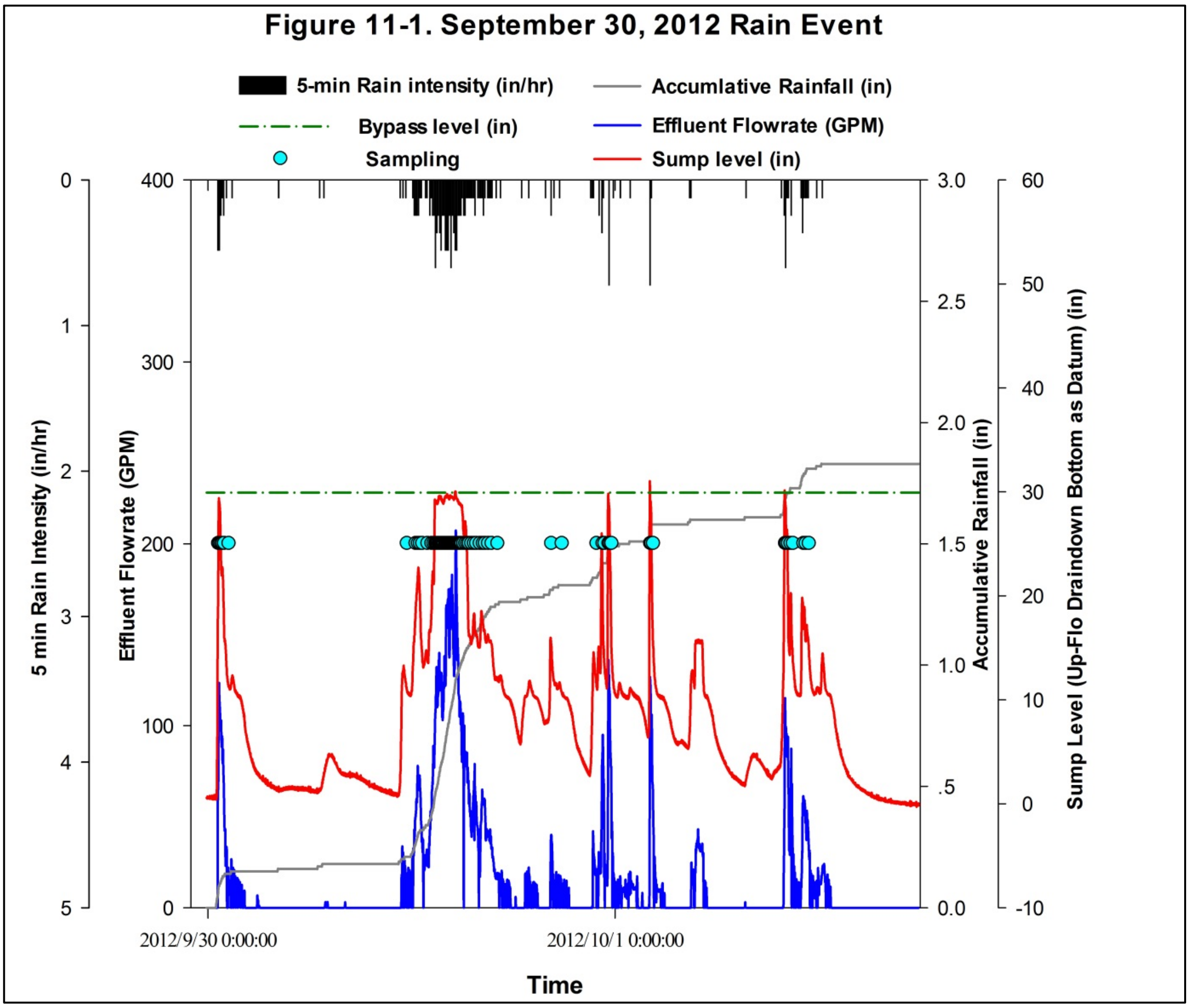


Figure 10-9. September 3, 2012 Rain Event
Turbidity vs. Rain Intensity
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
.1
.01
0:00:00
2:00:00
4:00:00
6:00:00
8:00:00
Time

Appendix F.11: September 30, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 11-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.72
Volumetric Runoff Coefficient (Rv)	0.88

Table 11-2. September 30, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/9/30 0:29
Rain Event End Date/Time:			2012/10/1 12:10
Total Precipitation (inch):	≥ 0.1	1.83	
Total Runoff Depth (inch):	NA	1.61	
Total Outflow (gallon):	NA	39335	
Rain Duration (hours):	≥ 1	35.68	
Flow Start Date/Time:			2012/9/30 0:35
Flow End Date/Time:			2012/10/1 12:44
Flow Duration (hours):	NA	36.15	
Average Rain Intensity (in/hr):	NA	0.05	
Average Runoff Rate (gallons/min):	NA	18	
Peak 5-min Rain Intensity (in/hr):	NA	0.72	
Peak Runoff Rate (gallons/min):	NA	206	
Peak to Average Runoff Ratio:	NA	11.36	
Bypassed flow volume (gallon):	NA	3	
Percentage of Bypassed Flow (%):	NA	0.01	
Inter-Event Time since prior rain (hours)	≥ 6.0	631.77	

Table 11-3. September 30, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	74	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	18.5	Total actual volume was a little bit lower than programmed ones (About 17 Liter)
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.87	

Table 11-4. September 30, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	21	8	61.9	SM 2540D	1 mg/L	Stillbrook Lab
TSS	21	4	83.7	SM 2540D	1 mg/L	UA Lab
SSC	30	8	73.3	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	23	6	75.8	ASTM D3977-97B	1 mg/L	UA Lab
TDS	38	39	-2.6	EPA 160.2	1 mg/L	UA Lab
VSS	13	1	92.3	SM 2540E	1 mg/L	UA Lab
Total N as N	0.9	0.7	22.2	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.09	0.08	11.1	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.71	0.55	22.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.58	0.49	15.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.022	0.011	50.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	18096	> 62.6	IDEXX Method	<1	UA Lab
E. Coli	3982	1061	73.4	IDEXX Method	<1	UA Lab
Enterococci	1003	171	83.0	IDEXX Method	<1	UA Lab
pH	6.62	6.94	-4.8	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	6.74	3.06	54.7	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	39.1	40.7	-4.1	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	26.3	26.0	1.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 11-5. September 30, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	30	NA*	NA*	8	NA*	NA*	73.3	NA*	NA*
UA Lab	22	2	23	5	0	6	75.3	82.2	75.8

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 11-6. September 30, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	12882	2518	17	4	1.3	1.6

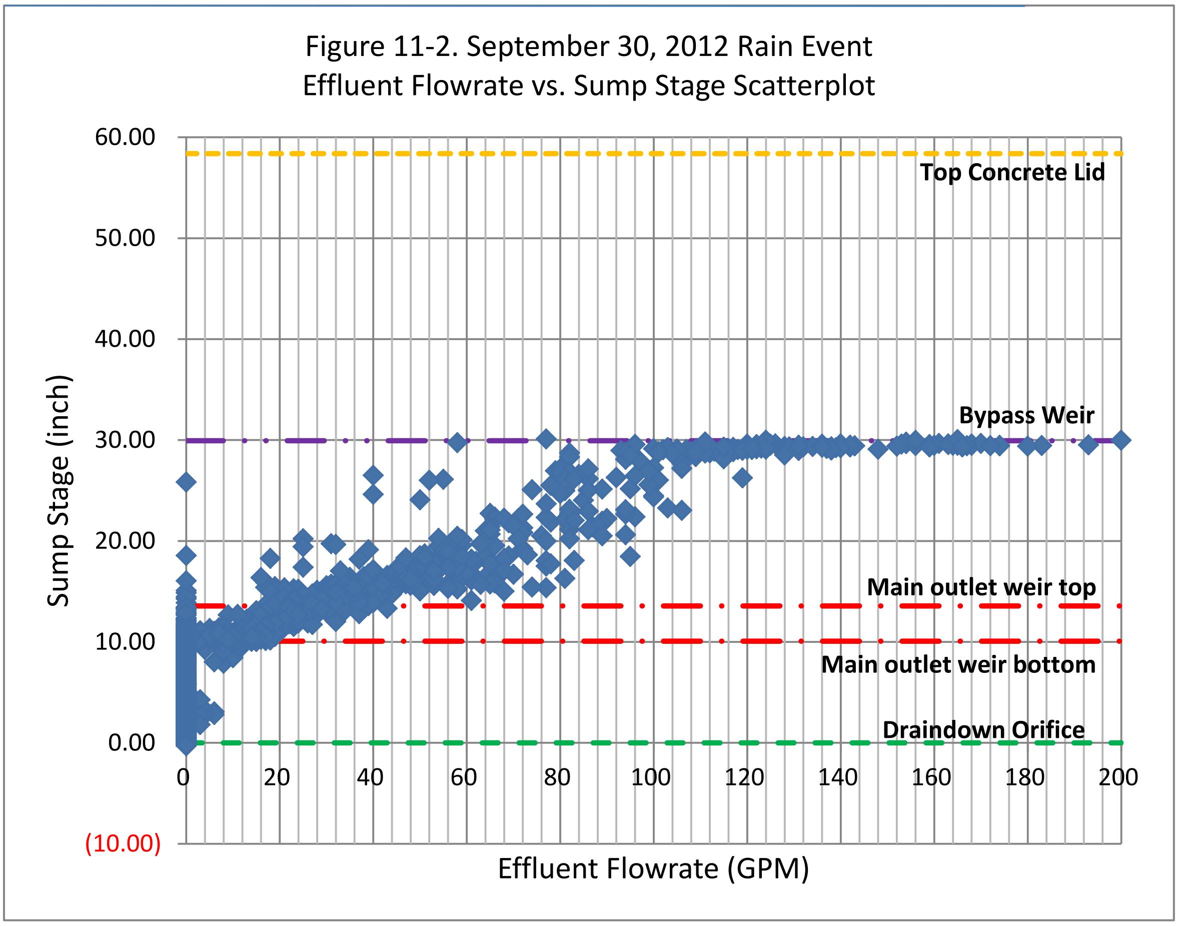
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 11-7. September 30, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	19	24	21	3	4	4
Millipore Membrane Filter, 0.45µm	13	16	15	3	3	3

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 11-8. September 30, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	19,863	16,328	18,096
E. Coli	5,172	2,792	3,982	933	1,188	1,061
Enterococci	1,014	992	1,003	97	244	171

Table 11-9. September 30, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	13	13	13	1	1	1



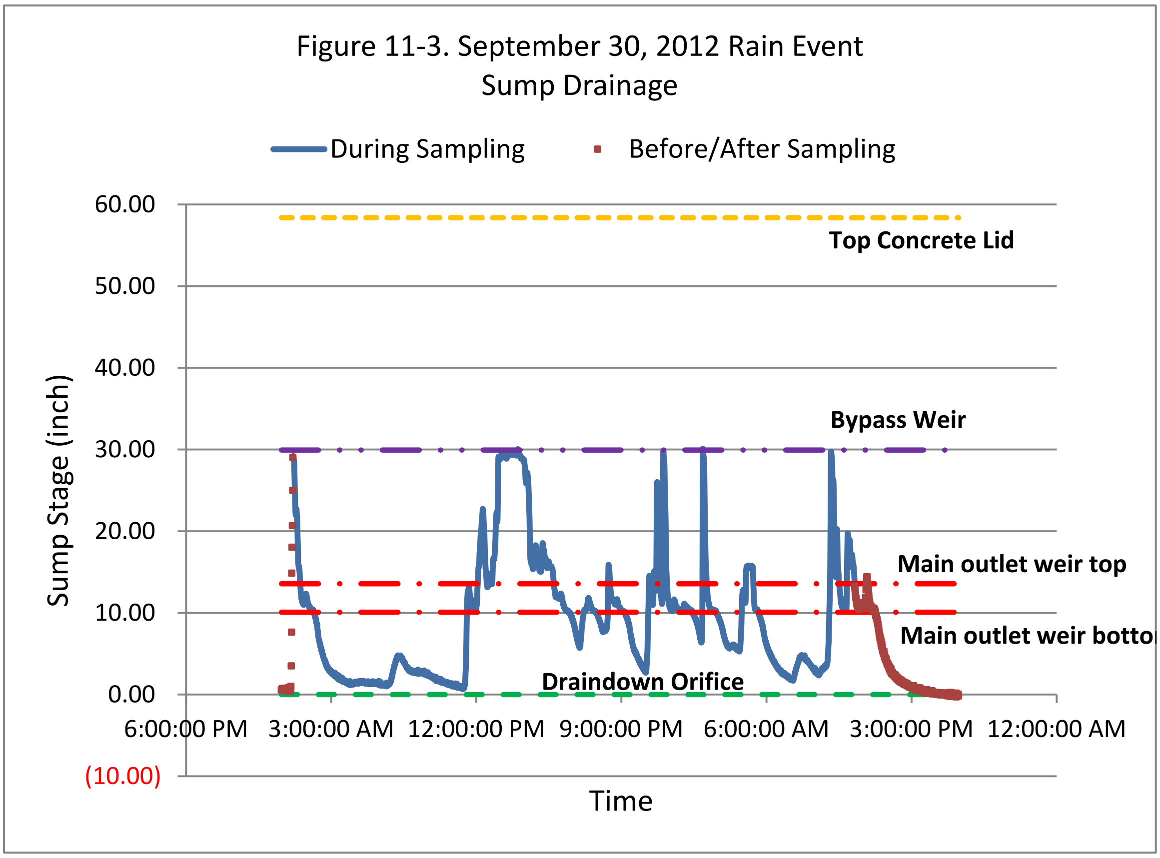


Figure 11-3. September 30, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir botto
Draindown Orifice
6:00:00 PM
3:00:00 AM
12:00:00 PM
9:00:00 PM
6:00:00 AM
3:00:00 PM
12:00:00 AM
Time

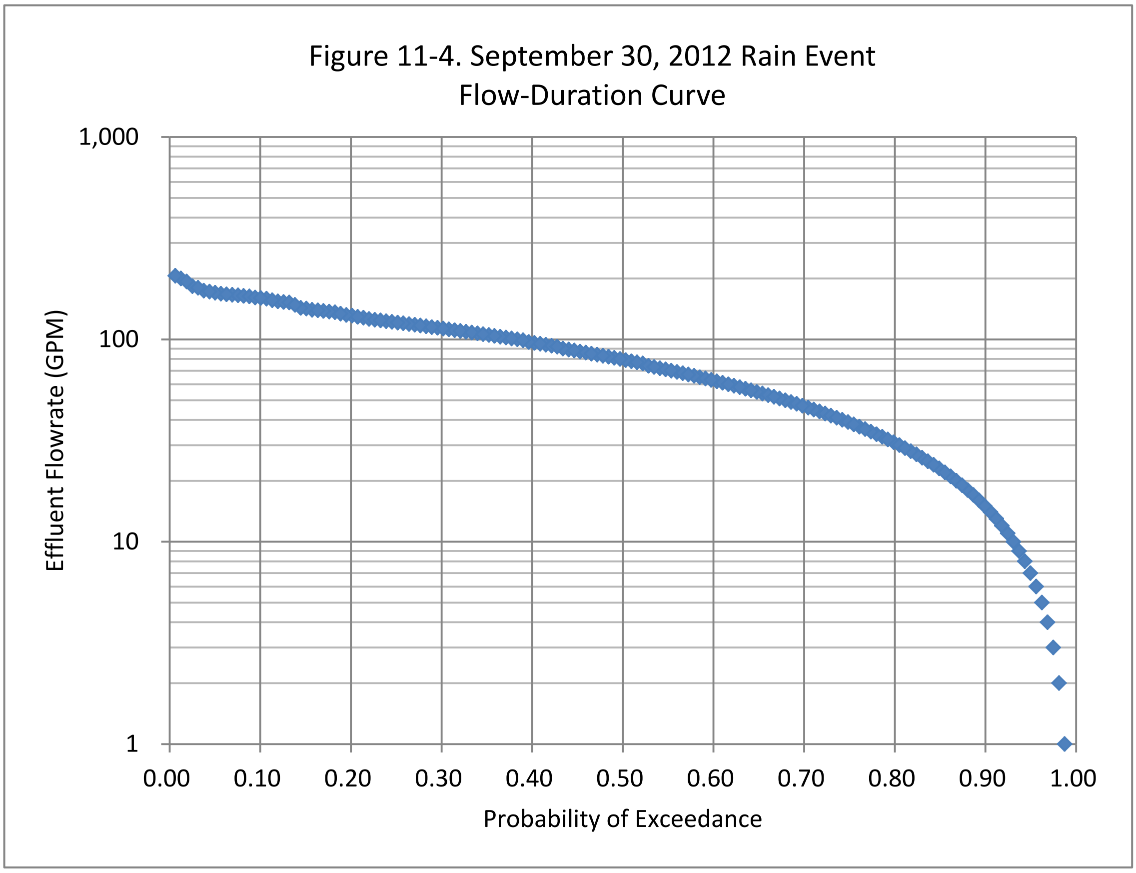
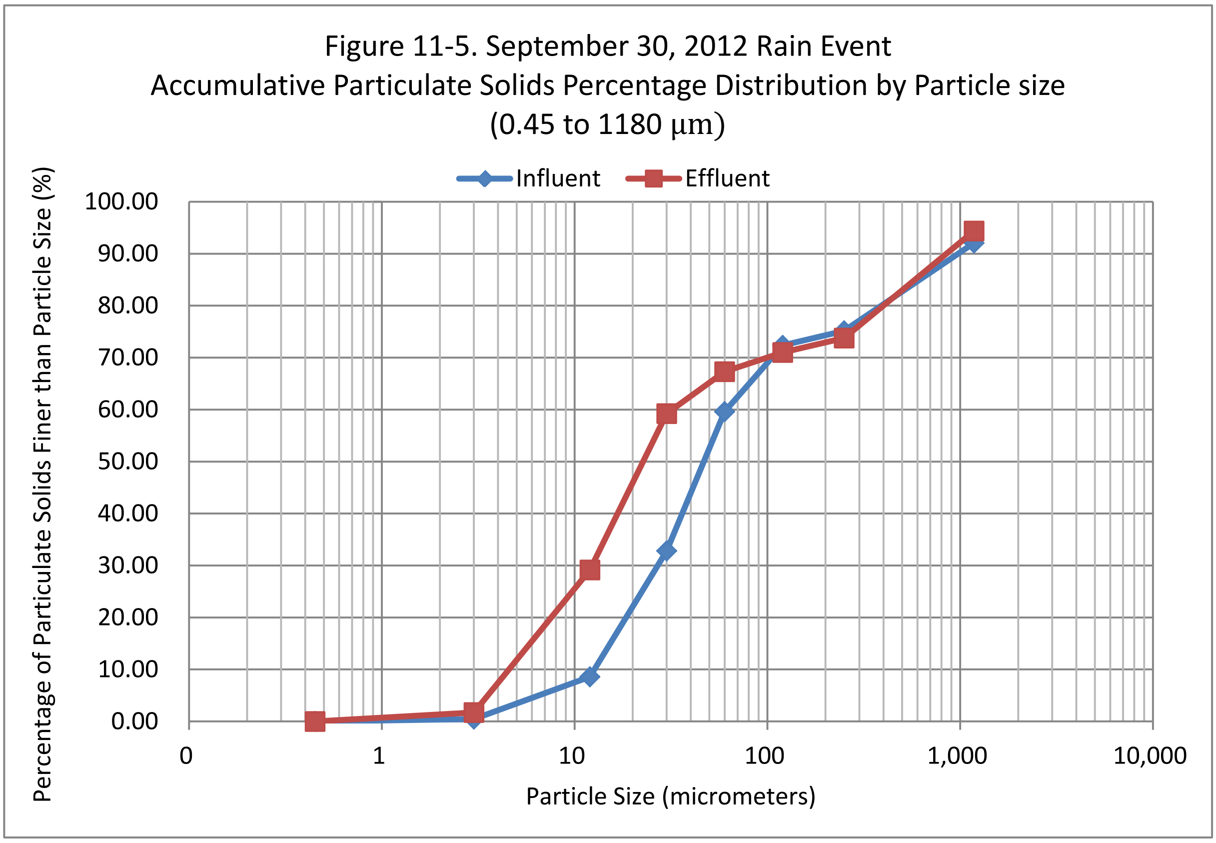
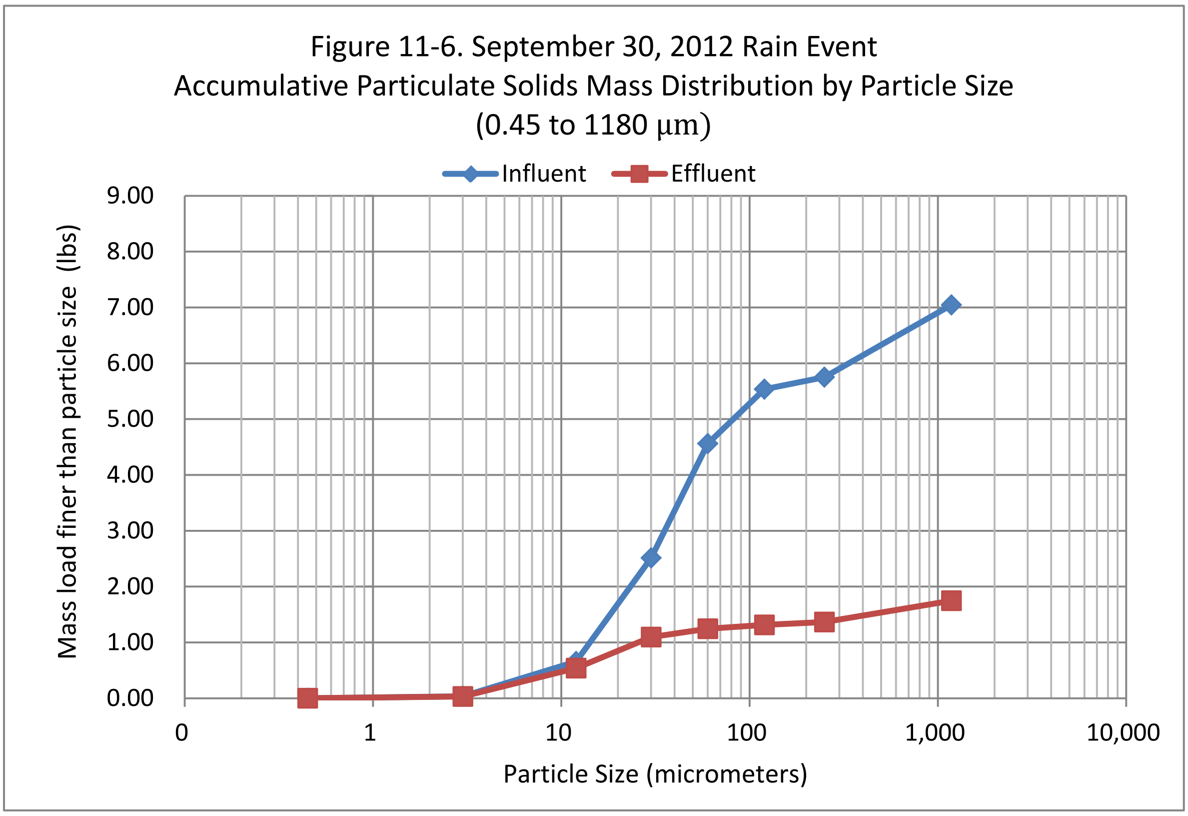


Figure 11-4. September 30, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 0.61 lbs larger than 1180 µm and the effluent had 0.10 lbs larger than 1180 µm (7.95% and 5.63% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 11-10. September 30, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.10	0.44	1.72	0.03	0.03	0.00	6.72
3 to 12	1.86	1.56	8.14	27.44	0.62	0.51	0.12	18.49
12 to 30	5.55	1.71	24.24	30.09	1.85	0.56	1.30	69.99
30 to 60	6.13	0.46	26.78	8.08	2.05	0.15	1.90	92.70
60 to 120	2.92	0.21	12.75	3.69	0.98	0.07	0.91	93.00
120 to 250	0.64	0.16	2.80	2.77	0.21	0.05	0.16	76.09
250 to 1180	3.87	1.17	16.90	20.59	1.29	0.38	0.91	70.54
>1180	1.82	0.32	7.95	5.63	0.61	0.10	0.50	82.88
Total	23	6	100.00	100.00	7.65	1.85	5.80	75.82

Table 11-11. September 30, 2012 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.44	1.72	0.03	0.03
<12	8.58	29.15	0.66	0.54
<30	32.82	59.24	2.51	1.10
<60	59.60	67.32	4.56	1.25
<120	72.36	71.01	5.54	1.31
<250	75.15	73.78	5.75	1.36
<1180	92.05	94.37	7.04	1.75
>1180	100.00	100.00	7.65	1.85

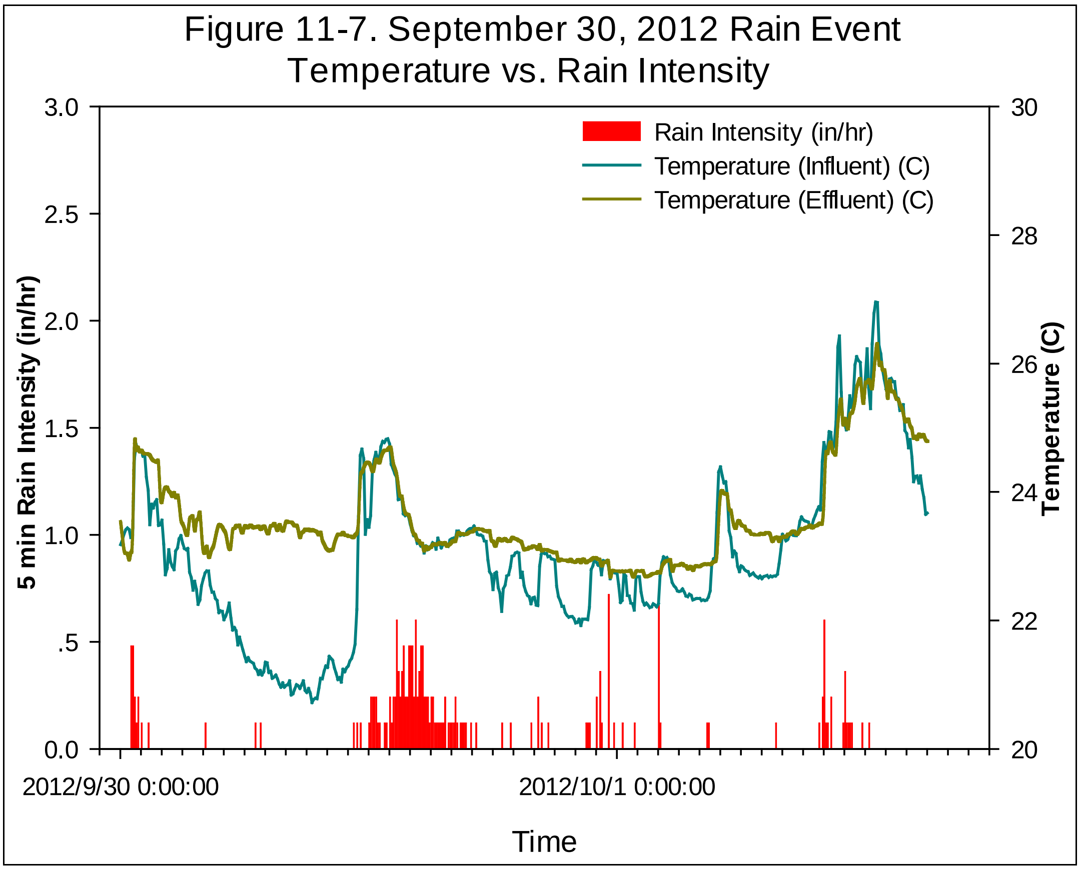


Figure 11-7. September 30, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
30
28
26
24
22
20
2012/9/30 0:00:00
2012/10/1 0:00:00
Time

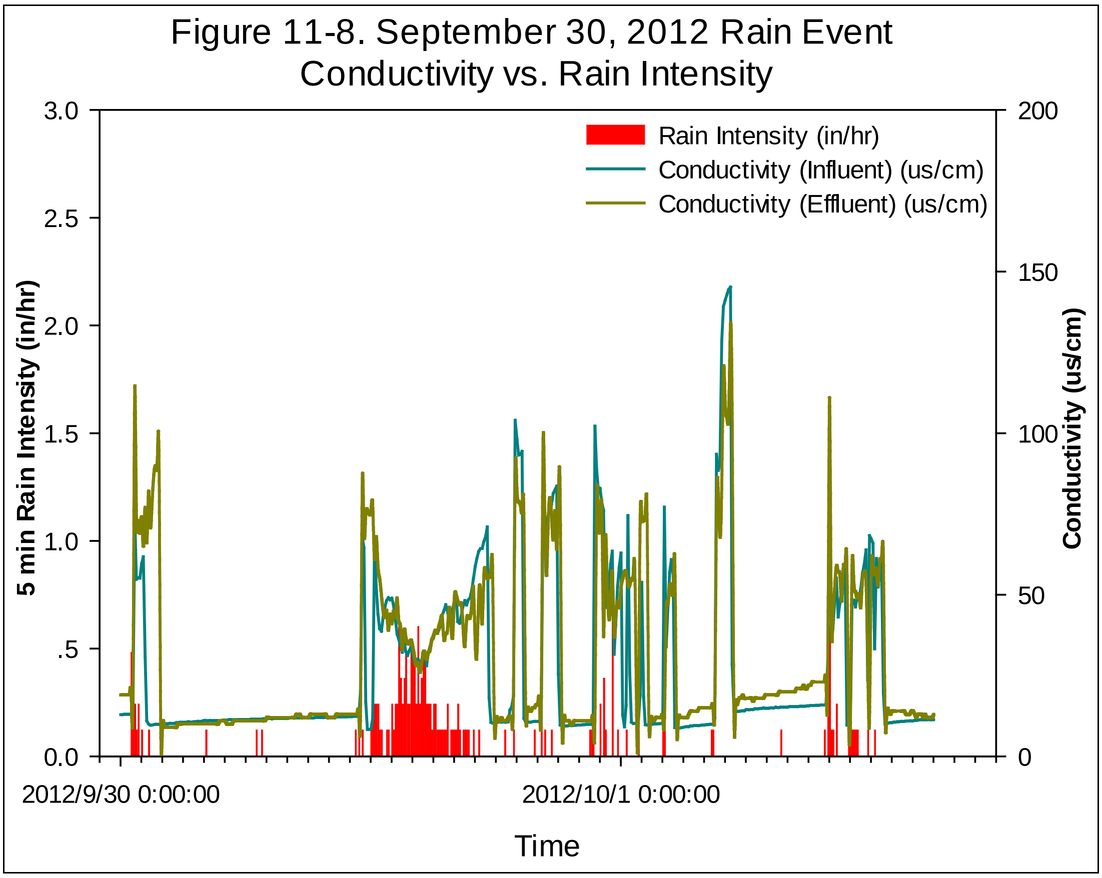


Figure 11-8. September 30, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
2012/9/30 0:00:00
2012/10/1 0:00:00
Time

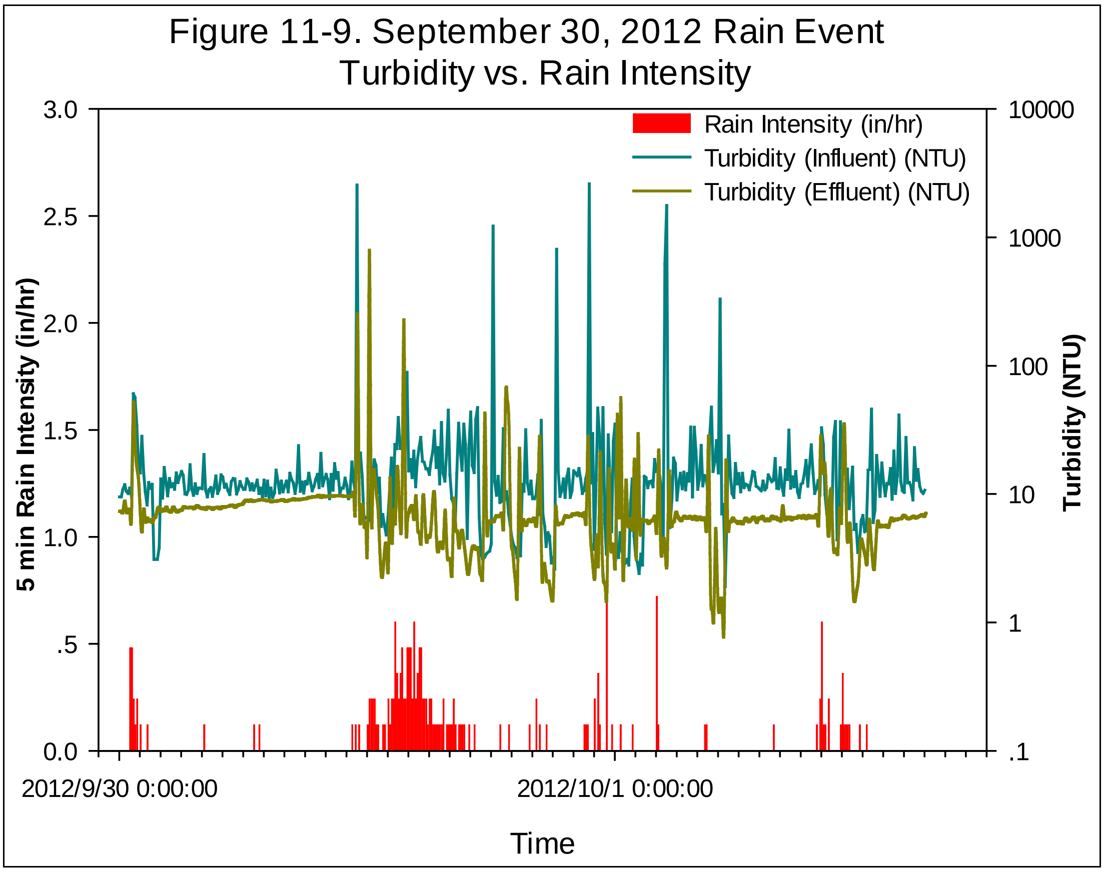
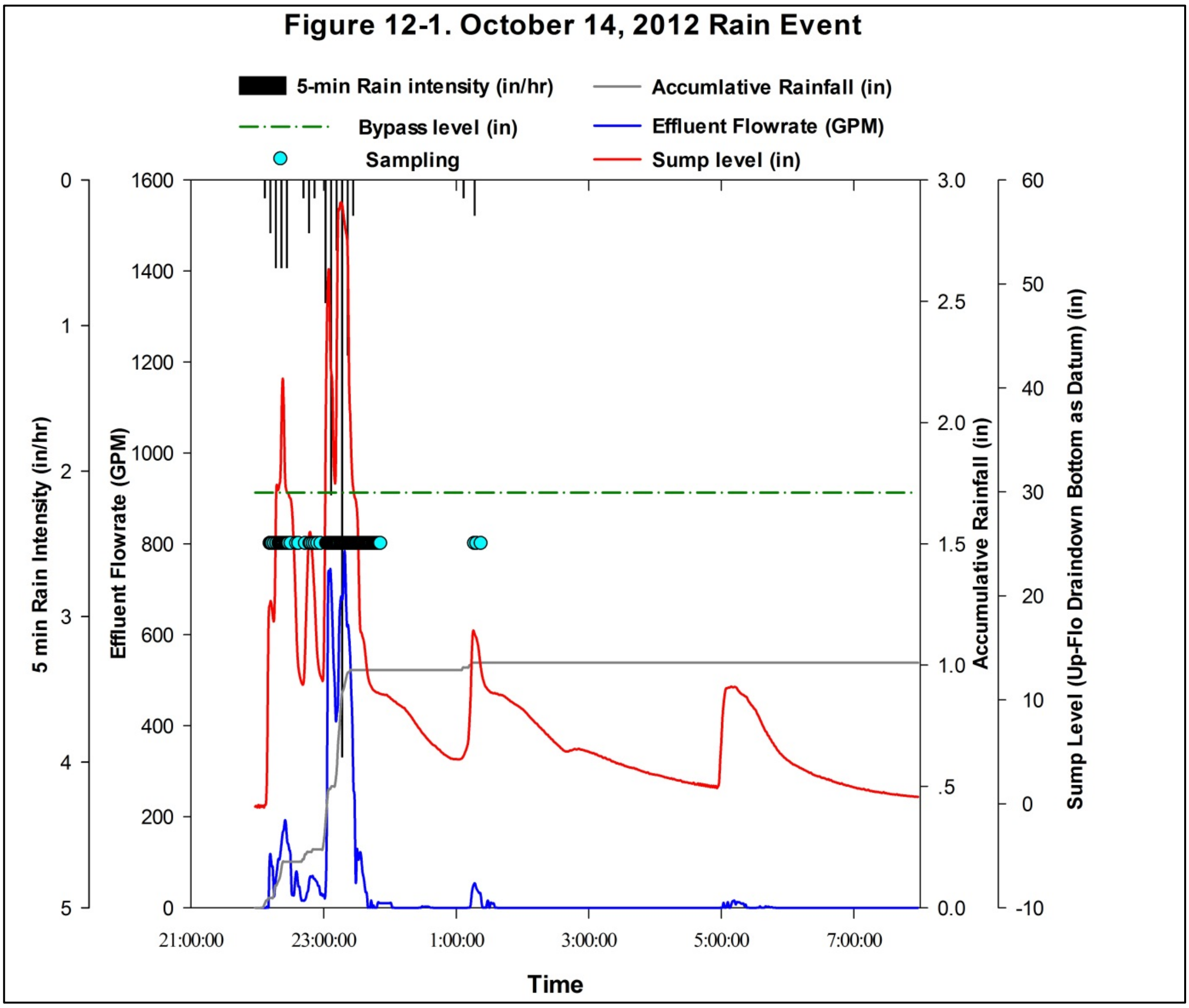


Figure 11-9. September 30, 2012 Rain Event
Turbidity vs. Rain Intensity
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
.1
2012/9/30 0:00:00
2012/10/1 0:00:00
Time

Appendix F.12: October 14, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 12-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.50
Volumetric Runoff Coefficient (Rv)	0.34

Table 12-2. October 14, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/10/14 22:06
Rain Event End Date/Time:			2012/10/15 1:14
Total Precipitation (inch):	≥ 0.1	1.01	
Total Runoff Depth (inch):	NA	0.34	
Total Outflow (gallon):	NA	20062	
Rain Duration (hours):	≥ 1	3.13	
Flow Start Date/Time:			2012/10/14 22:11
Flow End Date/Time:			2012/10/15 5:47
Flow Duration (hours):	NA	7.60	
Average Rain Intensity (in/hr):	NA	0.32	
Average Runoff Rate (gallons/min):	NA	44	
Peak 5-min Rain Intensity (in/hr):	NA	3.96	
Peak Runoff Rate (gallons/min):	NA	784	
Peak to Average Runoff Ratio:	NA	17.82	
Bypassed flow volume (gallon):	NA	9686	
Percentage of Bypassed Flow (%):	NA	48.28	
Inter-Event Time since prior rain (hours)	≥ 6.0	357.62	

Table 12-3. October 14, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	78	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	19.5	The actual volumes of both samples were visually only about 15 liter
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	98.27	

Table 12-4. October 14, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	39	21	46.2	SM 2540D	1 mg/L	Stillbrook Lab
TSS	47	19	60.2	SM 2540D	1 mg/L	UA Lab
SSC	58	24	58.6	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	83	16	80.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	40	44	-11.4	EPA 160.2	1 mg/L	UA Lab
VSS	23	9	60.9	SM 2540E	1 mg/L	UA Lab
Total N as N	1.2	1.0	16.7	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.9	0.8	11.1	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.20	0.20	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	2.21	1.99	10.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	1.47	0.92	37.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.43	0.37	14.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.006	BDL	> 16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.055	0.028	49.1	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.015	0.012	20.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	34658	19140	44.8	IDEXX Method	<1	UA Lab
Enterococci	1412	340	75.9	IDEXX Method	<1	UA Lab
pH	6.71	6.80	-1.3	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	17.00	4.16	75.6	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	47.4	51.5	-8.6	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	24.8	24.4	1.6	SM 212/ EPA 170.1	5 °C	UA Lab

Table 12-5. October 14, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	58	NA*	NA*	24	NA*	NA*	58.6	NA*	NA*
UA Lab	57	26	83	15	1	16	74.2	95.3	80.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 12-6. October 14, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	20225	16208	33	17	1.6	1.0

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

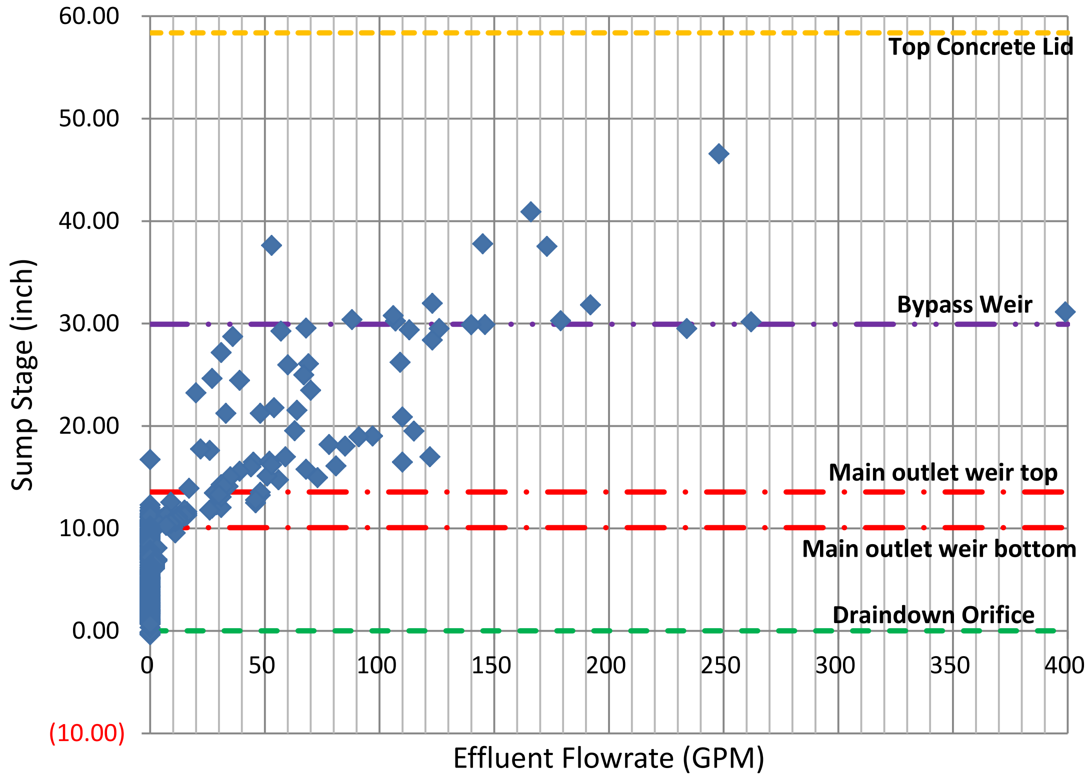
Table 12-7. October 14, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	49	44	47	19	18	19
Millipore Membrane Filter, 0.45µm	49	44	46	16	19	18

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 12-8. October 14, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	> 24,196	34,658	34,658	19,863	18,416	19,140
Enterococci	1,497	1,326	1,412	411	268	340

Table 12-9. October 14, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	23	23	23	9	9	9

Figure 12-2. October 14, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



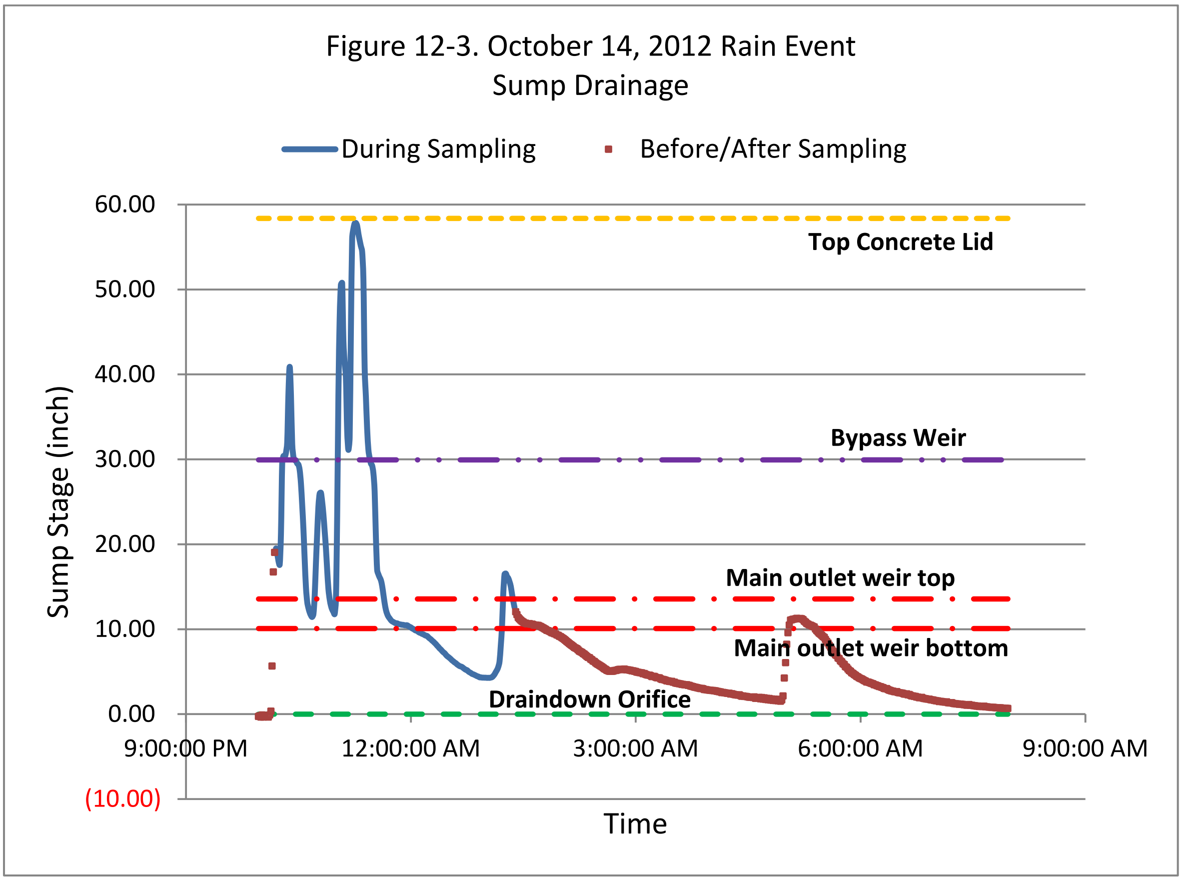


Figure 12-3. October 14, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
9:00:00 PM
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
Time

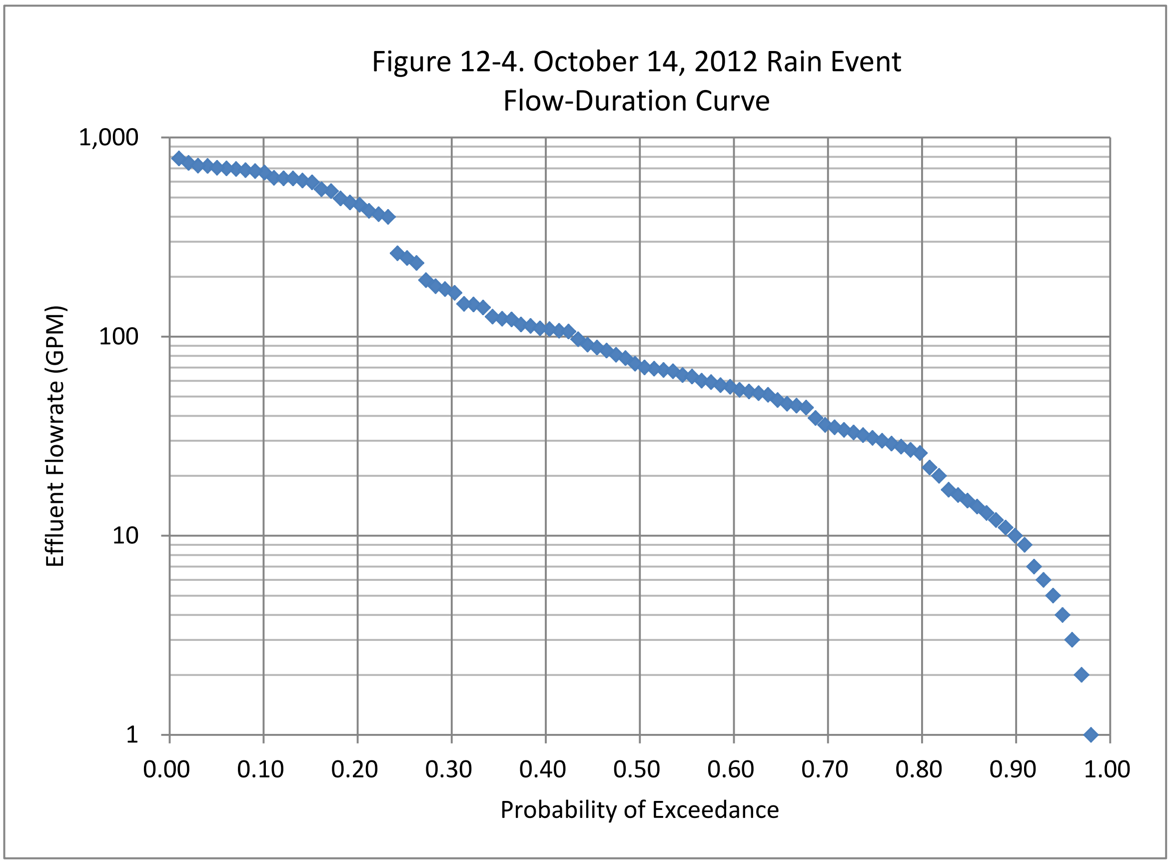
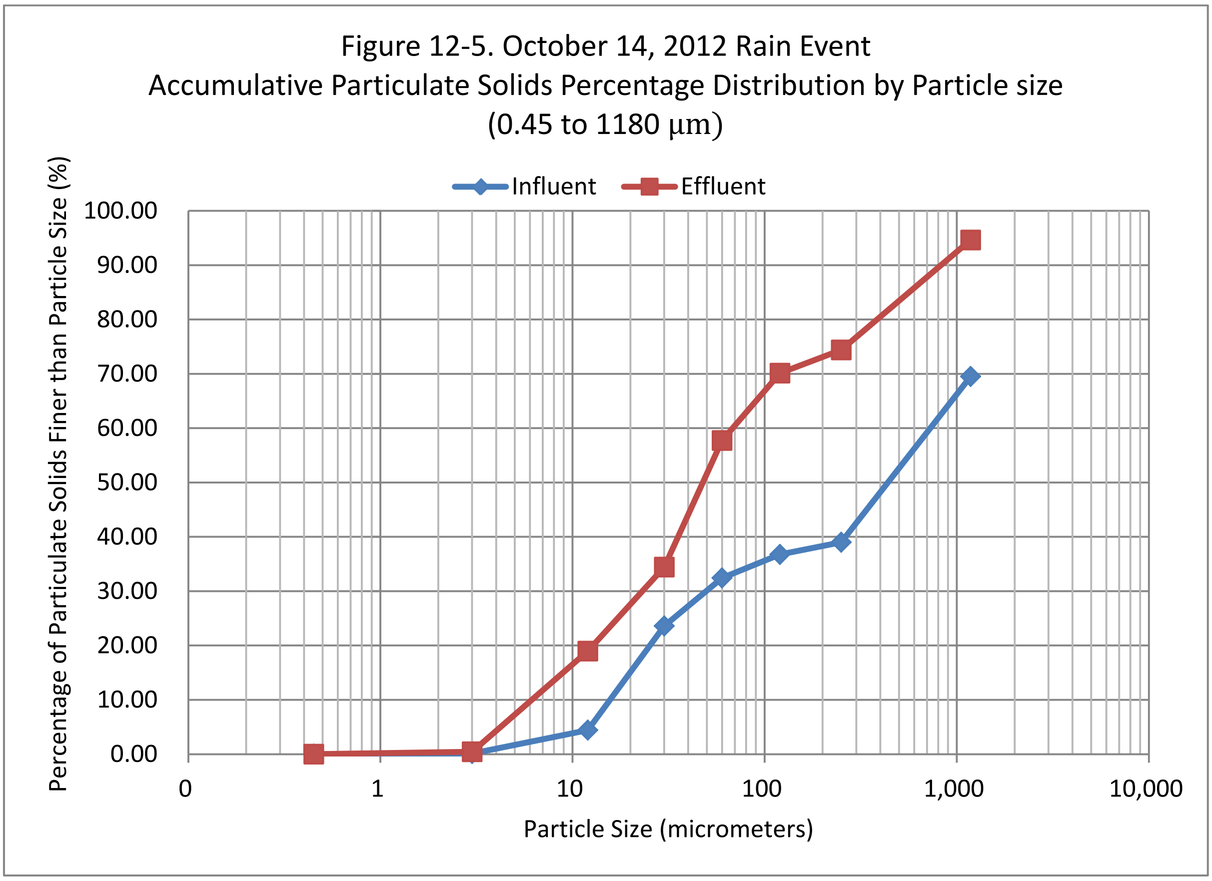
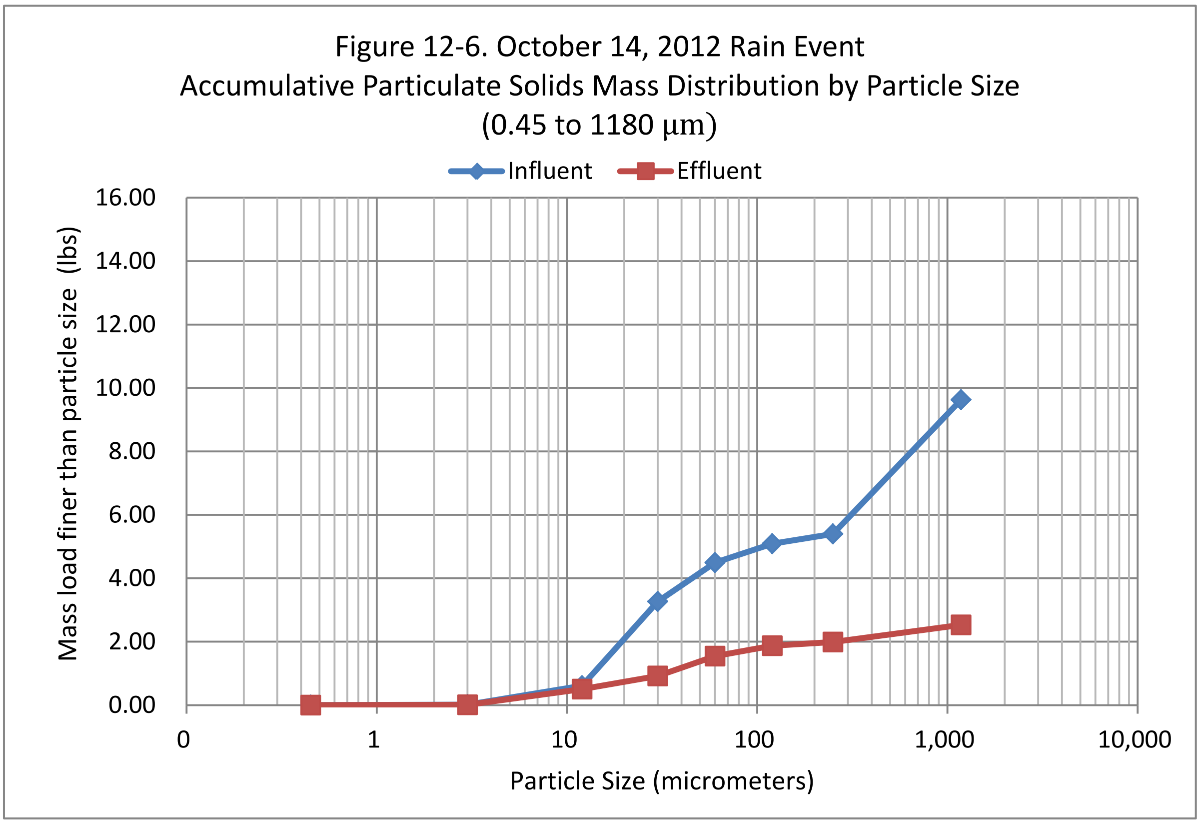


Figure 12-4. October 14, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 4.22 lbs larger than 1180 µm and the effluent had 0.14 lbs larger than 1180 µm (30.49% and 5.37% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 12-10. October 14, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.10	0.12	0.44	0.02	0.01	0.00	28.73
3 to 12	3.62	4.14	4.31	18.54	0.60	0.50	0.10	16.97
12 to 30	16.09	3.45	19.18	15.47	2.66	0.41	2.24	84.43
30 to 60	7.41	5.20	8.83	23.29	1.22	0.62	0.60	49.08
60 to 120	3.62	2.77	4.32	12.40	0.60	0.33	0.27	44.62
120 to 250	1.87	0.95	2.23	4.26	0.31	0.11	0.19	63.12
250 to 1180	25.60	4.52	30.52	20.25	4.23	0.54	3.69	87.19
>1180	25.57	1.20	30.49	5.37	4.22	0.14	4.08	96.60
Total	84	22	100.00	100.00	13.85	2.67	11.18	80.69

Table 12-11. October 14, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.12	0.44	0.02	0.01
<12	4.43	18.98	0.61	0.51
<30	23.61	34.44	3.27	0.92
<60	32.44	57.73	4.49	1.54
<120	36.76	70.13	5.09	1.87
<250	38.99	74.38	5.40	1.99
<1180	69.51	94.63	9.63	2.53
>1180	100.00	100.00	13.85	2.67

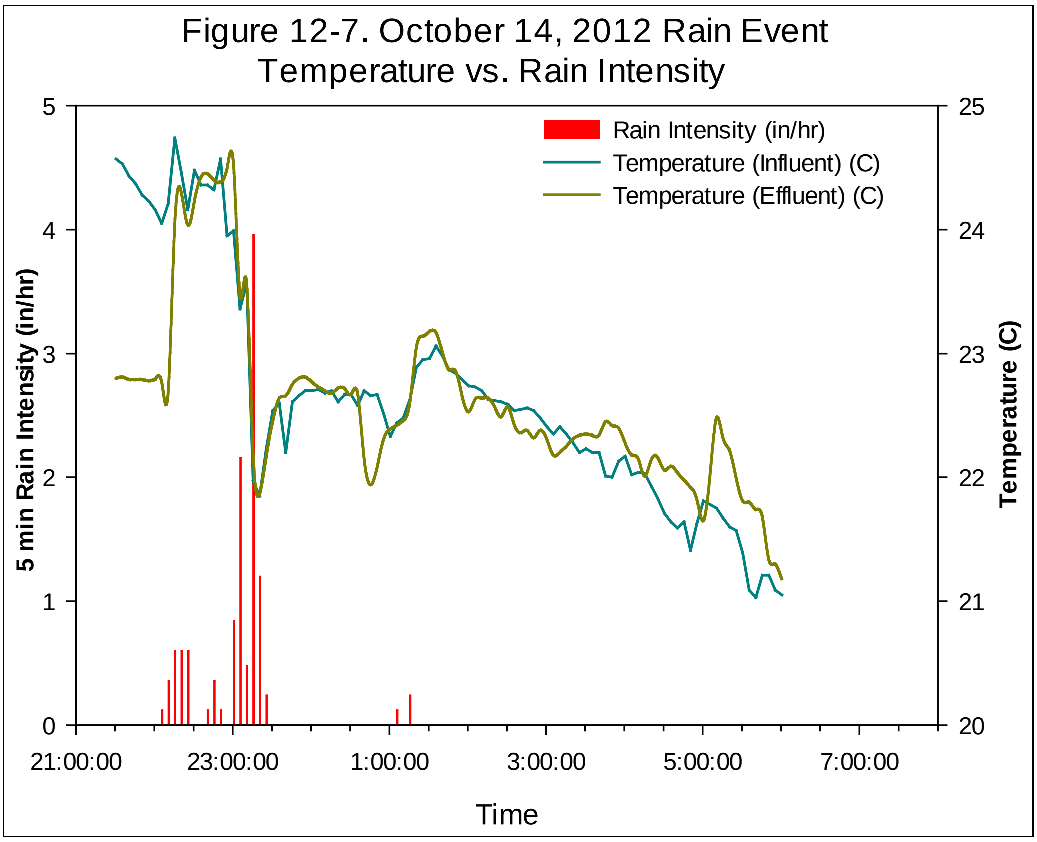


Figure 12-7. October 14, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
0
1
2
3
4
5
20
21
22
23
24
25
21:00:00
23:00:00
1:00:00
3:00:00
5:00:00
7:00:00
Time

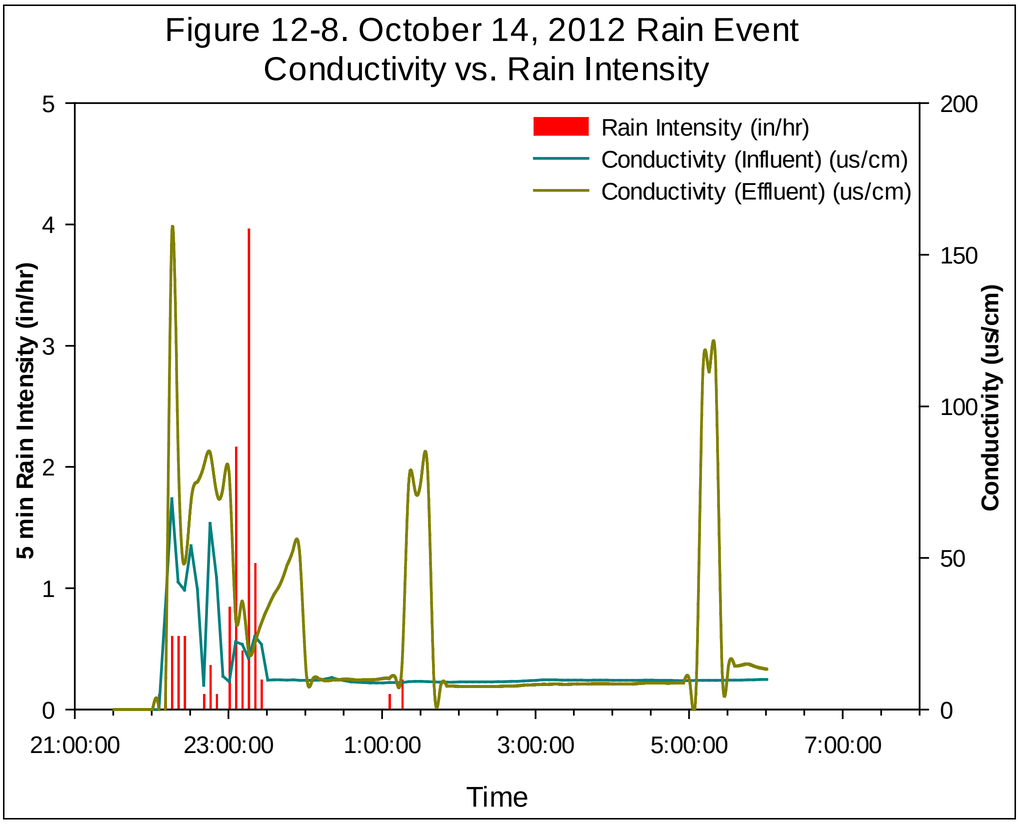


Figure 12-8. October 14, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
0
1
2
3
4
5
0
50
100
150
200
21:00:00
23:00:00
1:00:00
3:00:00
5:00:00
7:00:00
Time

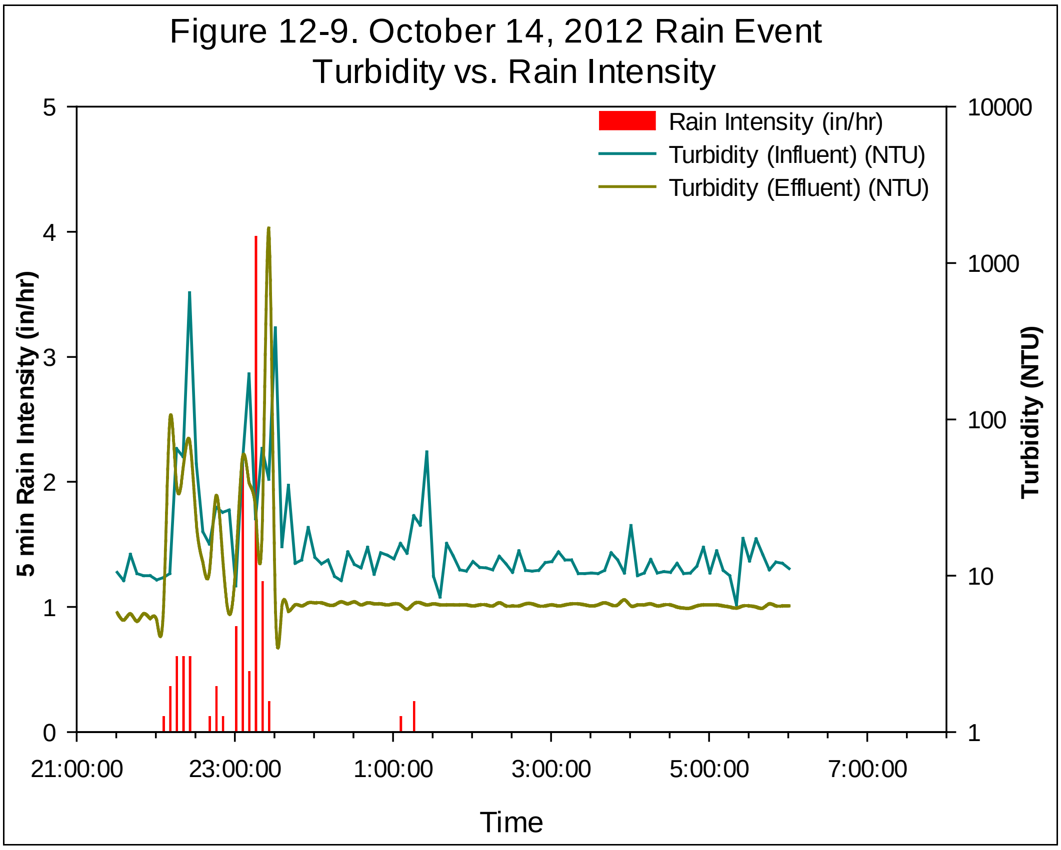
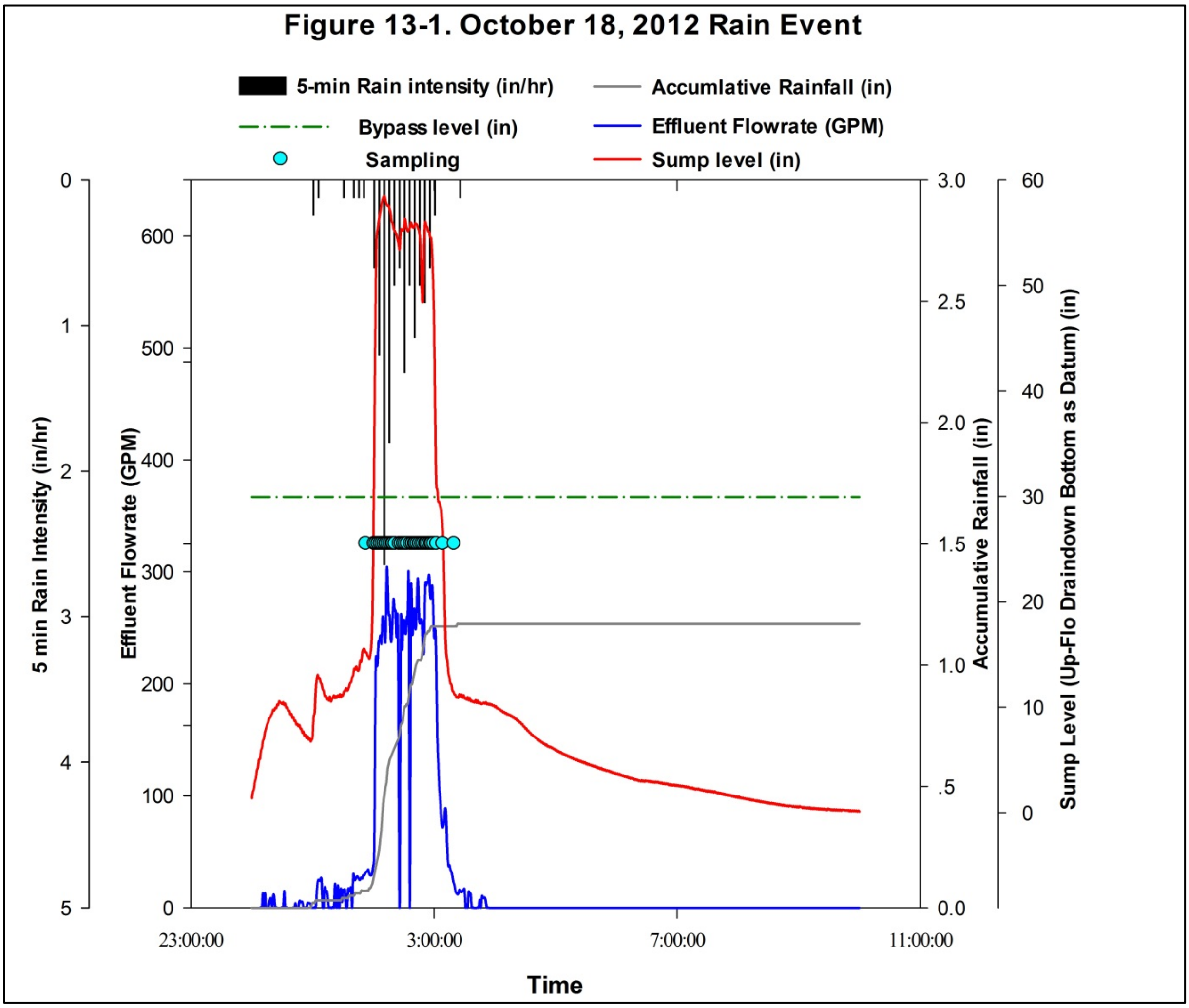


Figure 12-9. October 14, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
0
1
2
3
4
5
1
10
100
1000
10000
21:00:00
23:00:00
1:00:00
3:00:00
5:00:00
7:00:00
Time

Appendix F.13: October 18, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 13-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.28
Volumetric Runoff Coefficient (Rv)	0.41

Table 13-2. October 18, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/10/18 0:59
Rain Event End Date/Time:			2012/10/18 3:23
Total Precipitation (inch):	≥ 0.1	1.17	
Total Runoff Depth (inch):	NA	0.48	
Total Outflow (gallon):	NA	17650	
Rain Duration (hours):	≥ 1	2.40	
Flow Start Date/Time:			2012/10/18 0:11
Flow End Date/Time:			2012/10/18 3:52
Flow Duration (hours):	NA	3.68	
Average Rain Intensity (in/hr):	NA	0.49	
Average Runoff Rate (gallons/min):	NA	80	
Peak 5-min Rain Intensity (in/hr):	NA	2.64	
Peak Runoff Rate (gallons/min):	NA	299	
Peak to Average Runoff Ratio:	NA	3.74	
Bypassed flow volume (gallon):	NA	7320	
Percentage of Bypassed Flow (%):	NA	41.47	
Inter-Event Time since prior rain (hours)	≥ 6.0	74.88	

Table 13-3. October 18, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	35	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	8.8	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	93.88	

Table 13-4. October 18, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	48	27	43.8	SM 2540D	1 mg/L	Stillbrook Lab
TSS	62	34	46.0	SM 2540D	1 mg/L	UA Lab
SSC	58	32	44.8	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	85	38	55.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	38	23	38.2	EPA 160.2	1 mg/L	UA Lab
VSS	32	12	62.5	SM 2540E	1 mg/L	UA Lab
Total N as N	2.1	0.8	61.9	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	1.9	0.8	57.9	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	1.26	0.07	94.4	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	2.05	1.81	11.7	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	1.87	1.75	6.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.49	0.49	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	0.105	BDL	> 95.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	0.062	BDL	> 91.9	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.011	BDL	> 54.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	1.20	0.016	98.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.755	0.006	99.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	48392	> 0	IDEXX Method	<1	UA Lab
E. Coli	16872	15732	6.8	IDEXX Method	<1	UA Lab
Enterococci	5378	1284	76.1	IDEXX Method	<1	UA Lab
pH	5.80	6.67	-15.0	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	23.45	11.05	52.9	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	49.3	29.4	40.4	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	25.1	24.9	0.8	SM 212/ EPA 170.1	5 °C	UA Lab

Table 13-5. October 18, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	58	NA*	NA*	32	NA*	NA*	44.8	NA*	NA*
UA Lab	63	23	85	35	4	38	45.2	83.3	55.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 13-6. October 18, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	24344	12860	36	21	1.5	1.7

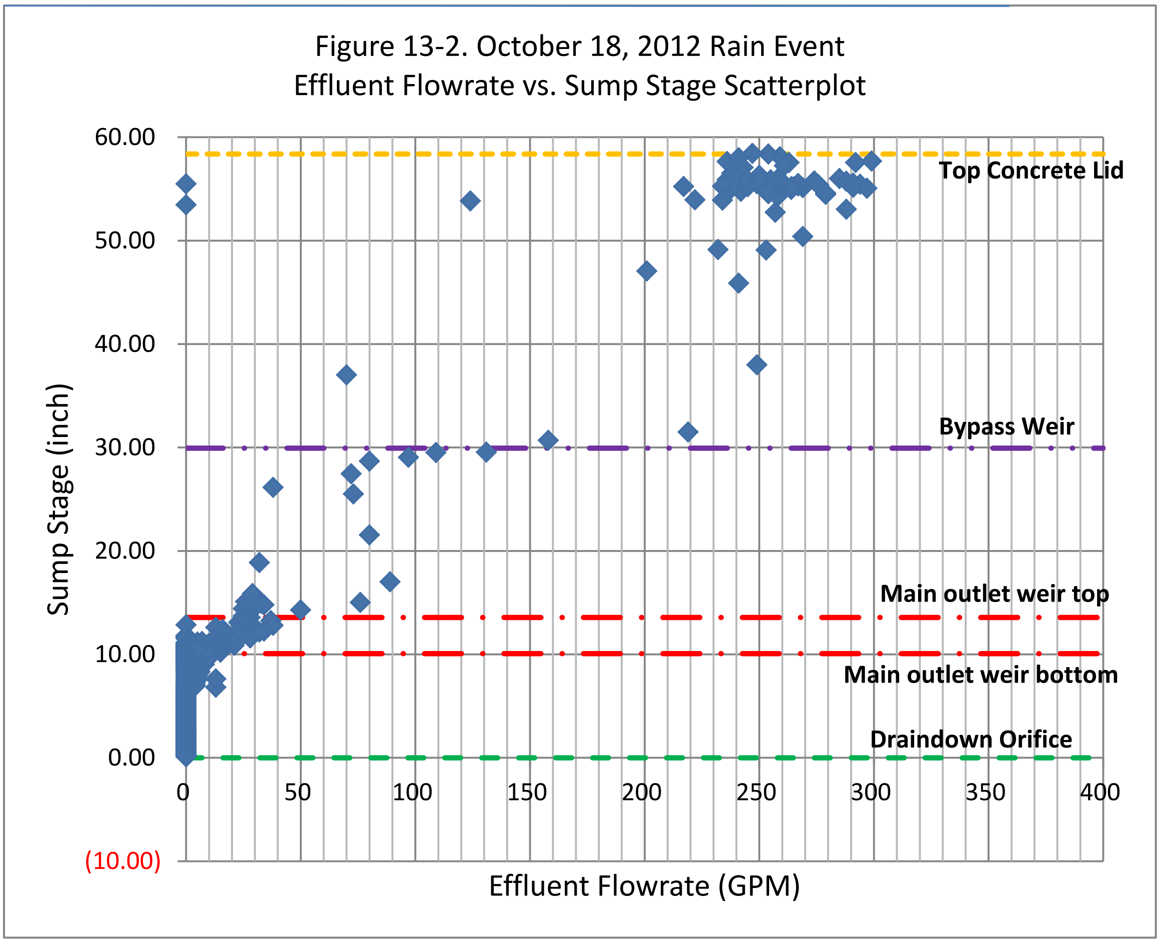
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 13-7. October 18, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	59	65	62	38	29	34
Millipore Membrane Filter, 0.45µm	55	50	53	22	28	25

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 13-8. October 18, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	48,392	48,392
E. Coli	14,136	19,608	16,872	14,136	17,328	15,732
Enterococci	5,794	4,962	5,378	1,421	1,146	1,284

Table 13-9. October 18, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	34	30	32	15	9	12



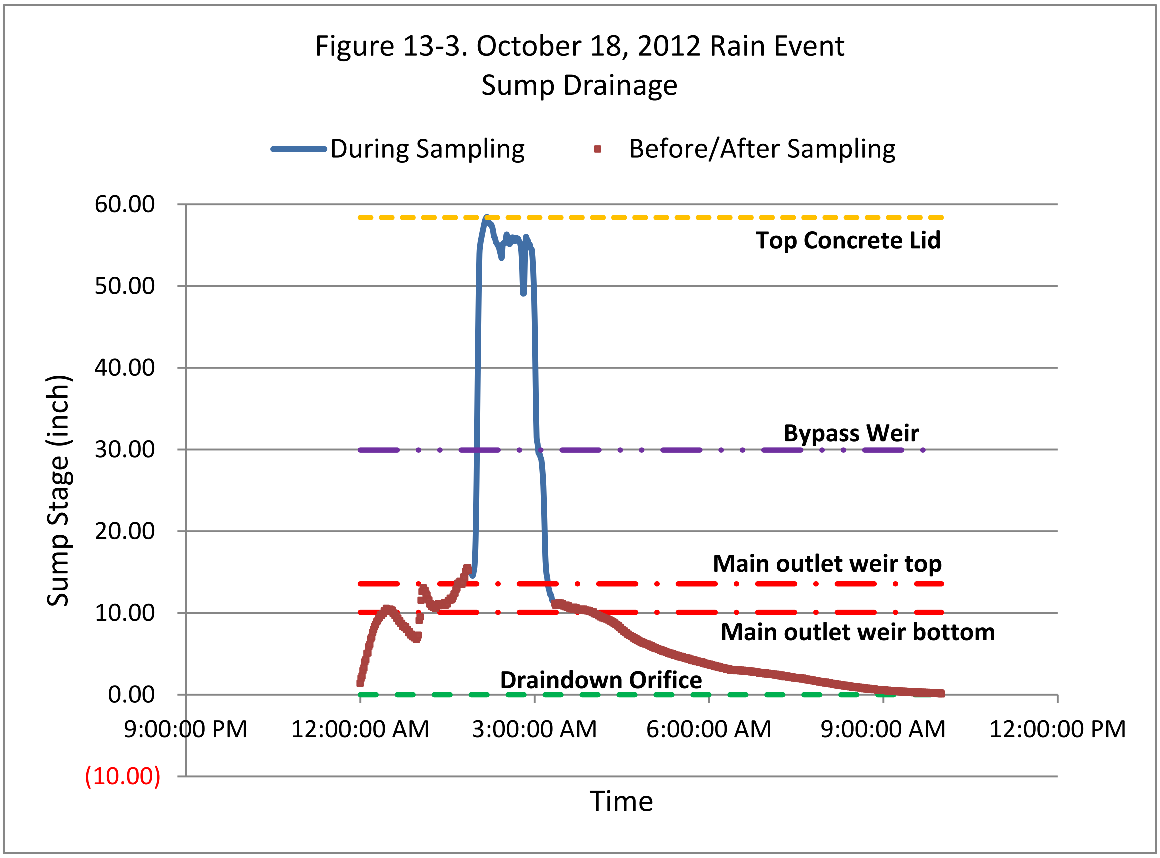


Figure 13-3. October 18, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
9:00:00 PM
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
12:00:00 PM
Time

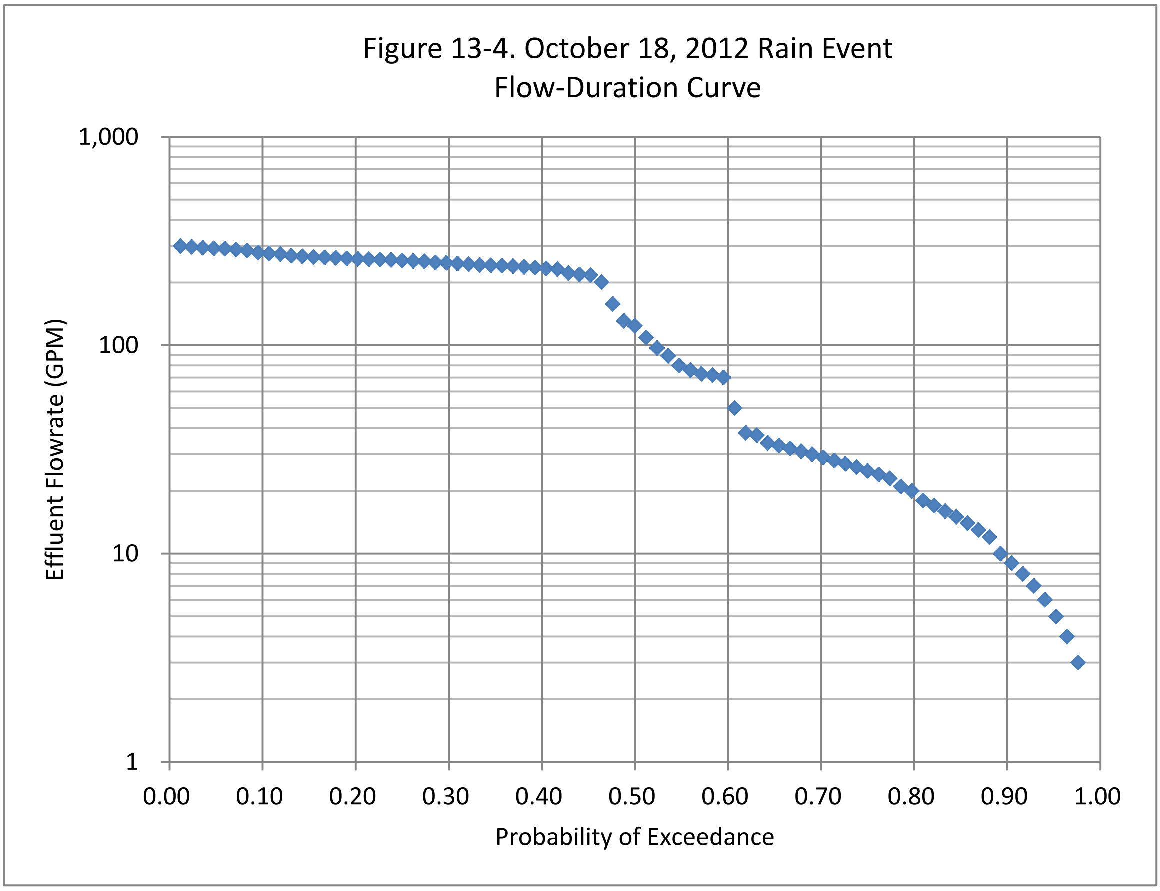
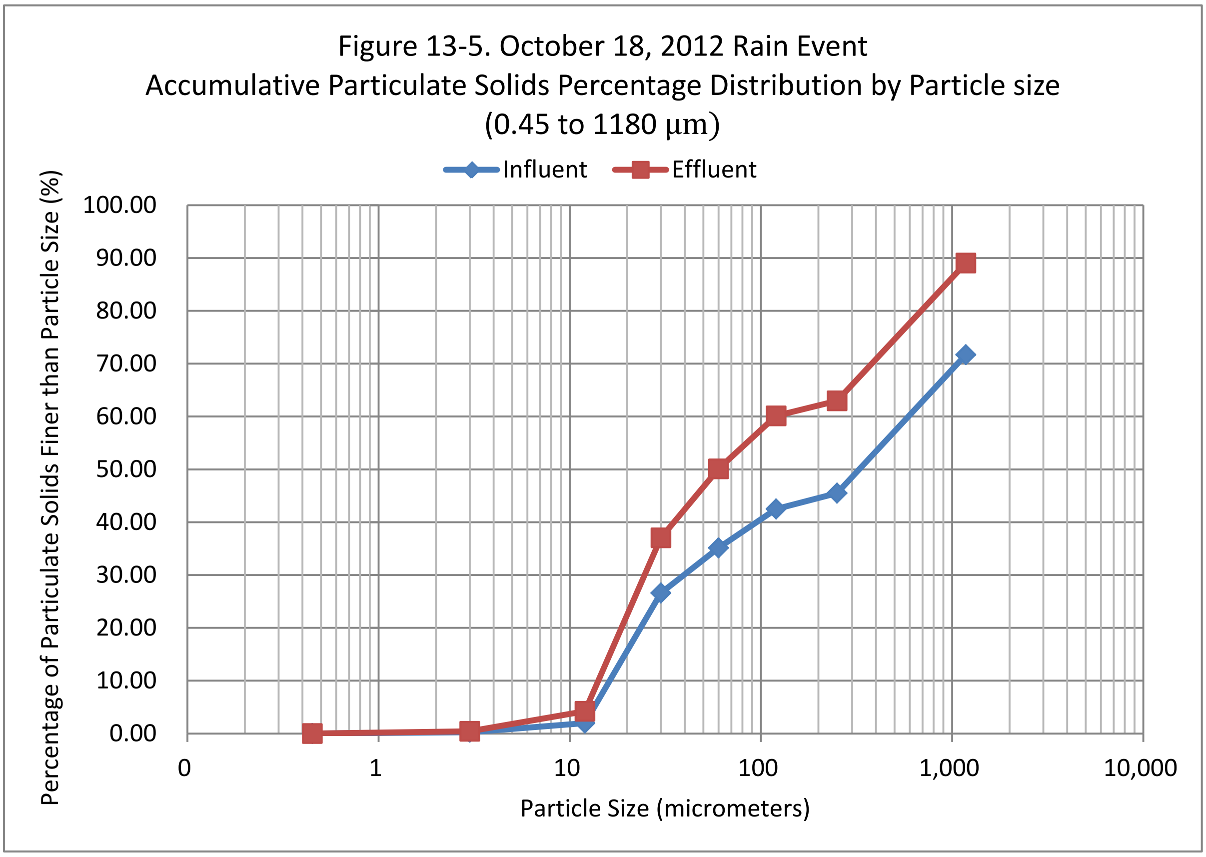
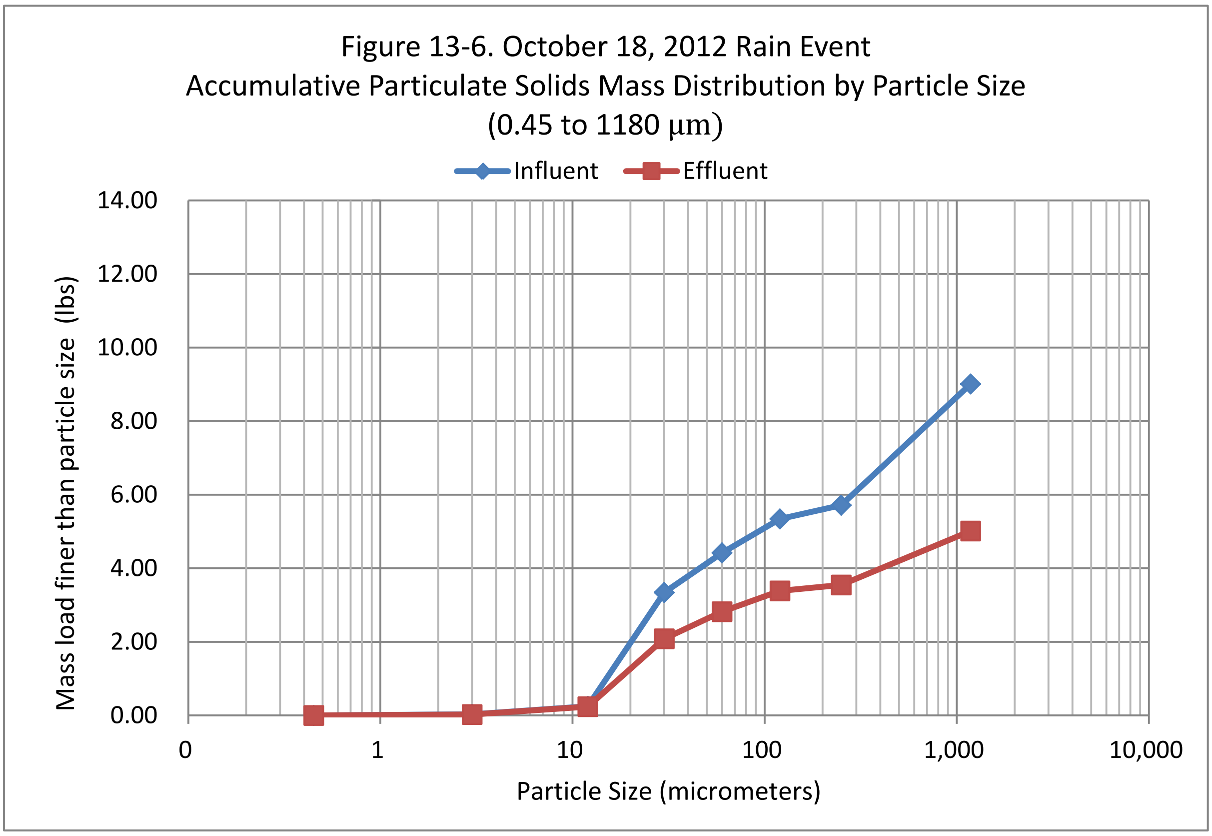


Figure 13-4. October 18, 2012 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 3.56 lbs larger than 1180 µm and the effluent had 0.62 lbs larger than 1180 µm (28.31% and 10.98% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 13-10. October 18, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.18	0.15	0.23	0.43	0.03	0.02	0.00	16.15
3 to 12	1.37	1.29	1.72	3.77	0.22	0.21	0.00	2.03
12 to 30	19.59	11.25	24.63	32.84	3.10	1.85	1.25	40.27
30 to 60	6.79	4.48	8.54	13.06	1.07	0.74	0.34	31.52
60 to 120	5.84	3.43	7.34	10.01	0.92	0.56	0.36	38.93
120 to 250	2.39	0.98	3.00	2.86	0.38	0.16	0.22	57.36
250 to 1180	20.85	8.93	26.22	26.06	3.29	1.47	1.83	55.48
>1180	22.51	3.76	28.31	10.98	3.56	0.62	2.94	82.63
Total	80	34	100.00	100.00	12.57	5.63	6.94	55.20

Table 13-11. October 18, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.23	0.43	0.03	0.02
<12	1.96	4.20	0.25	0.24
<30	26.59	37.04	3.34	2.09
<60	35.13	50.10	4.41	2.82
<120	42.48	60.11	5.34	3.38
<250	45.48	62.97	5.71	3.55
<1180	71.69	89.02	9.01	5.01
>1180	100.00	100.00	12.57	5.63

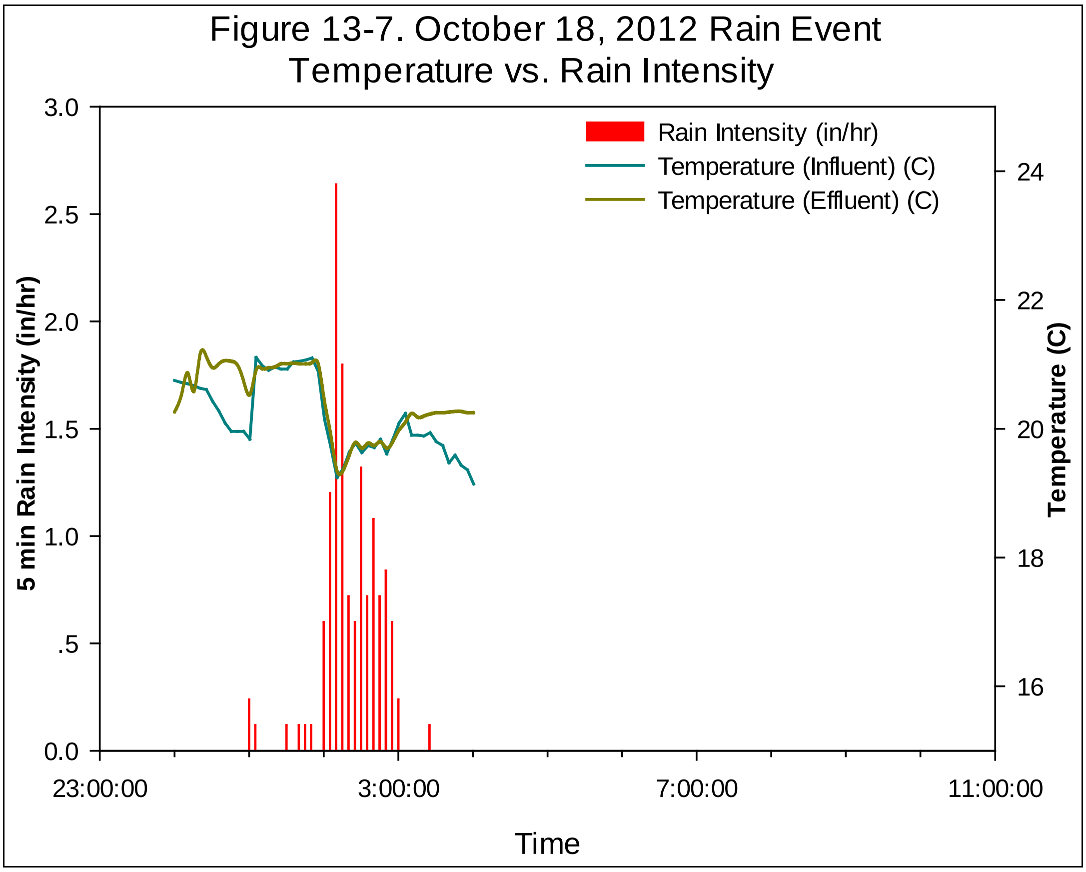


Figure 13-7. October 18, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
24
22
20
18
16
23:00:00
3:00:00
7:00:00
11:00:00
Time

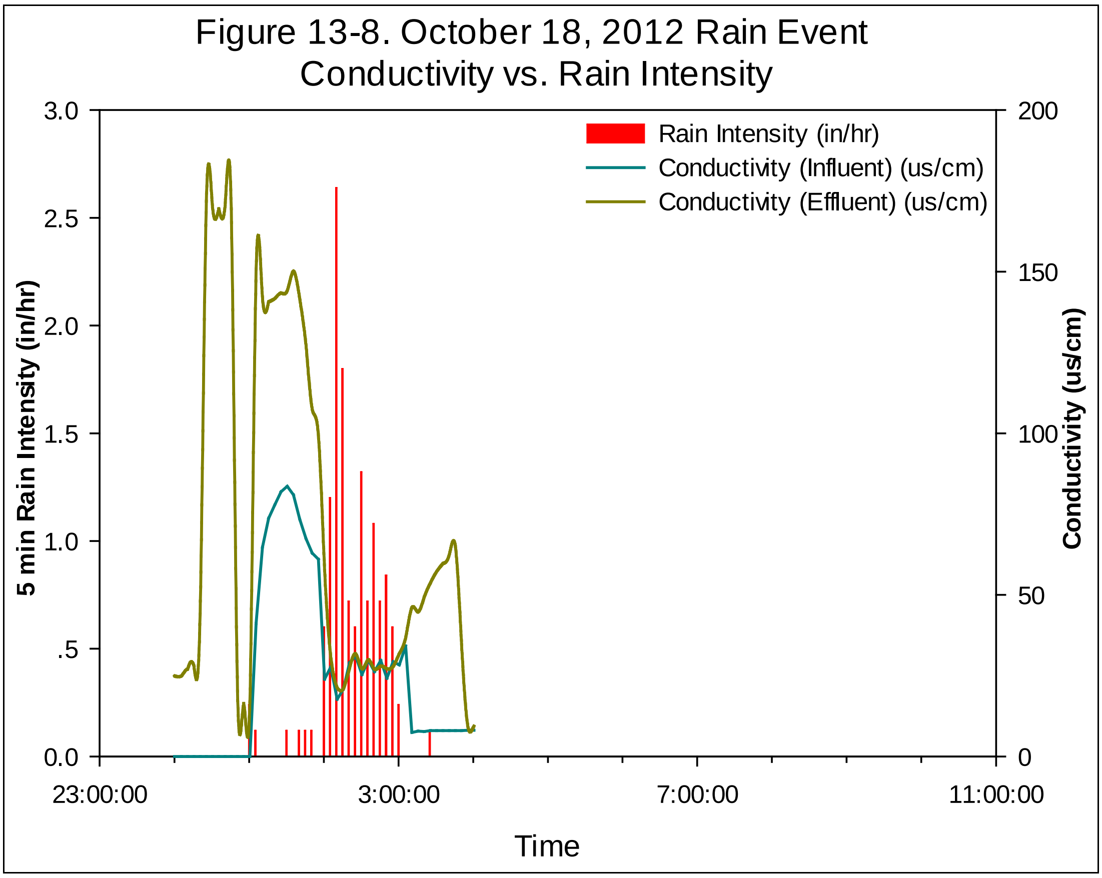


Figure 13-8. October 18, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
23:00:00
3:00:00
7:00:00
11:00:00
Time

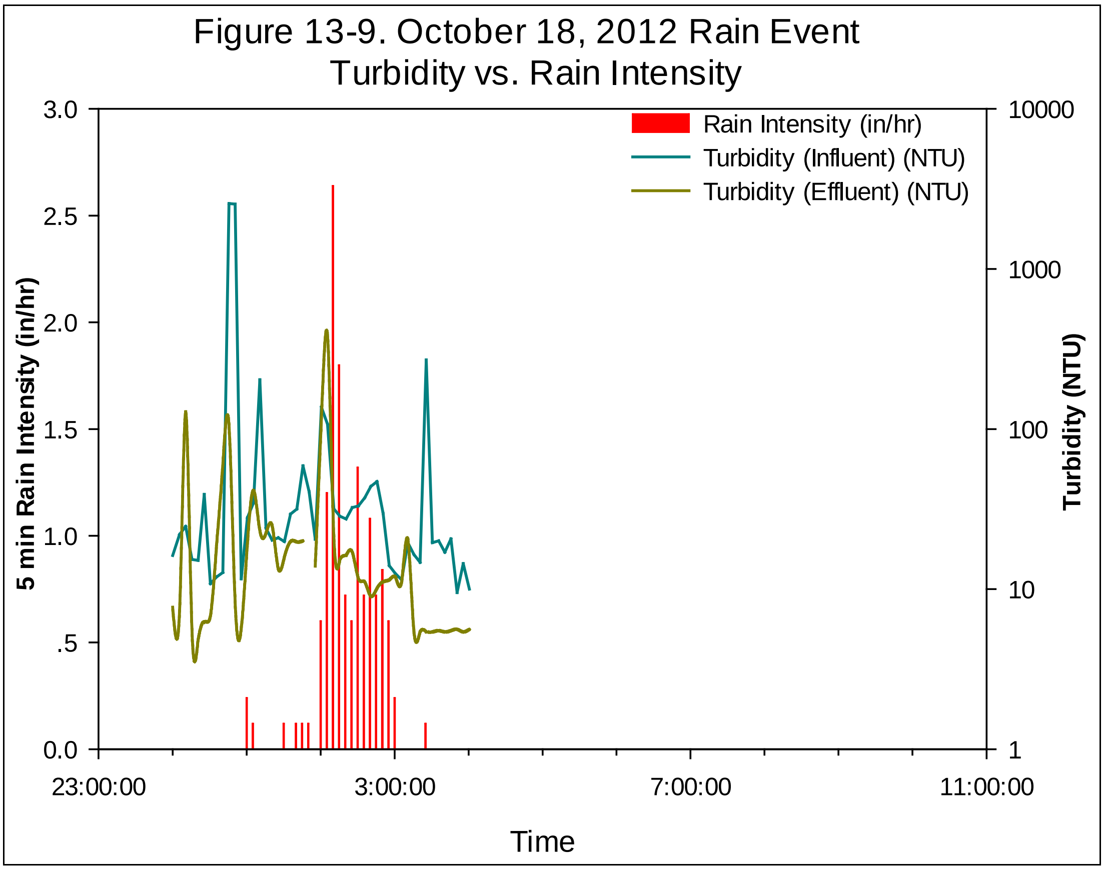
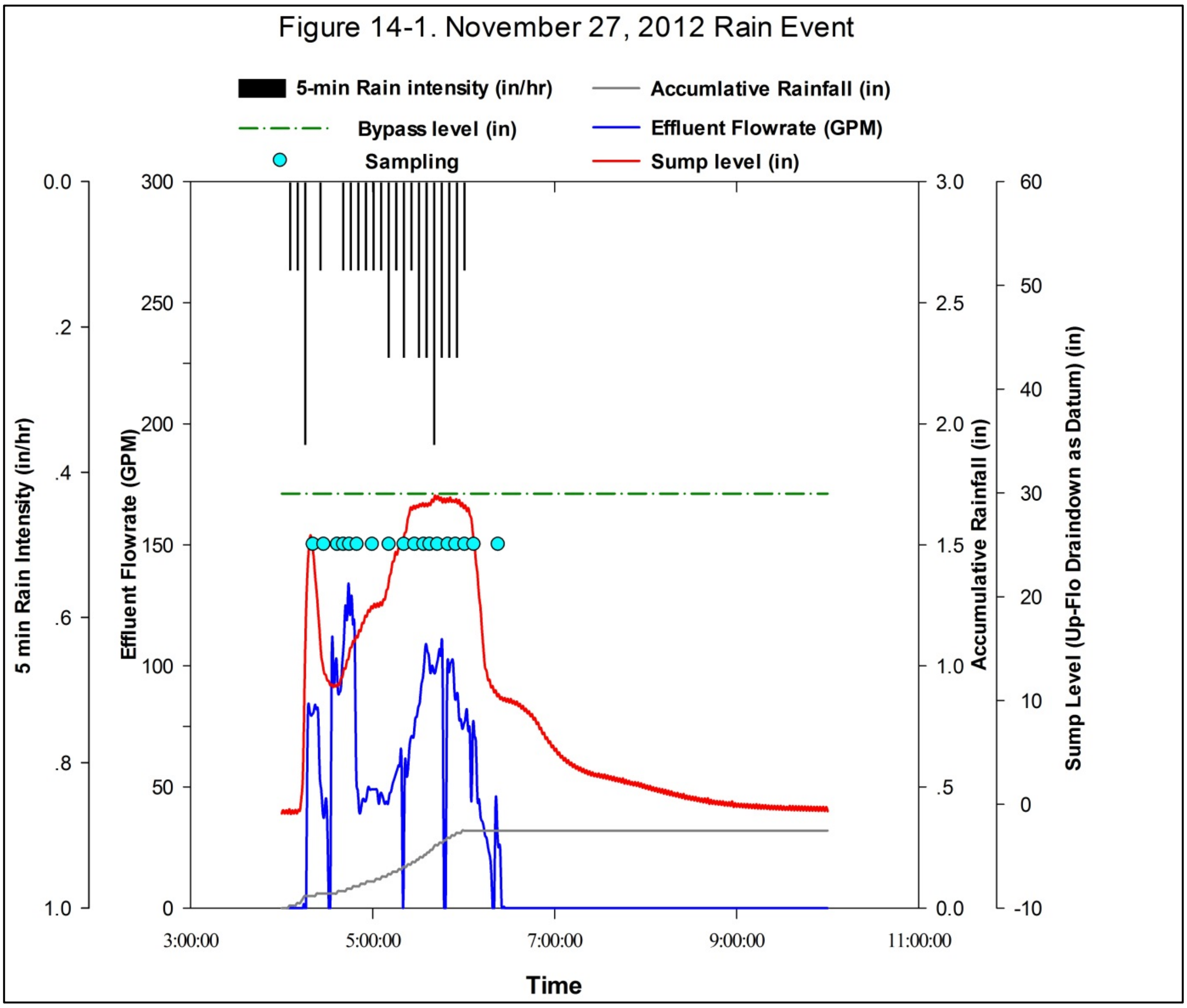


Figure 13-9. October 18, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
23:00:00
3:00:00
7:00:00
11:00:00
Time

Appendix F.14: November 27, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 14-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.93
Volumetric Runoff Coefficient (Rv)	0.98

Table 14-2. November 27, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/11/27 4:05
Rain Event End Date/Time:			2012/11/27 5:59
Total Precipitation (inch):	≥ 0.1	0.32	
Total Runoff Depth (inch):	NA	0.31	
Total Outflow (gallon):	NA	8510	
Rain Duration (hours):	≥ 1	1.90	
Flow Start Date/Time:			2012/11/27 4:17
Flow End Date/Time:			2012/11/27 6:25
Flow Duration (hours):	NA	2.13	
Average Rain Intensity (in/hr):	NA	0.17	
Average Runoff Rate (gallons/min):	NA	66	
Peak 5-min Rain Intensity (in/hr):	NA	0.36	
Peak Runoff Rate (gallons/min):	NA	134	
Peak to Average Runoff Ratio:	NA	2.02	
Bypassed flow volume (gallon):	NA	0	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	355.0	

Table 14-3. November 27, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	18	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	4.5	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.03	

Table 14-4. November 27, 2012 Rain Event
Water Quality Analysis Information

All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C

Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	76	22	71.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	59	10	83.9	SM 2540D	1 mg/L	UA Lab
SSC	55	14	74.5	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	86	11	87.0	ASTM D3977-97B	1 mg/L	UA Lab
TDS	67	68	-1.5	EPA 160.2	1 mg/L	UA Lab
VSS	34	6	82.6	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.5	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.07	0.14	-100.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	2.09	1.50	28.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	1.56	1.23	21.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	0.40	0.52	-30.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.25	0.31	-24.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.006	BDL	> 16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.058	0.028	51.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.009	0.014	-55.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	949	388	59.1	IDEXX Method	<1	UA Lab
Enterococci	680	346	49.2	IDEXX Method	<1	UA Lab
pH	6.78	6.89	-1.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	24.15	7.35	69.6	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	59.3	72.5	-22.3	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	15.0	14.8	1.3	SM 212/ EPA 170.1	5 °C	UA Lab

Table 14-5. November 27, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	55	NA*	NA*	14	NA*	NA*	74.5	NA*	NA*
UA Lab	59	27	86	10	1	11	82.5	96.9	87.0

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 14-6. November 27, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	15945	7432	29	9	1.8	1.2

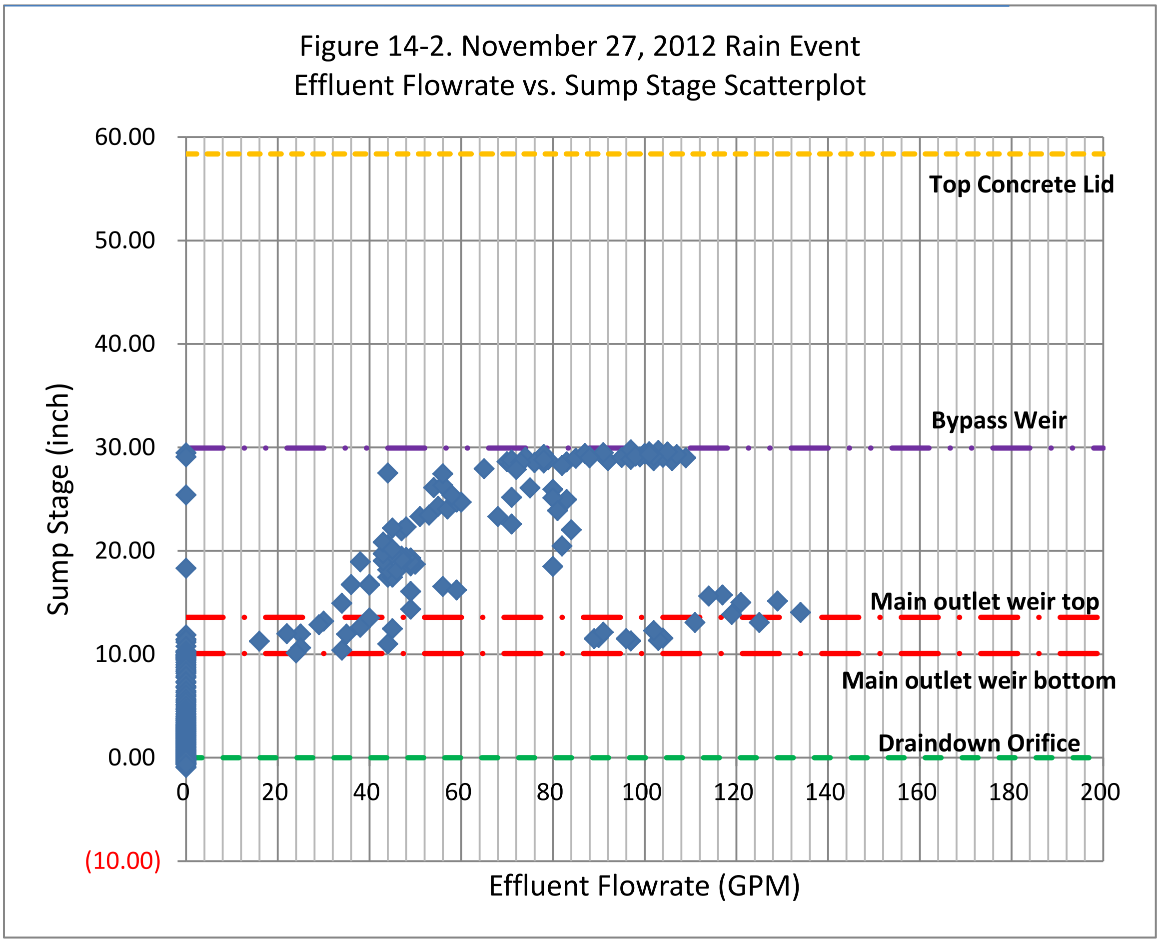
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 14-7. November 27, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	55	63	59	10	9	10
Millipore Membrane Filter, 0.45µm	57	54	56	4	3	3

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 14-8. November 27, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	1,100	798	949	350	426	388
Enterococci	670	690	680	369	322	346

Table 14-9. November 27, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	34	35	34	7	5	6



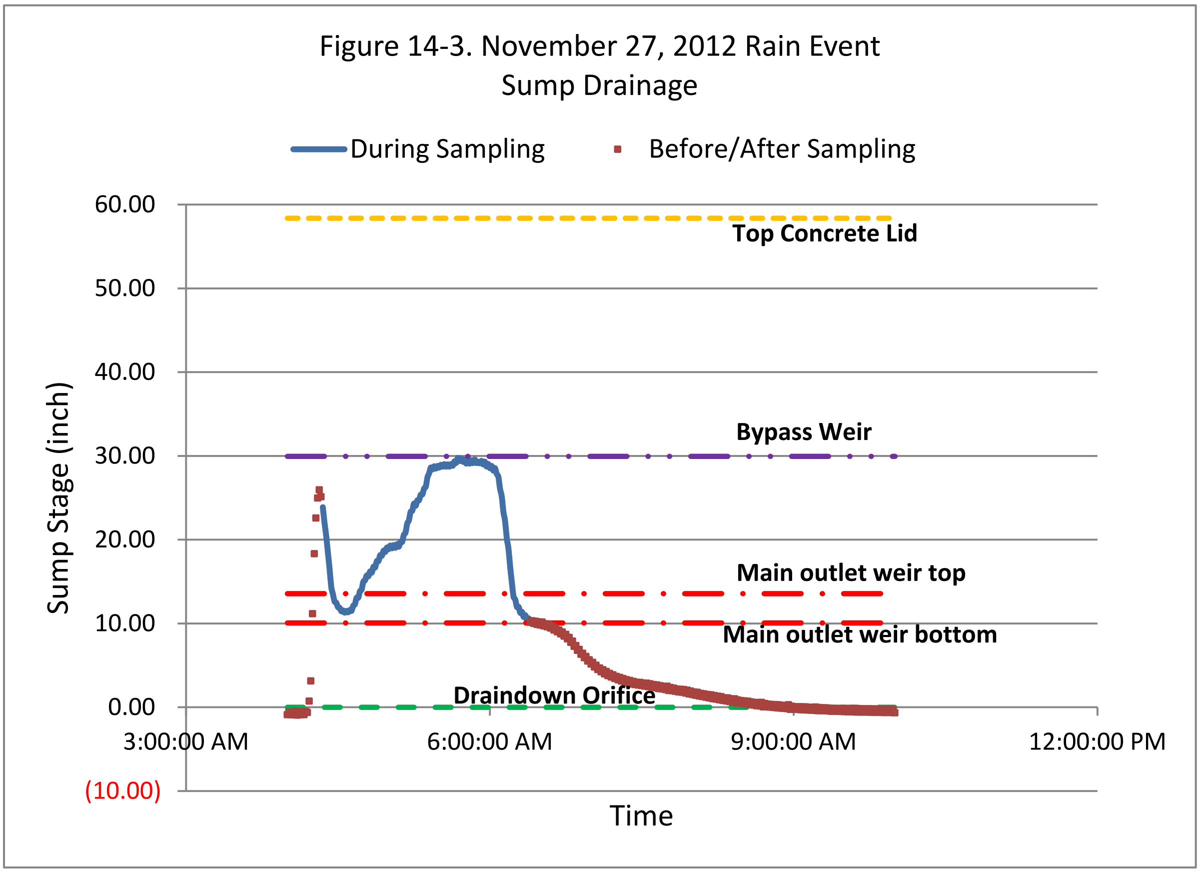


Figure 14-3. November 27, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
3:00:00 AM
6:00:00 AM
9:00:00 AM
12:00:00 PM
Time

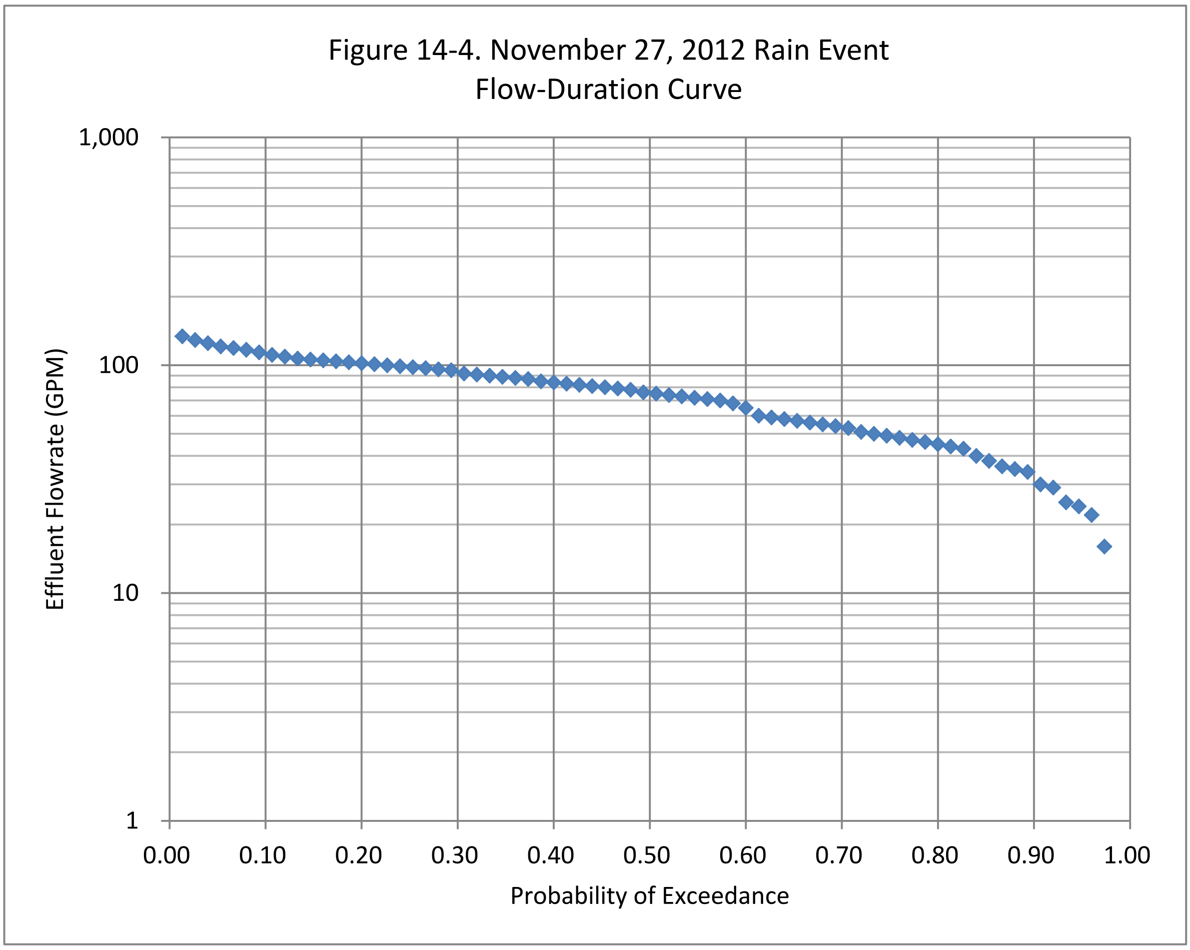


Figure 14-4. November 27, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 14-5. November 27, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

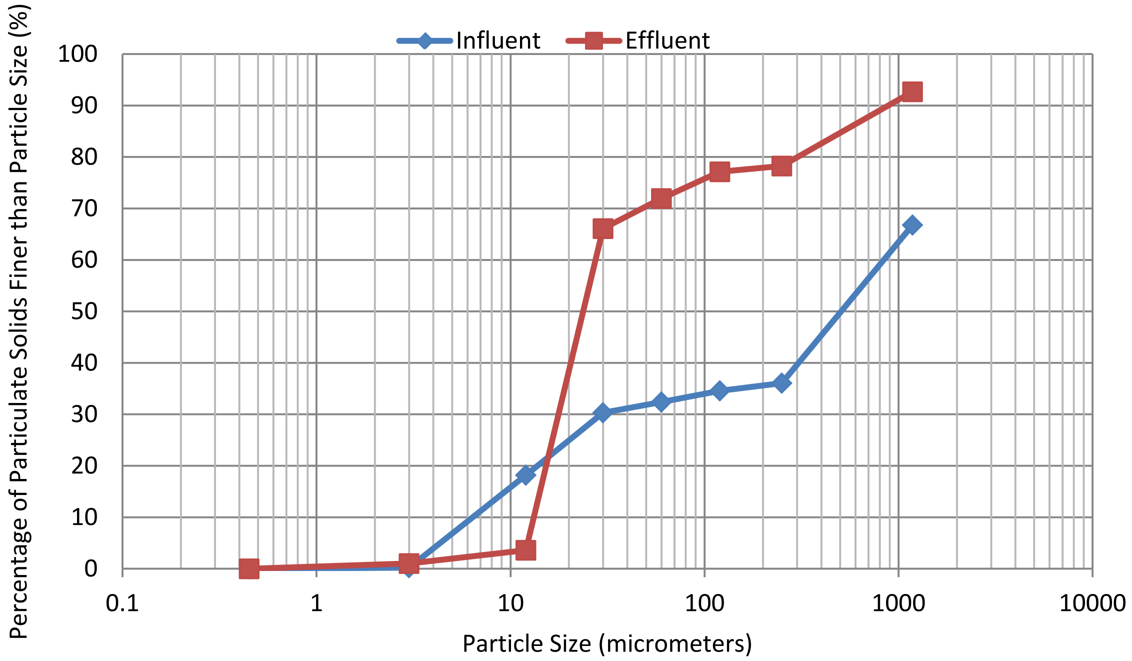
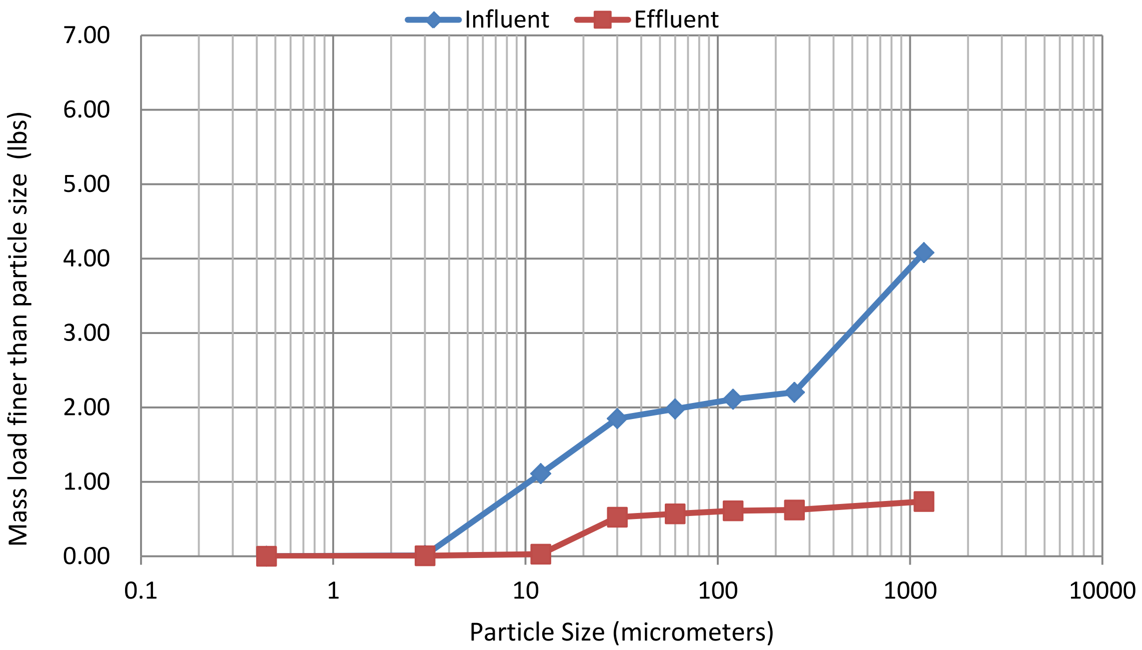


Figure 14-6. November 27, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 2.03 lbs larger than 1180 µm and the effluent had 0.06 lbs larger than 1180 µm (33.22% and 7.32% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 14-10. November 27, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.17	0.12	0.20	1.03	0.01	0.01	0.00	34.62
3 to 12	14.50	0.29	17.97	2.56	1.10	0.02	1.08	98.15
12 to 30	9.78	7.19	12.12	62.50	0.74	0.50	0.24	32.93
30 to 60	1.70	0.67	2.11	5.86	0.13	0.05	0.08	63.86
60 to 120	1.73	0.59	2.15	5.17	0.13	0.04	0.09	68.68
120 to 250	1.21	0.13	1.50	1.14	0.09	0.01	0.08	90.09
250 to 1180	24.79	1.66	30.73	14.42	1.88	0.11	1.76	93.90
>1180	26.81	0.84	33.22	7.32	2.03	0.06	1.97	97.13
Total	81	12	100.00	100.00	6.11	0.79	5.32	86.99

Table 14-11. November 27, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.20	1.03	0.01	0.01
<12	18.18	3.59	1.11	0.03
<30	30.30	66.09	1.85	0.53
<60	32.40	71.95	1.98	0.57
<120	34.55	77.12	2.11	0.61
<250	36.05	78.26	2.20	0.62
<1180	66.78	92.68	4.08	0.74
>1180	100.00	100.00	6.11	0.79

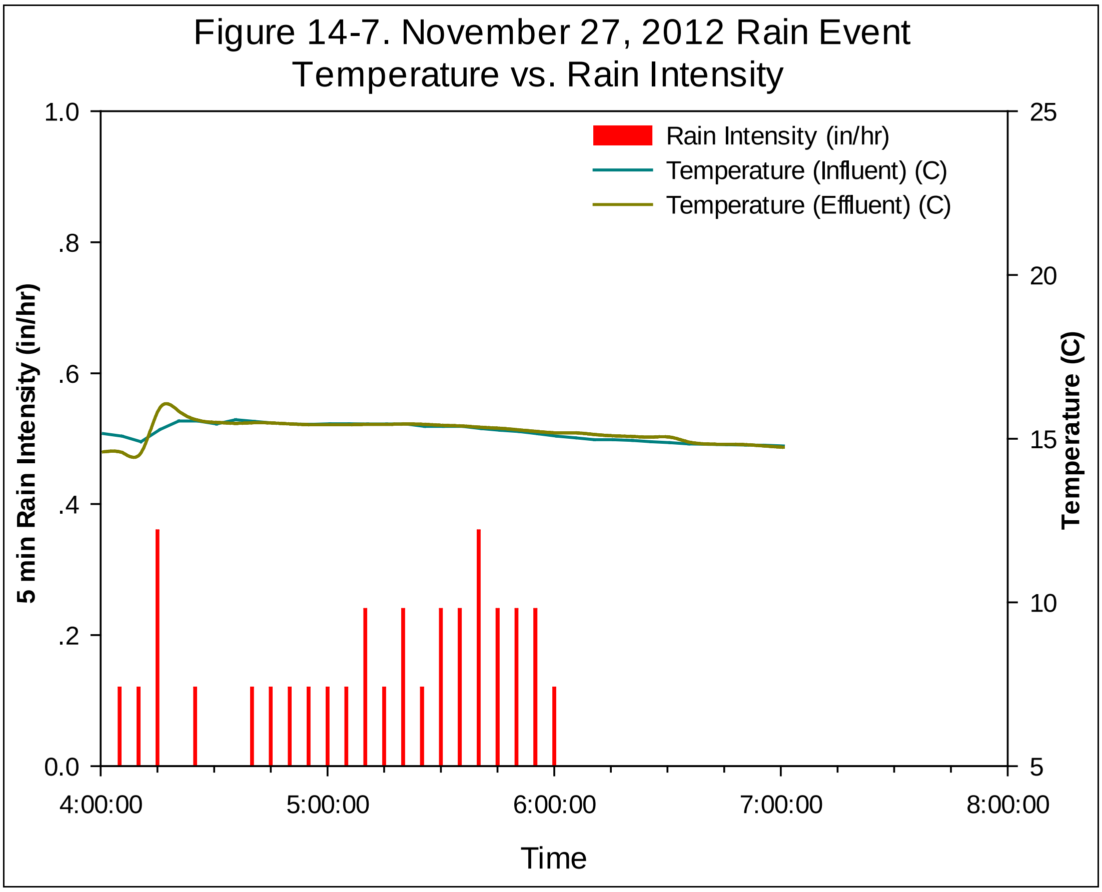


Figure 14-7. November 27, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
1.0
.8
.6
.4
.2
0.0
25
20
15
10
5
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
Time

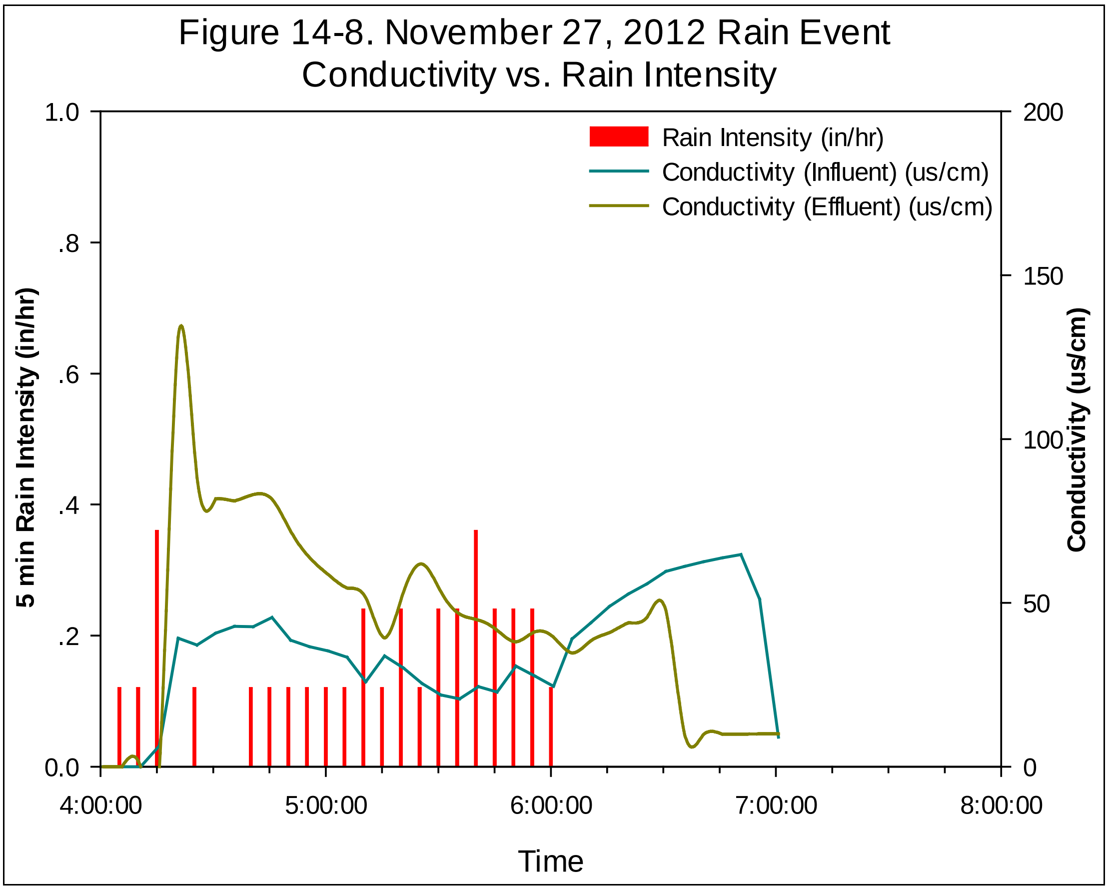


Figure 14-8. November 27, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
1.0
.8
.6
.4
.2
0.0
200
150
100
50
0
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
Time

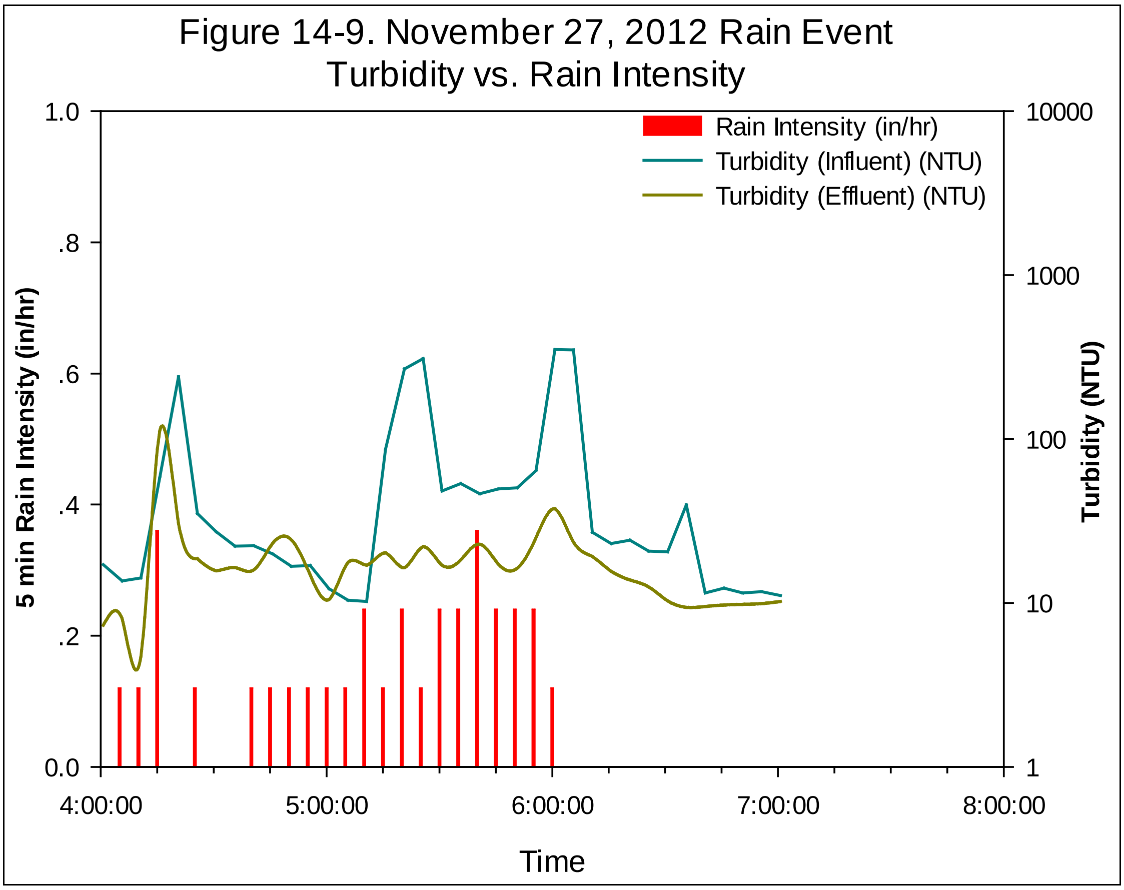
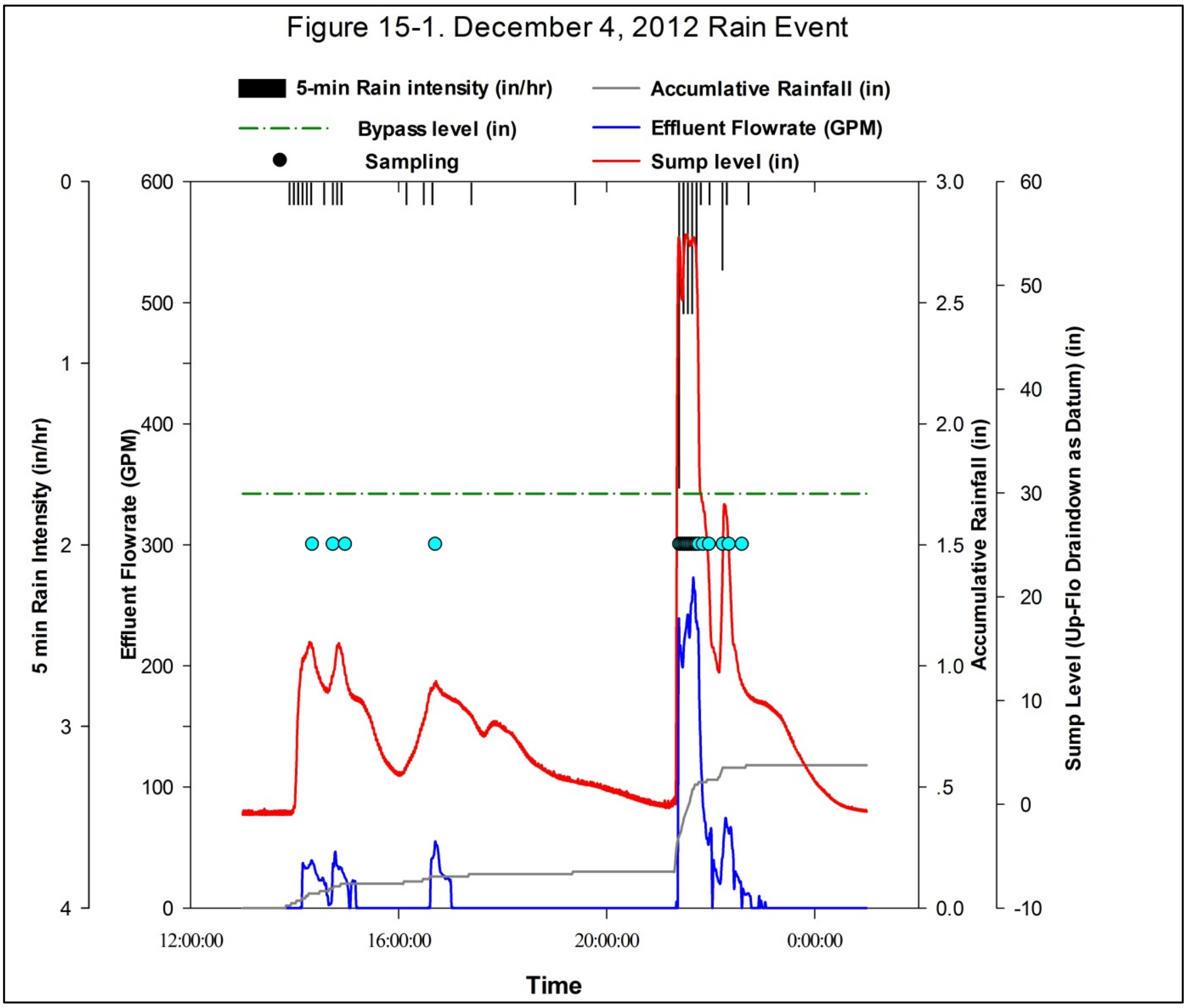


Figure 14-9. November 27, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
1.0
.8
.6
.4
.2
0.0
10000
1000
100
10
1
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
Time

Appendix F.15: December 4, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 15-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.41
Volumetric Runoff Coefficient (Rv)	0.75

Table 15-2. December 4, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/12/4 13:50
Rain Event End Date/Time:			2012/12/4 22:41
Total Precipitation (inch):	≥ 0.1	0.59	
Total Runoff Depth (inch):	NA	0.44	
Total Outflow (gallon):	NA	10693	
Rain Duration (hours):	≥ 1	8.85	
Flow Start Date/Time:			2012/12/4 14:09
Flow End Date/Time:			2012/12/4 23:04
Flow Duration (hours):	NA	8.92	
Average Rain Intensity (in/hr):	NA	0.07	
Average Runoff Rate (gallons/min):	NA	20	
Peak 5-min Rain Intensity (in/hr):	NA	1.68	
Peak Runoff Rate (gallons/min):	NA	273	
Peak to Average Runoff Ratio:	NA	13.66	
Bypassed flow volume (gallon):	NA	2824	
Percentage of Bypassed Flow (%):	NA	26.41	
Inter-Event Time since prior rain (hours)	≥ 6.0	175.8	

Table 15-3. December 4, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	21	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	5.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	94.90	

Table 15-4. December 4, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	72	49	31.9	SM 2540D	1 mg/L	Stillbrook Lab
TSS	124	27	77.7	SM 2540D	1 mg/L	UA Lab
SSC	64	40	37.5	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	239	27	88.5	ASTM D3977-97B	1 mg/L	UA Lab
TDS	41	39	3.7	EPA 160.2	1 mg/L	UA Lab
VSS	27	14	45.3	SM 2540E	1 mg/L	UA Lab
Total N as N	0.8	0.4	50.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.6	0.4	33.3	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.03	BDL	> 33.3	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	1.35	1.81	-34.1	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.95	0.98	-3.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	0.74	0.52	29.7	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.52	0.31	40.4	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.034	0.072	-111.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.009	0.010	-11.1	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	> 48,392	NA	IDEXX Method	<1	UA Lab
E. Coli	3713	2224	40.1	IDEXX Method	<1	UA Lab
Enterococci	2121	908	57.2	IDEXX Method	<1	UA Lab
pH	6.74	6.85	-1.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	63.50	12.20	80.8	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	65.6	44.1	32.8	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	15.0	14.8	1.3	SM 212/ EPA 170.1	5 °C	UA Lab

Table 15-5. December 4, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	64	NA*	NA*	40	NA*	NA*	37.5	NA*	NA*
UA Lab	201	38	239	26	2	27	87.3	95.1	88.5

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 15-6. December 4, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	14578	11346	46	20	3.2	1.8

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

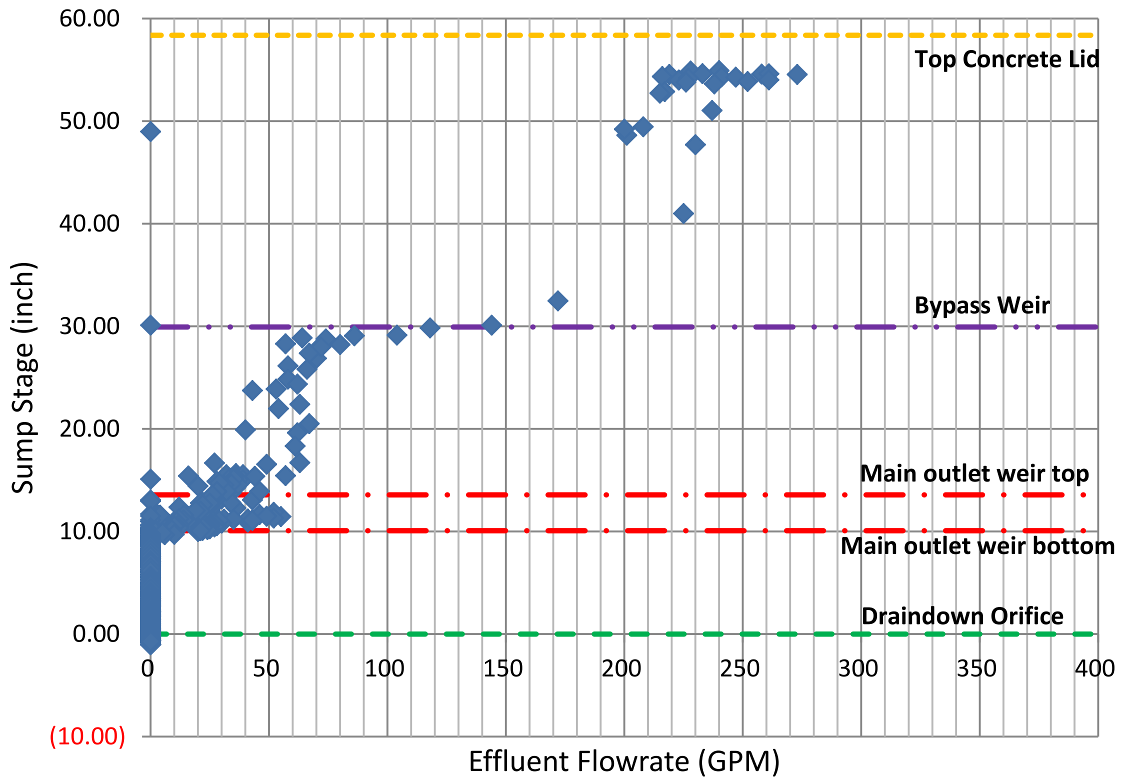
Table 15-7. December 4, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	118	129	124	27	28	27
Millipore Membrane Filter, 0.45µm	161	127	144	7	6	6

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 15-8. December 4, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	> 48,392	> 48,392
E. Coli	3,448	3,978	3,713	1,956	2,492	2,224
Enterococci	2,481	1,760	2,121	960	856	908

Table 15-9. December 4, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	28	25	27	14	15	14

Figure 15-2. December 4, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



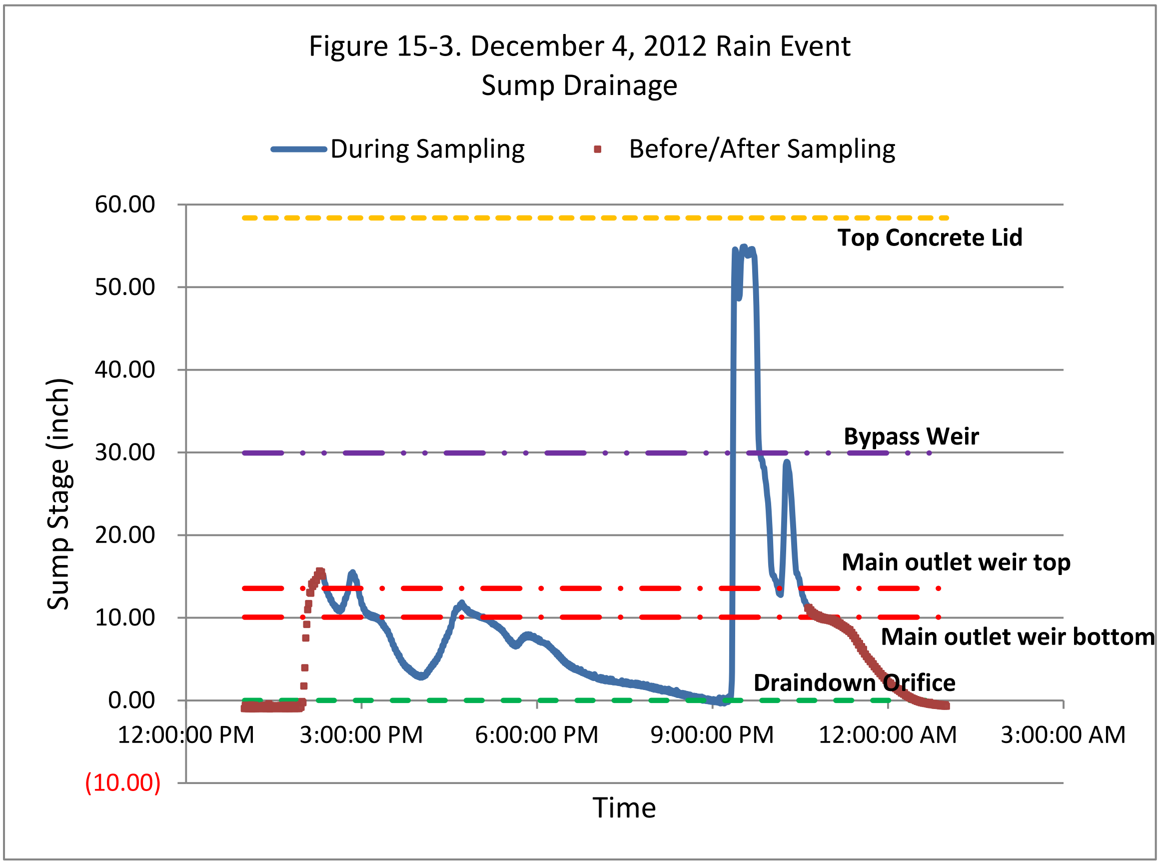


Figure 15-3. December 4, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Sump Stage (inch)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
3:00:00 PM
6:00:00 PM
9:00:00 PM
12:00:00 AM
3:00:00 AM
Time

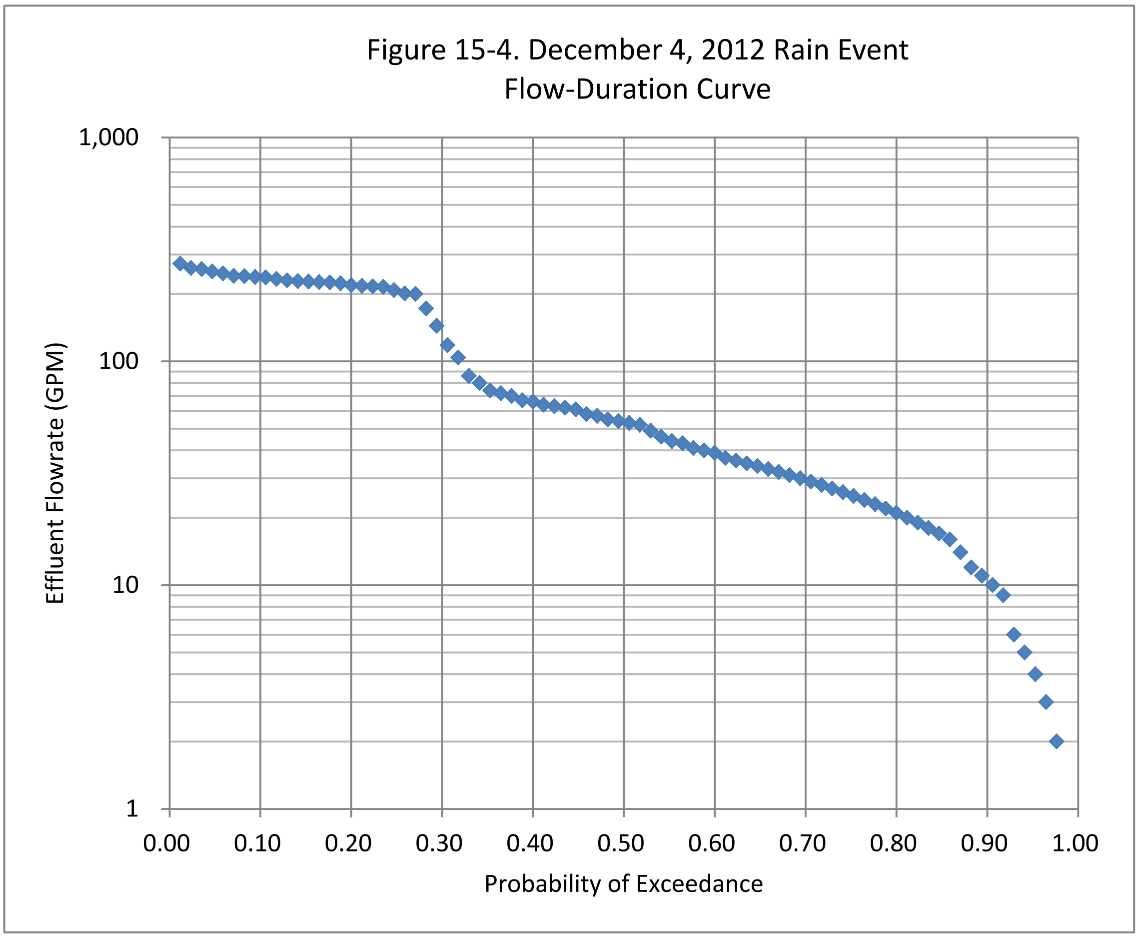
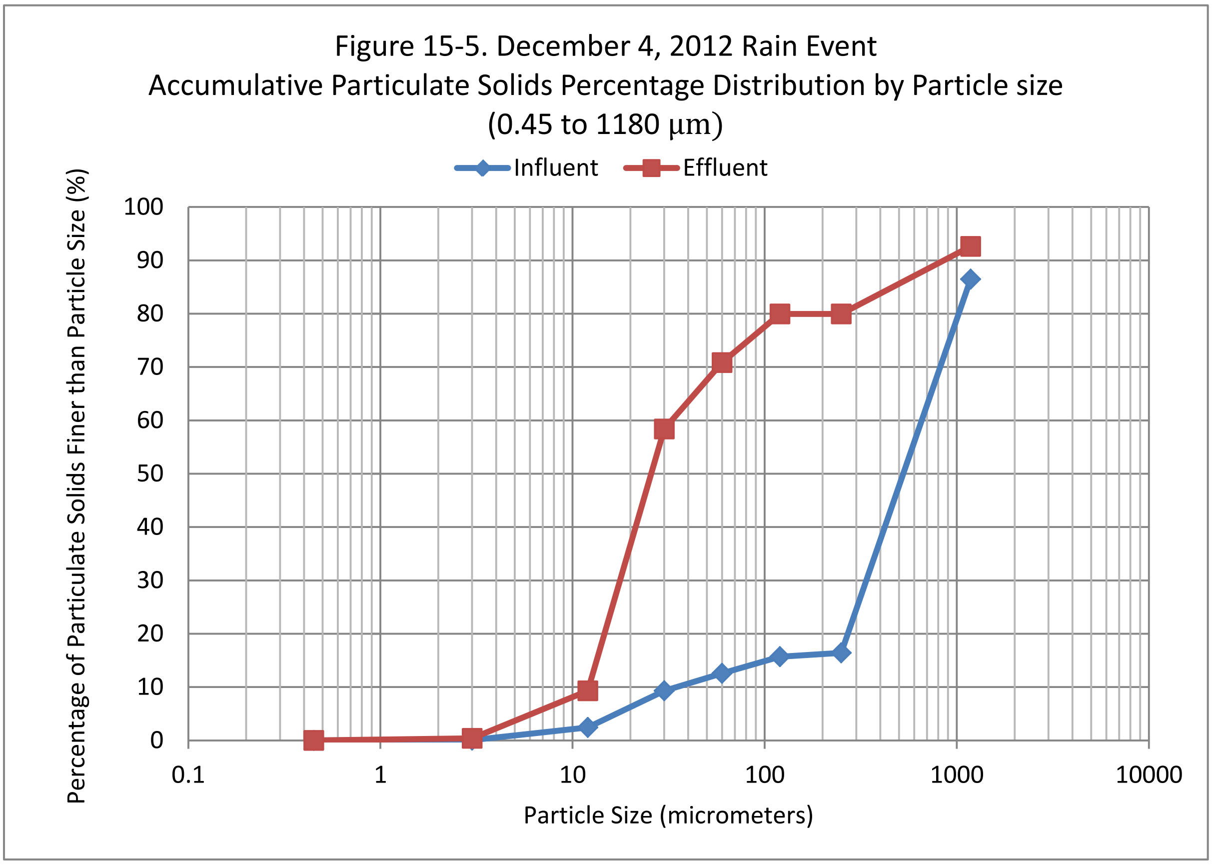
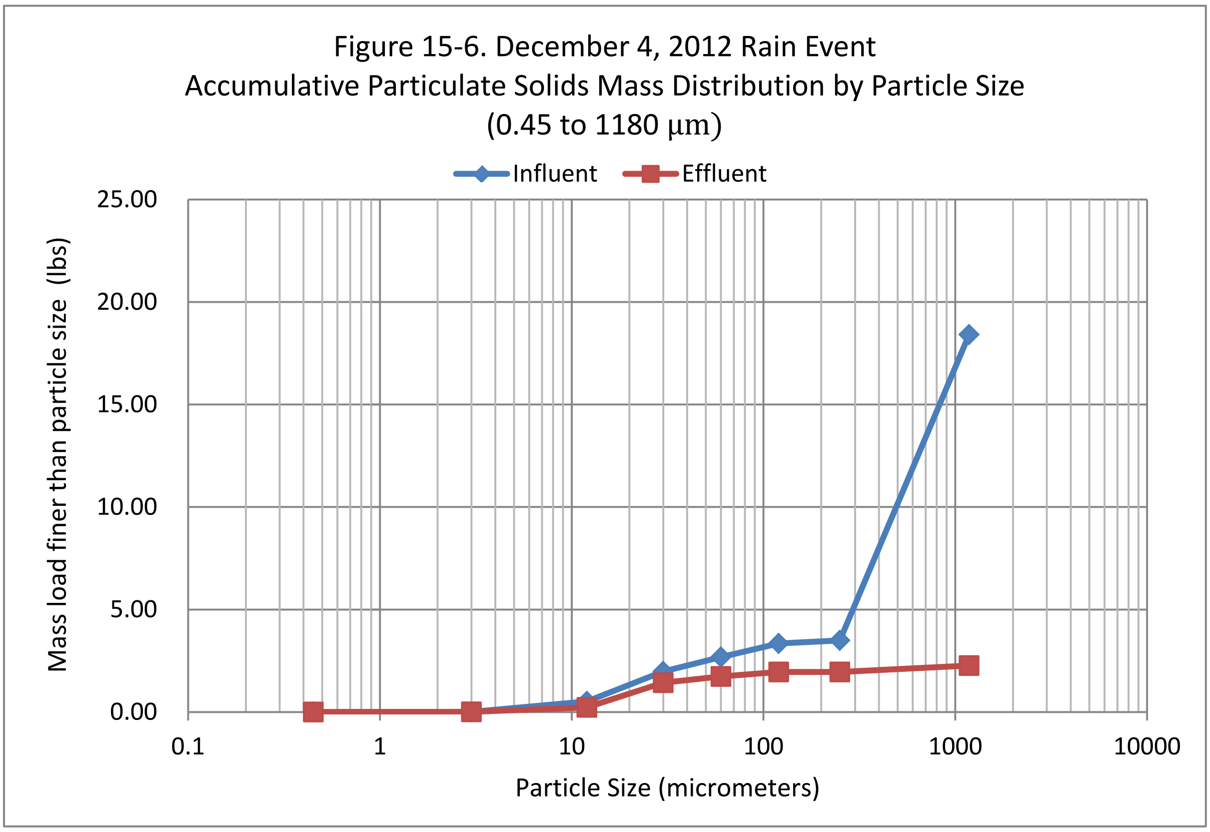


Figure 15-4. December 4, 2012 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 2.88 lbs larger than 1180 µm and the effluent had 0.18 lbs larger than 1180 µm (13.53% and 7.39% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 15-10. December 4, 2012 Rain Event
Particle Size Distribution Information

Particle Size (um)	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.14	0.10	0.05	0.40	0.01	0.01	0.00	8.30
3 to 12	6.77	2.28	2.39	8.91	0.51	0.22	0.29	57.12
12 to 30	19.44	12.54	6.85	49.07	1.46	1.20	0.26	17.76
30 to 60	9.32	3.18	3.28	12.45	0.70	0.30	0.39	56.46
60 to 120	8.86	2.33	3.12	9.12	0.67	0.22	0.44	66.44
120 to 250	2.03	0.00	0.71	0.00	0.15	0.00	0.15	100.00
250 to 1180	198.73	3.24	70.06	12.66	14.92	0.31	14.61	97.92
>1180	38.37	1.89	13.53	7.39	2.88	0.18	2.70	93.72
Total	284	26	100.00	100.00	21.30	2.45	18.85	88.51

Table 15-11. December 4, 2012 Rain Event
Particle Size Distribution Information

Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.05	0.40	0.01	0.01
<12	2.44	9.31	0.52	0.23
<30	9.29	58.37	1.98	1.43
<60	12.57	70.82	2.68	1.73
<120	15.70	79.95	3.34	1.96
<250	16.41	79.95	3.50	1.96
<1180	86.47	92.61	18.42	2.27
>1180	100.00	100.00	21.30	2.45

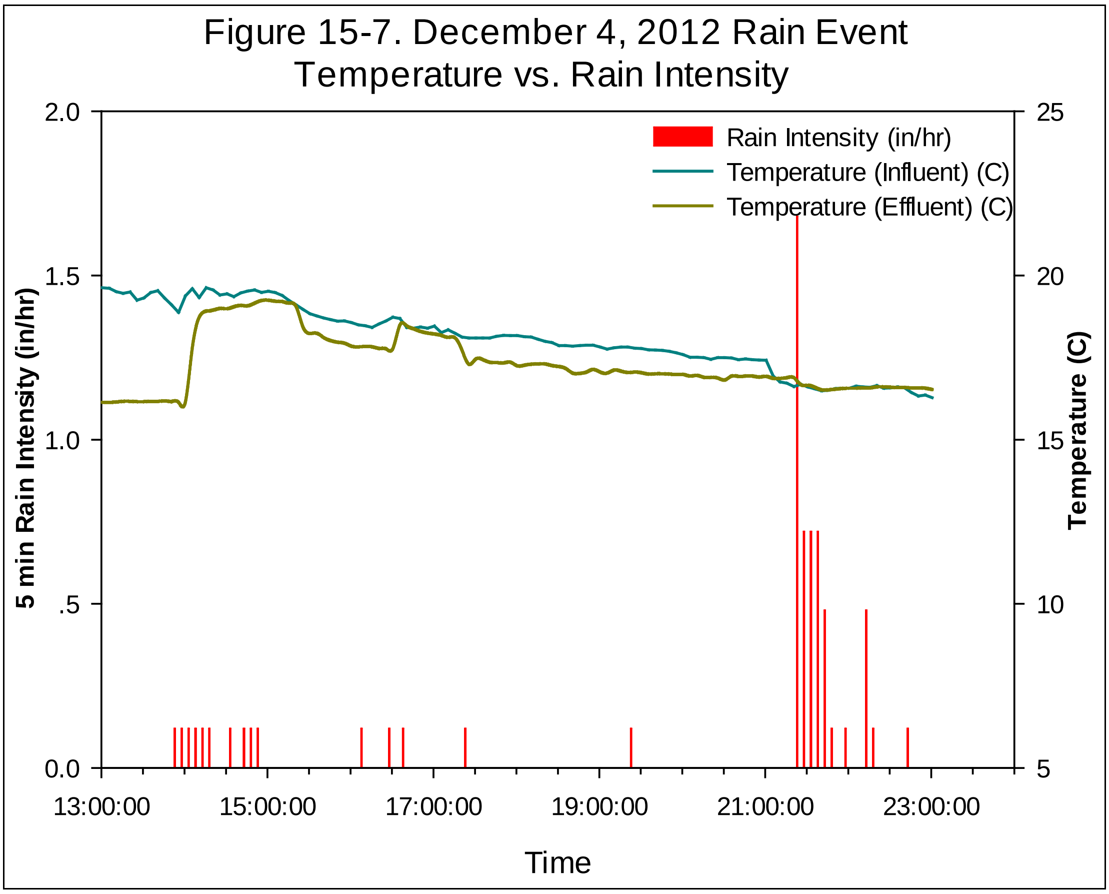


Figure 15-7. December 4, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
2.0
1.5
1.0
.5
0.0
25
20
15
10
5
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

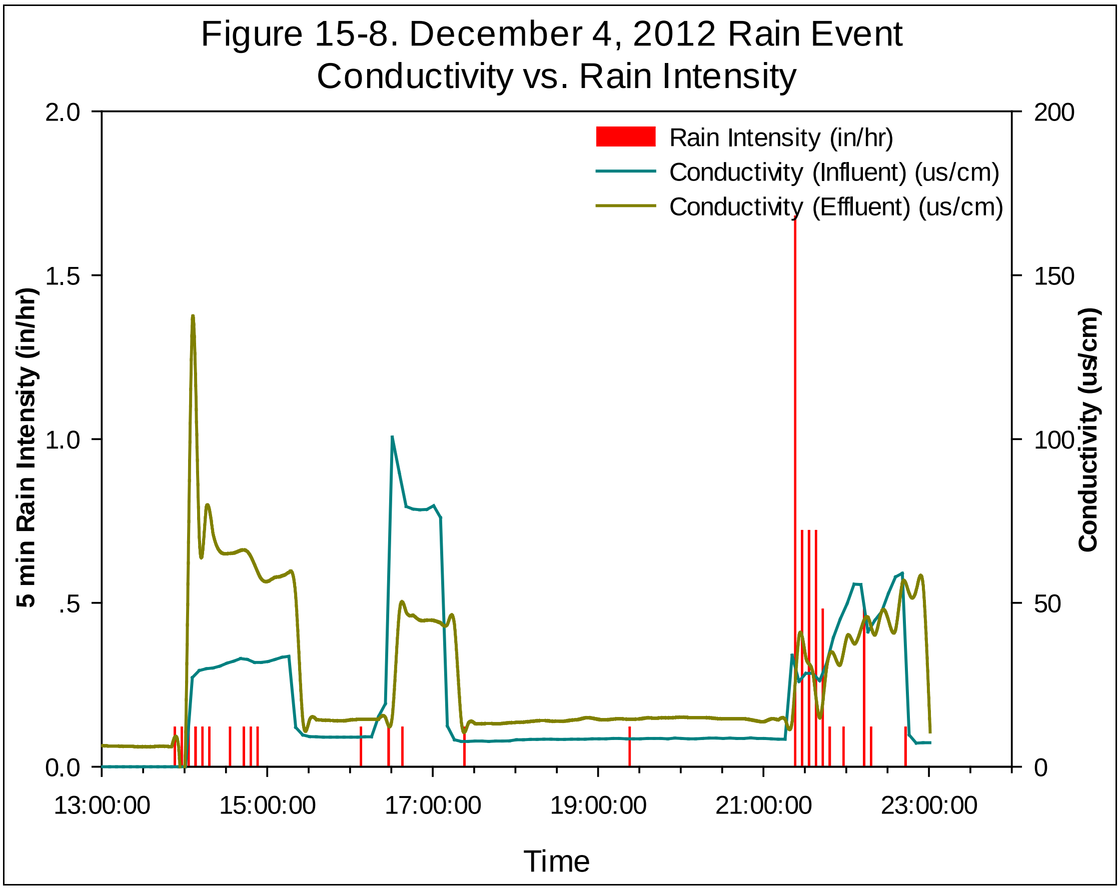


Figure 15-8. December 4, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

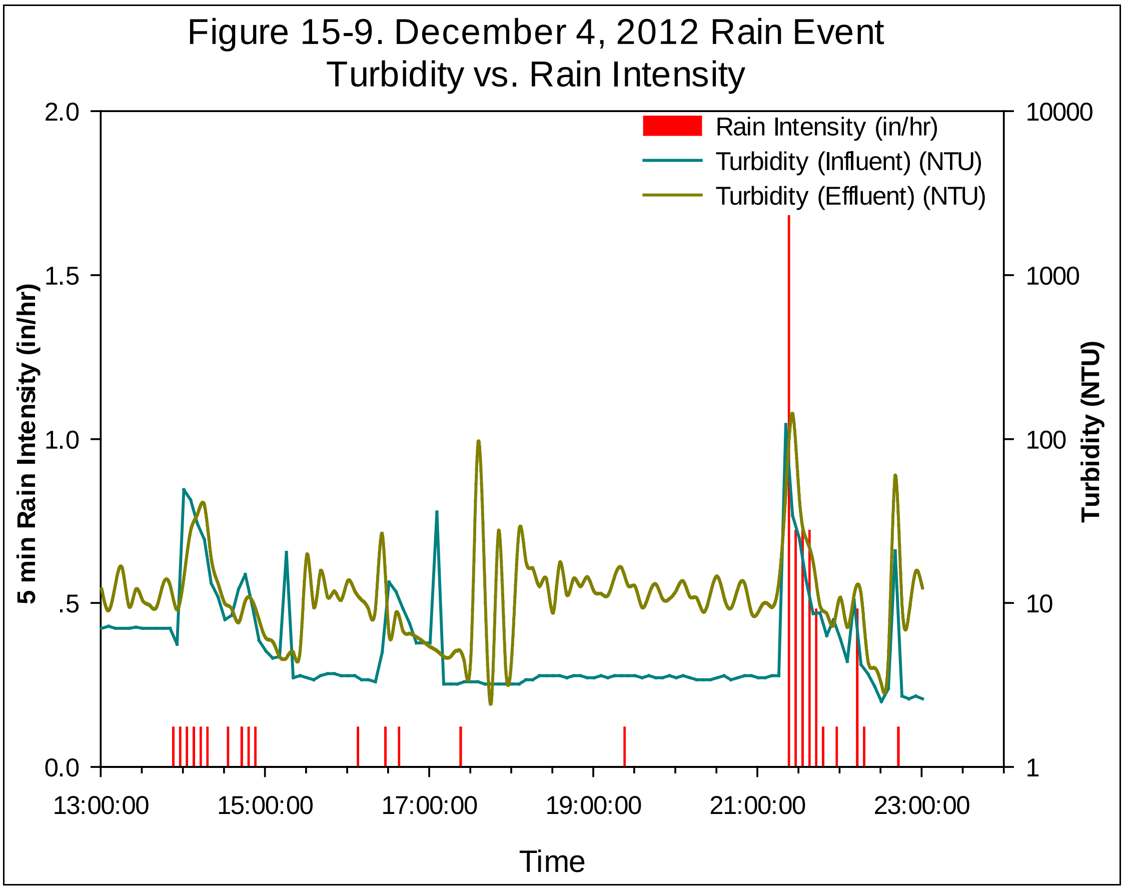
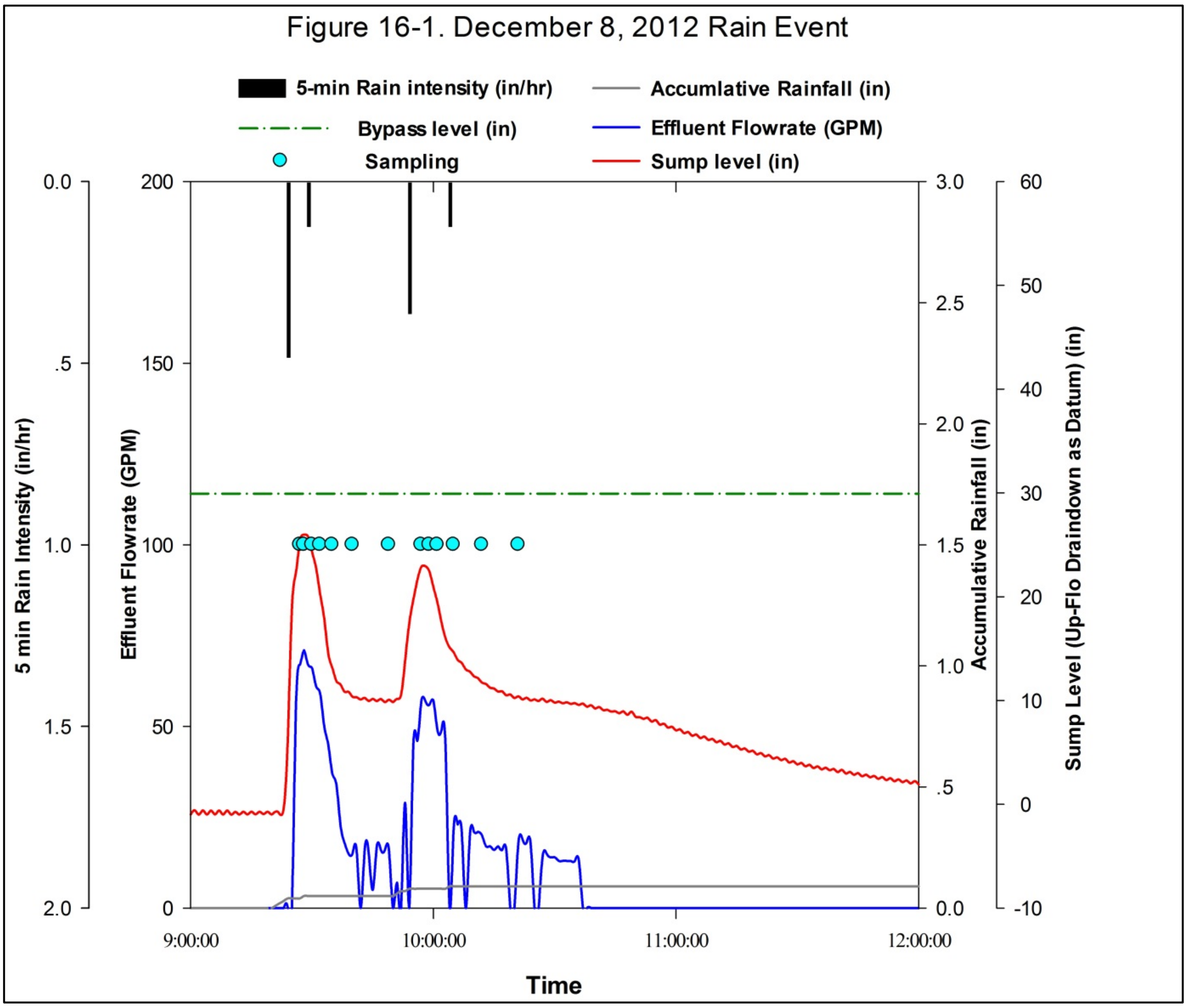


Figure 15-9. December 4, 2012 Rain Event
Turbidity vs. Rain Intensity
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
Time

Appendix F.16: December 8, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 16-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.37
Volumetric Runoff Coefficient (Rv)	0.49

Table 16-2. December 8, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/12/8 9:21
Rain Event End Date/Time:			2012/12/8 10:04
Total Precipitation (inch):	≥ 0.1	0.09	Totalizing rain gage showed this event had about 0.14 inch
Total Runoff Depth (inch):	NA	0.04	
Total Outflow (gallon):	NA	1750	
Rain Duration (hours):	≥ 1	0.72	
Flow Start Date/Time:			2012/12/8 9:26
Flow End Date/Time:			2012/12/8 10:37
Flow Duration (hours):	NA	1.18	
Average Rain Intensity (in/hr):	NA	0.13	
Average Runoff Rate (gallons/min):	NA	25	
Peak 5-min Rain Intensity (in/hr):	NA	0.48	
Peak Runoff Rate (gallons/min):	NA	71	
Peak to Average Runoff Ratio:	NA	2.88	
Bypassed flow volume (gallon):	NA	0	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	82.7	

Table 16-3. December 8, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	13	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	3.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	86.00	

Table 16-4. December 8, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	27	9	66.7	SM 2540D	1 mg/L	Stillbrook Lab
TSS	25	6	78.0	SM 2540D	1 mg/L	UA Lab
SSC	29	14	51.7	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	26	7	72.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	70	58	17.1	EPA 160.2	1 mg/L	UA Lab
VSS	12	4	70.8	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.8	-14.3	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.7	-40.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.07	BDL	> 71.4	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.95	1.23	-29.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.55	0.86	-56.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	0.28	0.40	-42.9	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.18	0.37	-105.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.009	BDL	> 44.4	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.039	0.016	59.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.006	0.009	-50.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	20924	> 56.8	IDEXX Method	<1	UA Lab
E. Coli	96	36	62.3	IDEXX Method	<1	UA Lab
Enterococci	915	199	78.3	IDEXX Method	<1	UA Lab
pH	6.81	6.86	-0.7	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	29.30	4.97	83.0	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	57.0	62.4	-9.5	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	14.5	14.8	-2.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 16-5. December 8, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	29	NA*	NA*	14	NA*	NA*	51.7	NA*	NA*
UA Lab	26	1	26	7	0	7	72.0	100.0	72.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 16-6. December 8, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	11601	4859	20	3	1.7	0.6

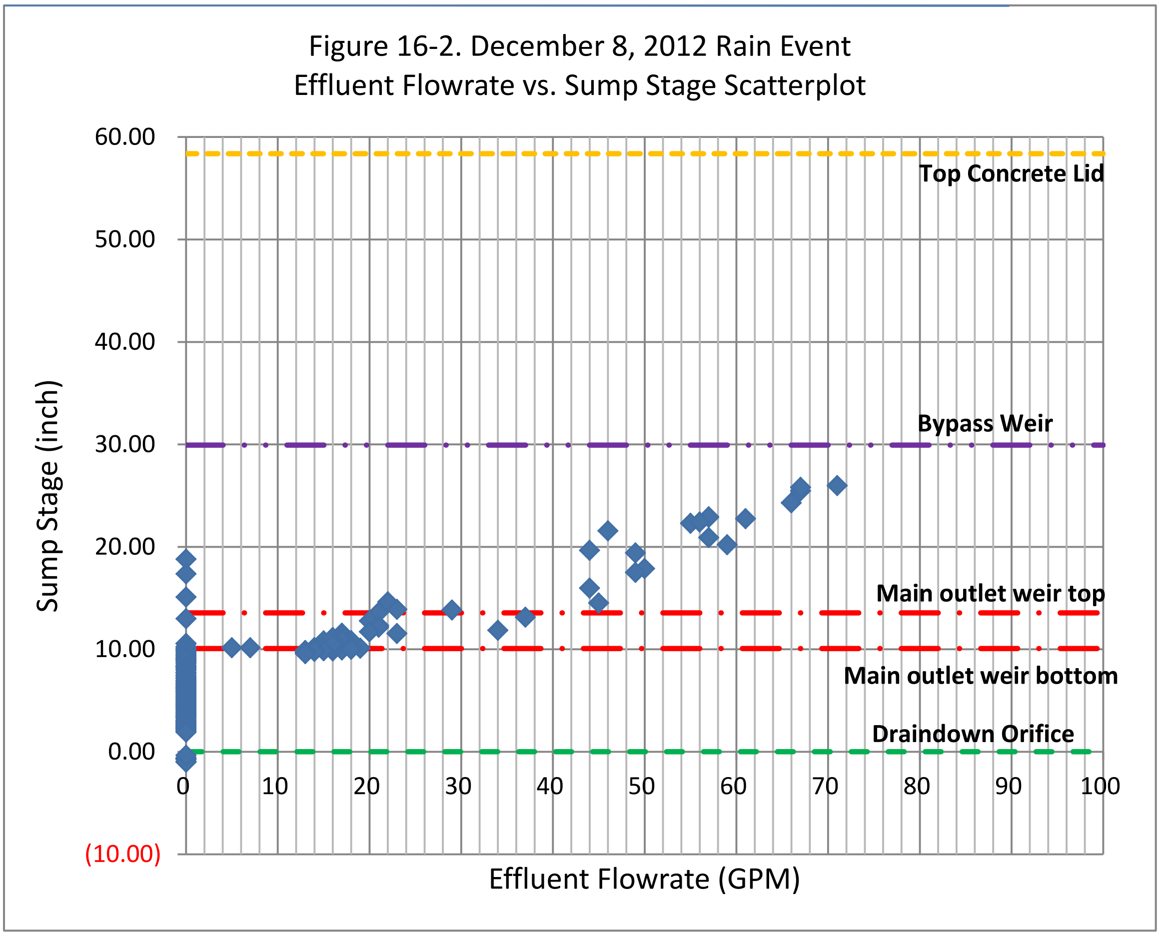
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 16-7. December 8, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	24	26	25	6	5	6
Millipore Membrane Filter, 0.45µm	10	10	10	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 16-8. December 8, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	20924	20,924
E. Coli	109	82	96	52	20	36
Enterococci	504	1,326	915	249	148	199

Table 16-9. December 8, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	12	12	12	4	3	4



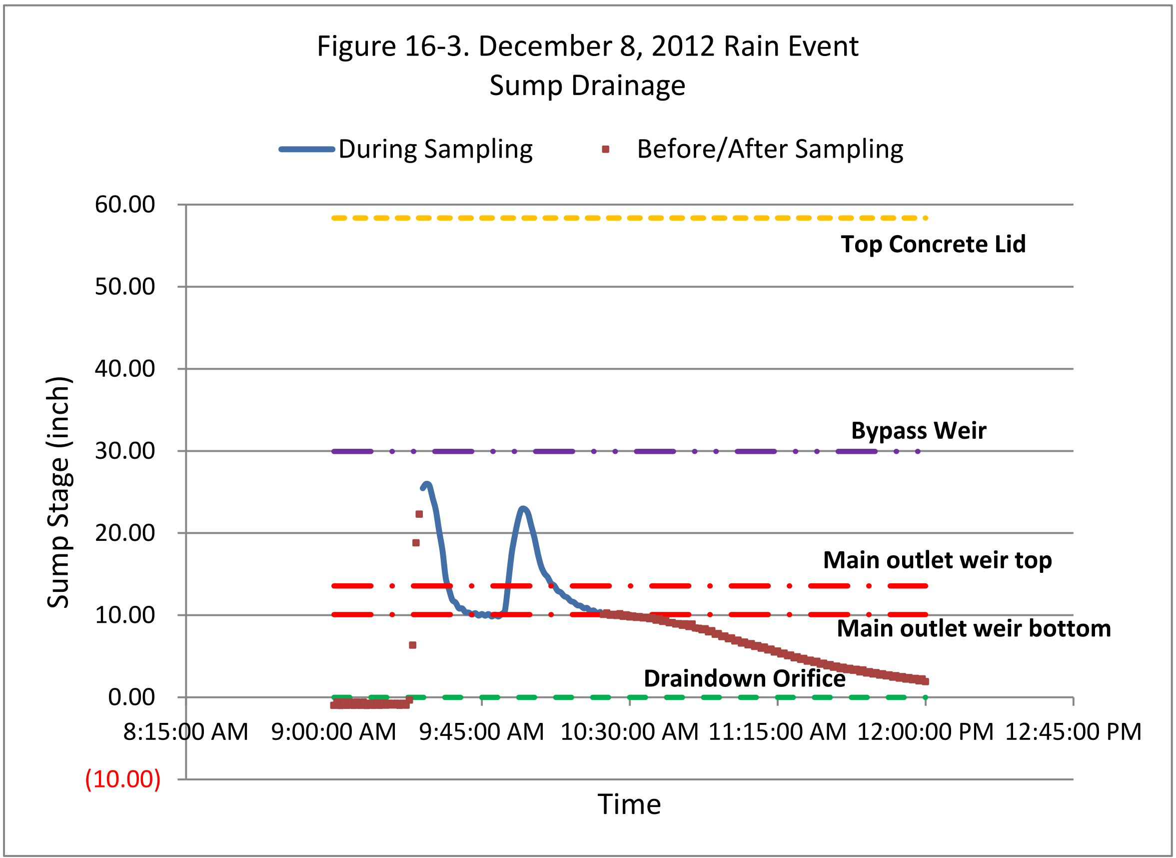


Figure 16-3. December 8, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
Time

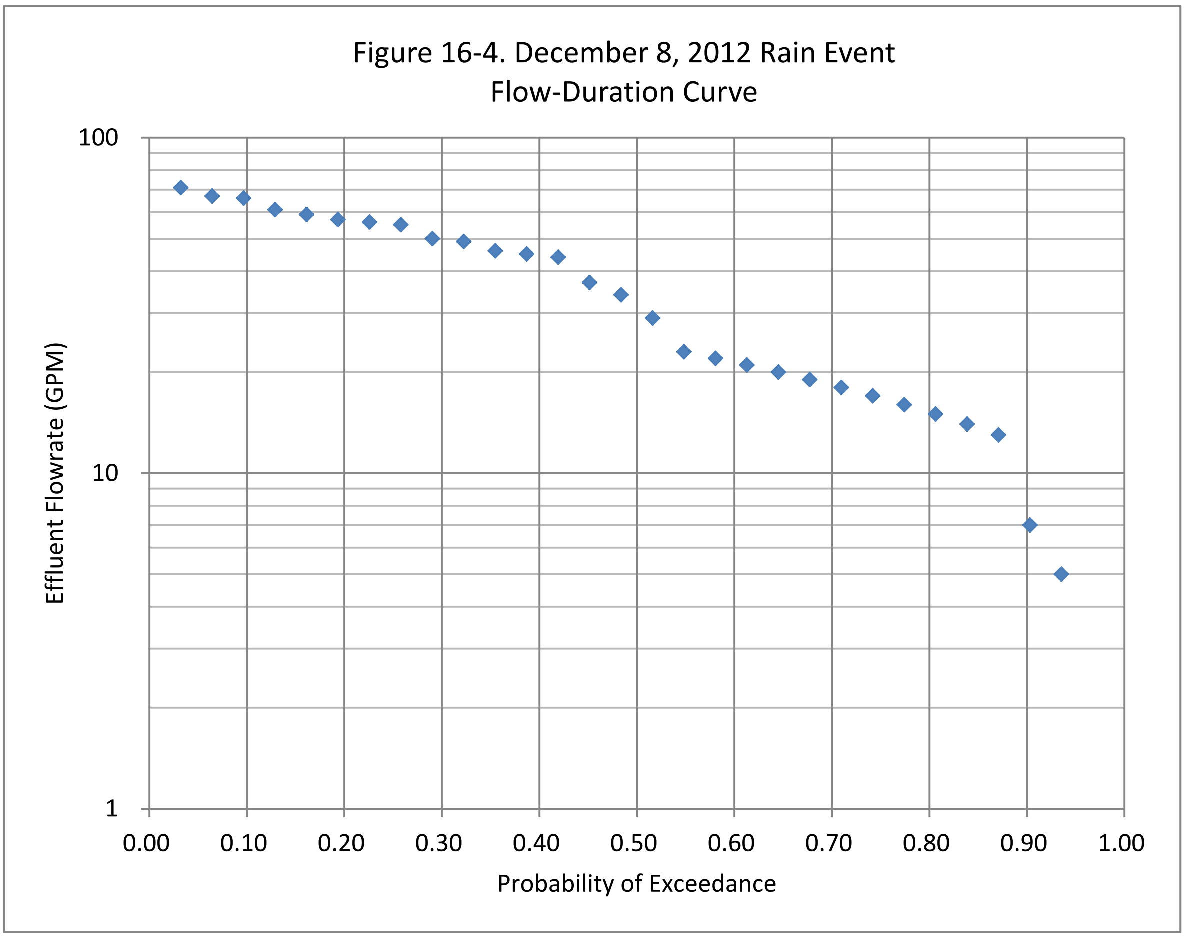


Figure 16-4. December 8, 2012 Rain Event
Flow-Duration Curve
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 16-5. December 8, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

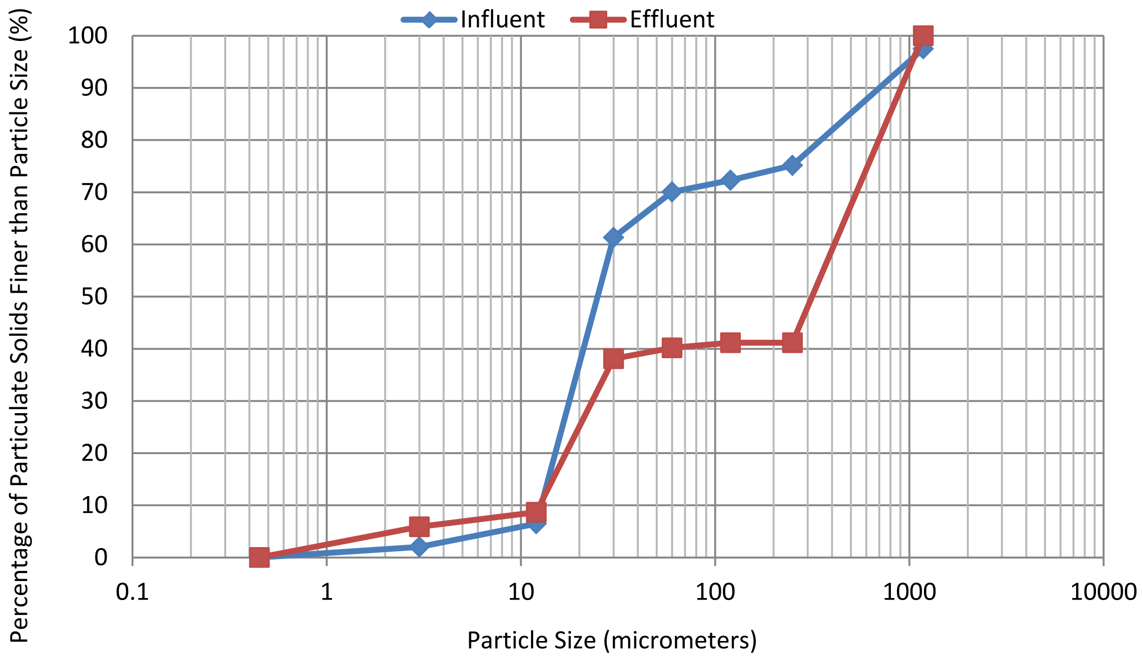
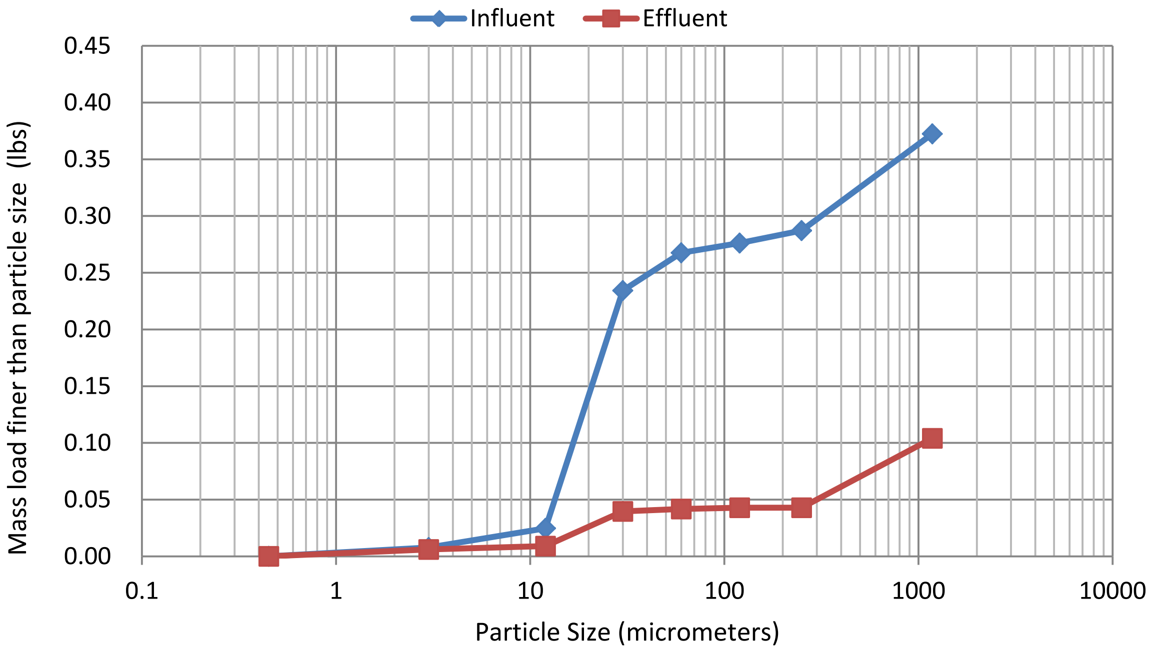


Figure 16-6. December 8, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 0.01 lbs larger than 1180 µm and the effluent had 0.0 lbs larger than 1180 µm (2.49% and 0.0% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 16-10. December 8, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.54	0.45	2.03	5.88	0.01	0.01	0.00	21.09
3 to 12	1.19	0.21	4.45	2.80	0.02	0.00	0.01	82.87
12 to 30	14.67	2.23	54.85	29.43	0.21	0.03	0.18	85.38
30 to 60	2.33	0.16	8.72	2.08	0.03	0.00	0.03	93.49
60 to 120	0.60	0.07	2.25	0.98	0.01	0.00	0.01	88.11
120 to 250	0.76	0.00	2.85	0.00	0.01	0.00	0.01	100.00
250 to 1180	5.98	4.46	22.35	58.82	0.09	0.06	0.02	28.26
>1180	0.67	0.00	2.49	0.00	0.01	0.00	0.01	100.00
Total	27	8	100.00	100.00	0.38	0.10	0.28	72.75

Table 16-11. December 8, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	2.03	5.88	0.01	0.01
<12	6.48	8.68	0.02	0.01
<30	61.34	38.11	0.23	0.04
<60	70.06	40.19	0.27	0.04
<120	72.31	41.18	0.28	0.04
<250	75.16	41.18	0.29	0.04
<1180	97.51	100.00	0.37	0.10
>1180	100.00	100.00	0.38	0.10

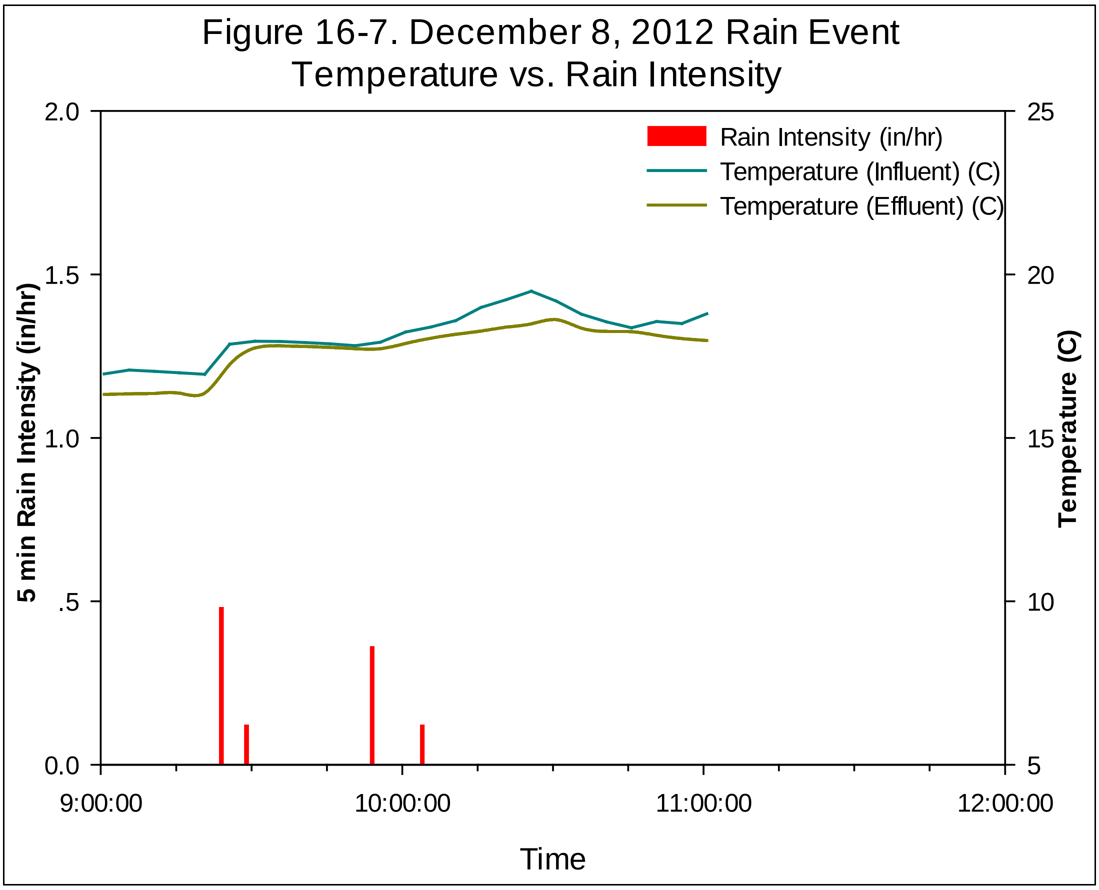


Figure 16-7. December 8, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
2.0
1.5
1.0
.5
0.0
25
20
15
10
5
9:00:00
10:00:00
11:00:00
12:00:00
Time

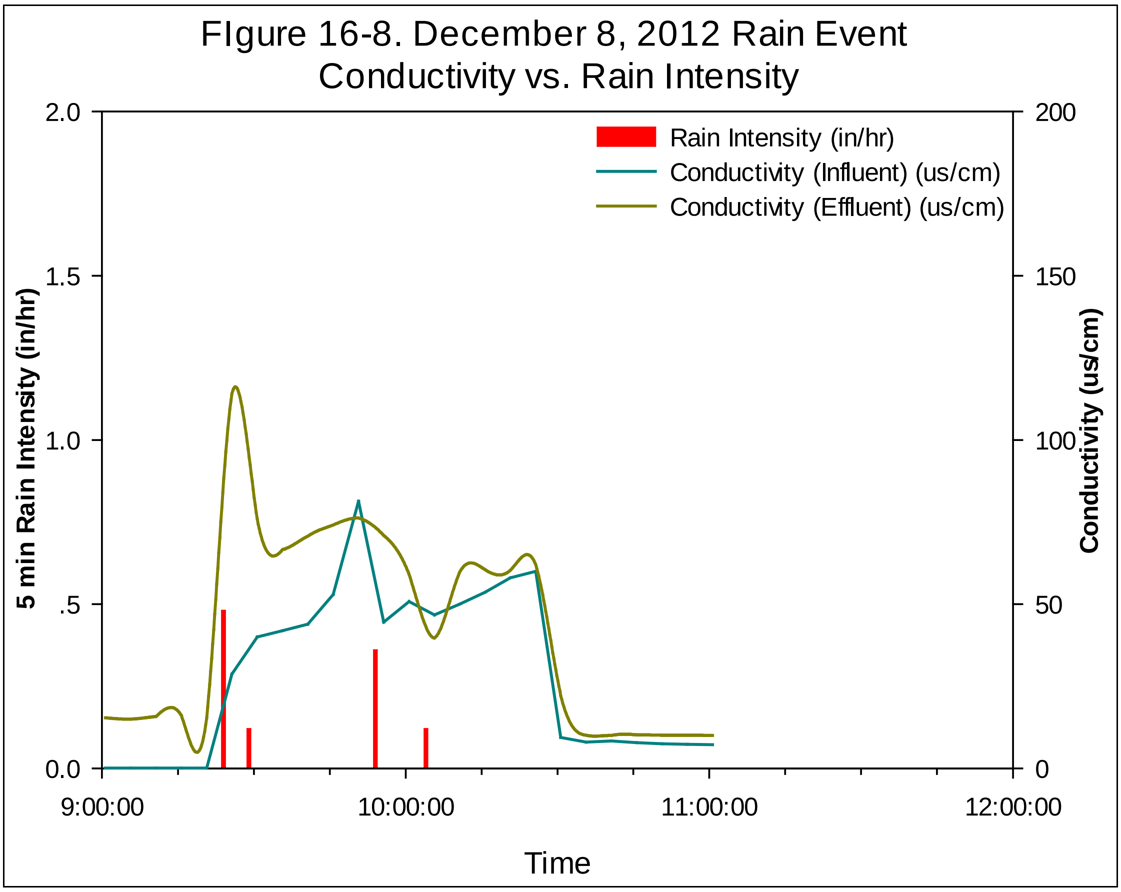


FIgure 16-8. December 8, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
9:00:00
10:00:00
11:00:00
12:00:00
Time

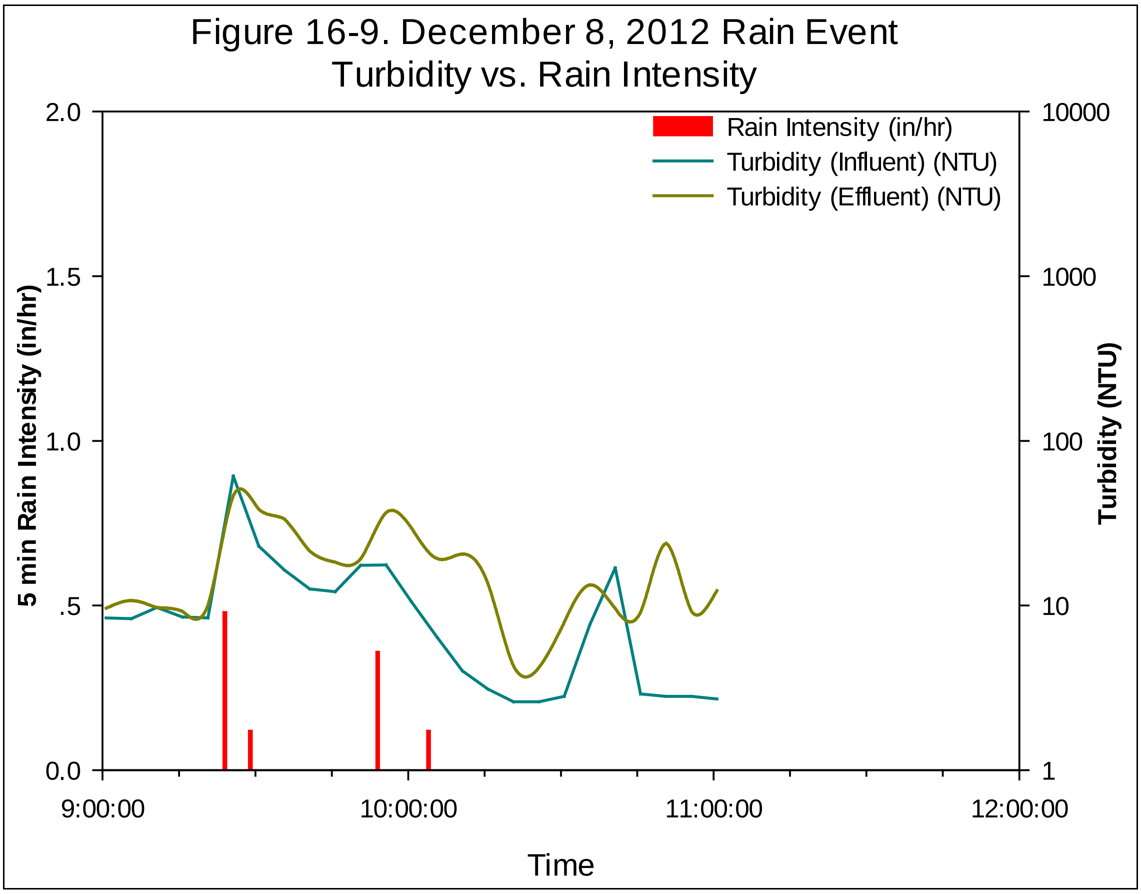
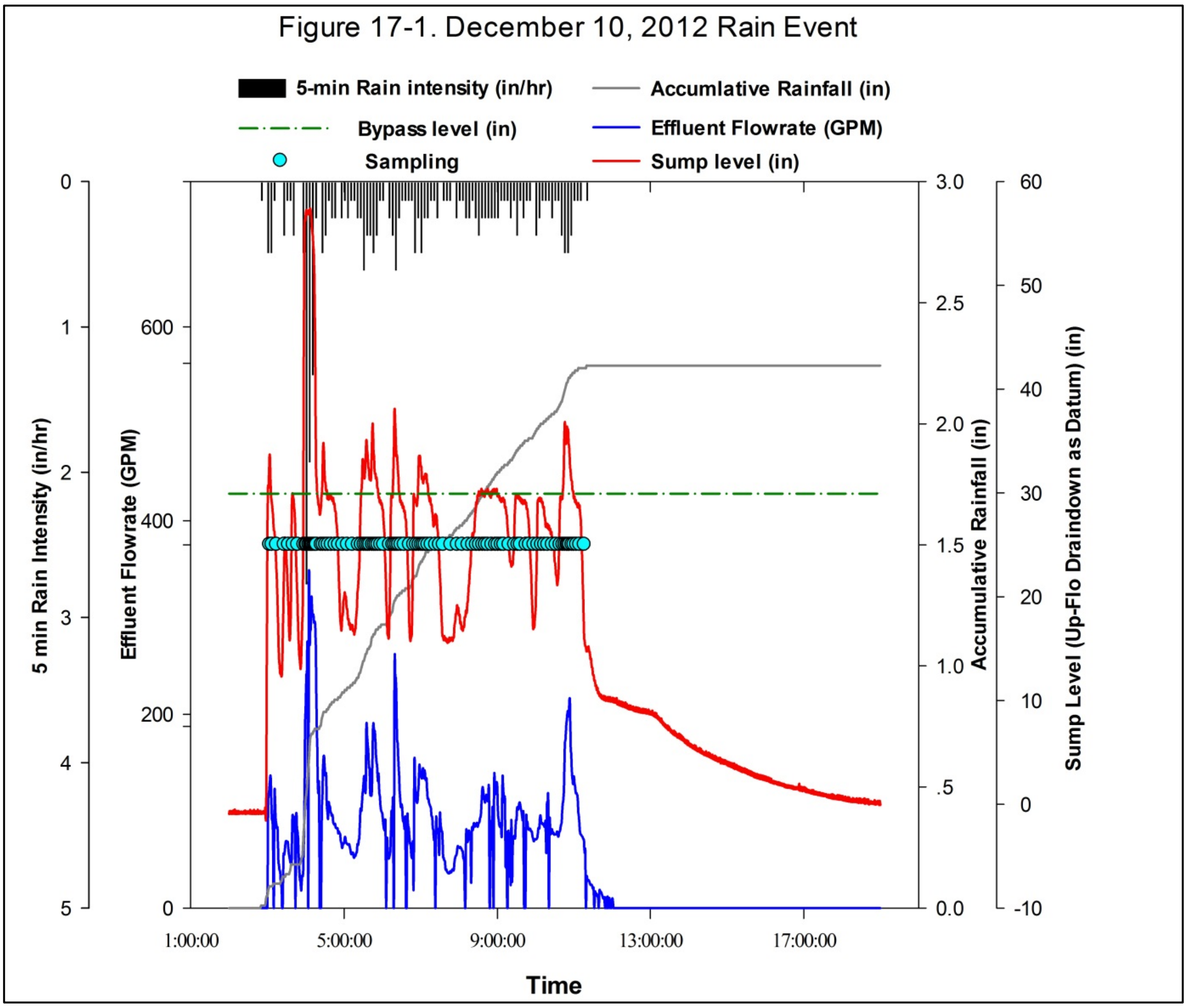


Figure 16-9. December 8, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
9:00:00
10:00:00
11:00:00
12:00:00
Time

Appendix F.17: December 10, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 17-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.29
Volumetric Runoff Coefficient (Rv)	0.84

Table 17-2. December 10, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/12/10 2:50
Rain Event End Date/Time:			2012/12/10 11:20
Total Precipitation (inch):	≥ 0.1	2.24	
Total Runoff Depth (inch):	NA	1.87	
Total Outflow (gallon):	NA	47830	
Rain Duration (hours):	≥ 1	8.50	
Flow Start Date/Time:			2012/12/10 3:01
Flow End Date/Time:			2012/12/10 12:02
Flow Duration (hours):	NA	9.02	
Average Rain Intensity (in/hr):	NA	0.26	
Average Runoff Rate (gallons/min):	NA	88	
Peak 5-min Rain Intensity (in/hr):	NA	2.76	
Peak Runoff Rate (gallons/min):	NA	325	
Peak to Average Runoff Ratio:	NA	3.68	
Bypassed flow volume (gallon):	NA	4988	
Percentage of Bypassed Flow (%):	NA	10.43	
Inter-Event Time since prior rain (hours)	≥ 6.0	40.8	

Table 17-3. December 10, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	98	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	24.5	The actual volumes of both samples were only visually about 16 liters
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	97.98	

Table 17-4. December 10, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	22	19	13.6	SM 2540D	1 mg/L	Stillbrook Lab
TSS	22	13	40.9	SM 2540D	1 mg/L	UA Lab
SSC	30	19	36.7	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	34	16	51.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	21	16	26.2	EPA 160.2	1 mg/L	UA Lab
VSS	7	5	30.8	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.5	-25.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.08	0.09	-12.5	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.67	0.74	-10.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.43	0.55	-27.9	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	0.21	0.34	-61.9	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	0.18	0.28	-55.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.011	0.009	18.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	39726	> 17.9	IDEXX Method	<1	UA Lab
E. Coli	4091	3544	13.4	IDEXX Method	<1	UA Lab
Enterococci	1862	1565	16.0	IDEXX Method	<1	UA Lab
pH	6.79	6.86	-1.0	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	10.45	8.02	23.3	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	32.7	32.8	-0.3	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	14.5	14.8	-2.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 17-5. December 10, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	30	NA*	NA*	19	NA*	NA*	36.7	NA*	NA*
UA Lab	33	1	34	16	1	16	51.5	56.2	51.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 17-6. December 10, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	5602	6472	18	13	3.1	2.0

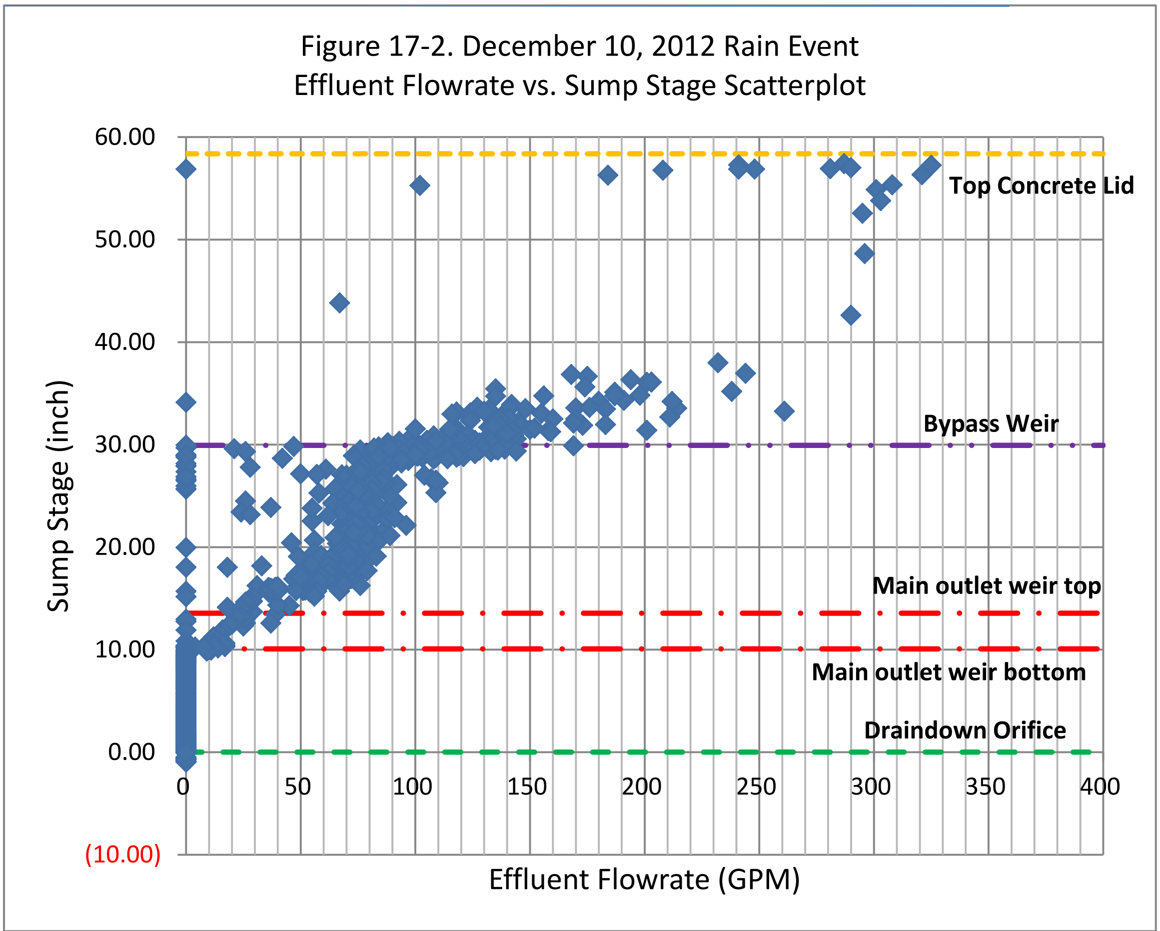
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 17-7. December 10, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	22	22	22	14	12	13
Millipore Membrane Filter, 0.45µm	5	6	5	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 17-8. December 10, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	> 24,196	39726	39,726
E. Coli	4,611	3,570	4,091	3,873	3,214	3,544
Enterococci	2,098	1,626	1,862	1,314	1,816	1,565

Table 17-9. December 10, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	7	6	7	5	4	5



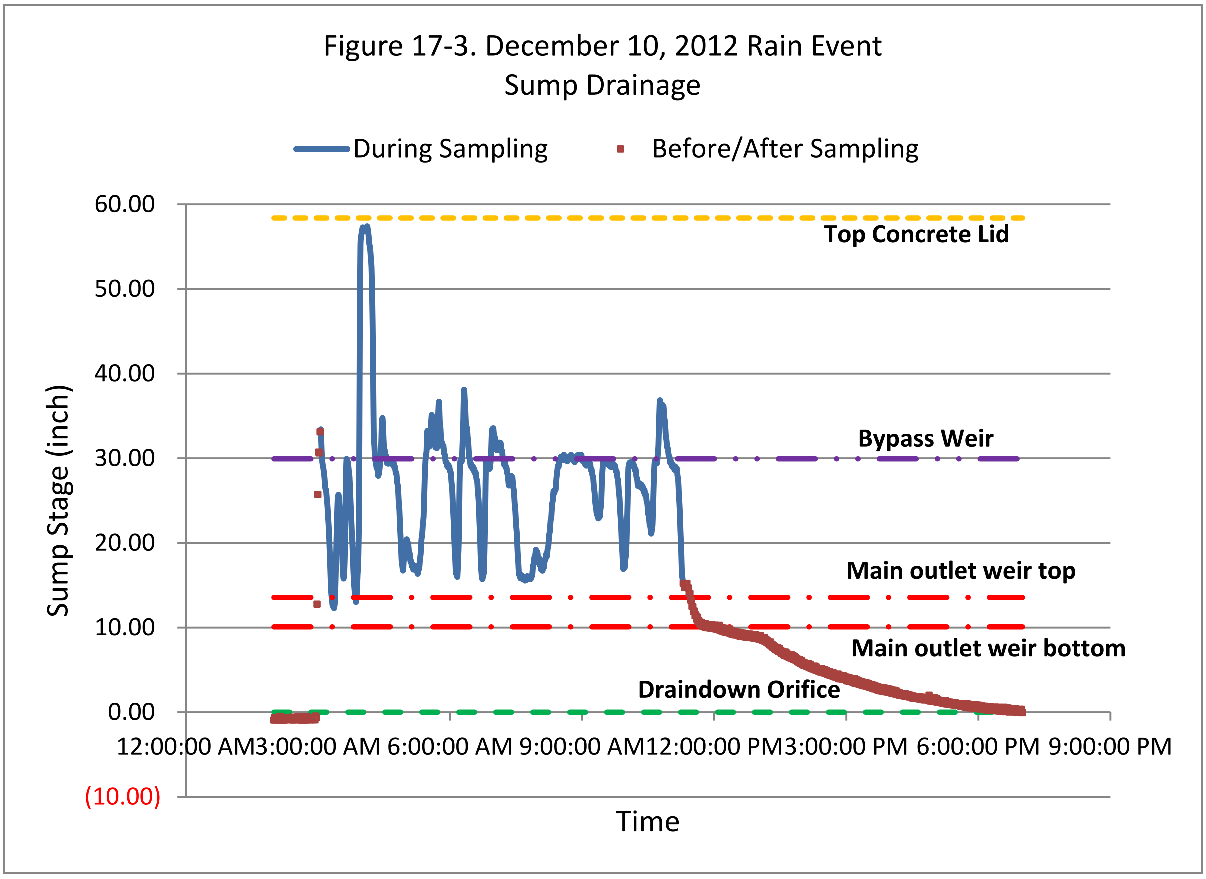


Figure 17-3. December 10, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
12:00:00 PM
3:00:00 PM
6:00:00 PM
9:00:00 PM
Time

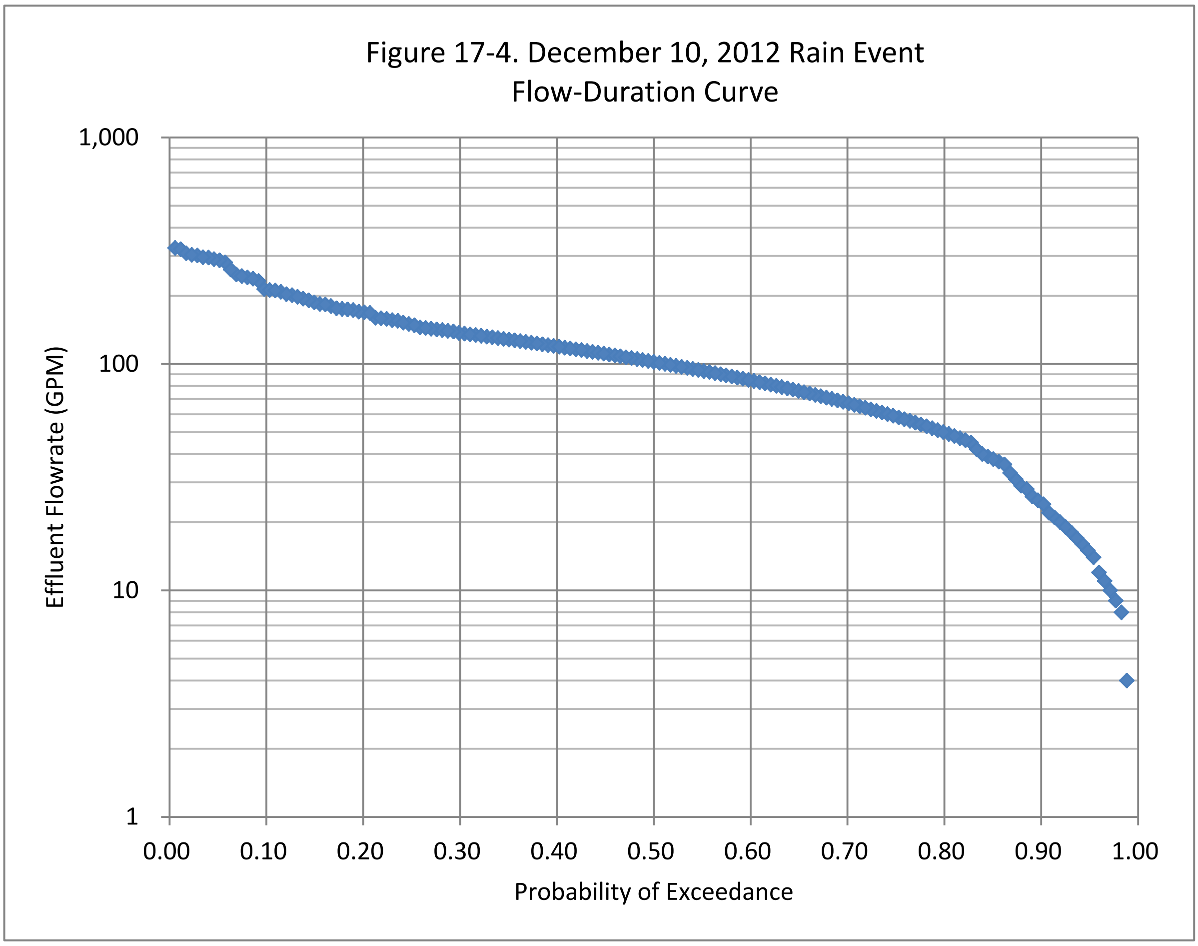


Figure 17-4. December 10, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 17-5. December 10, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 μm)

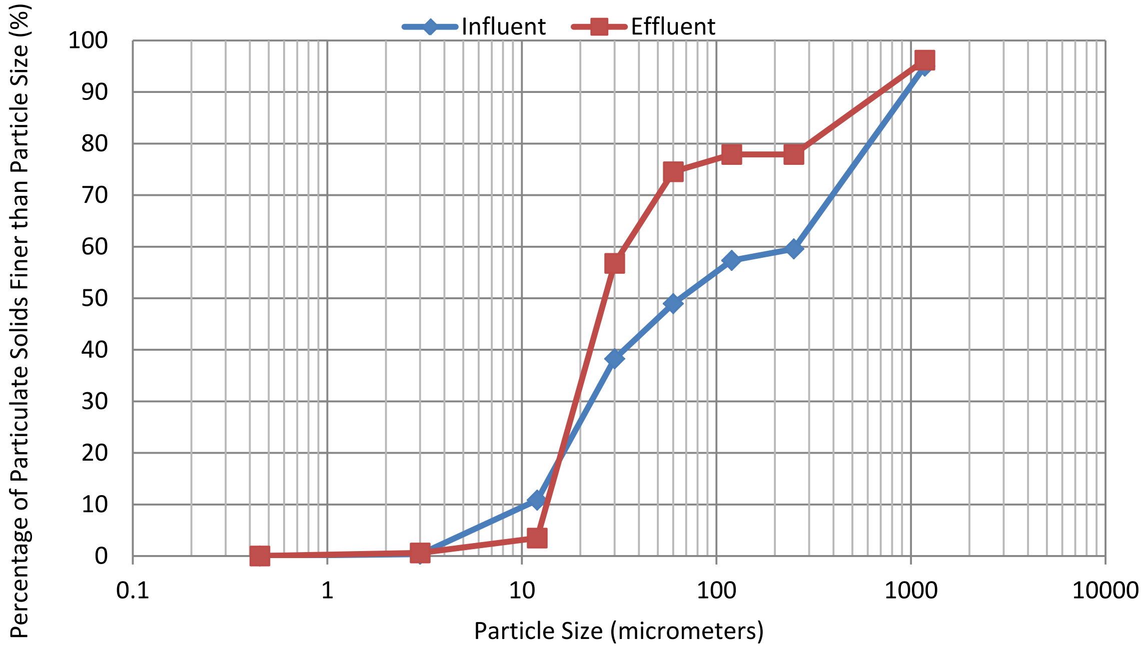
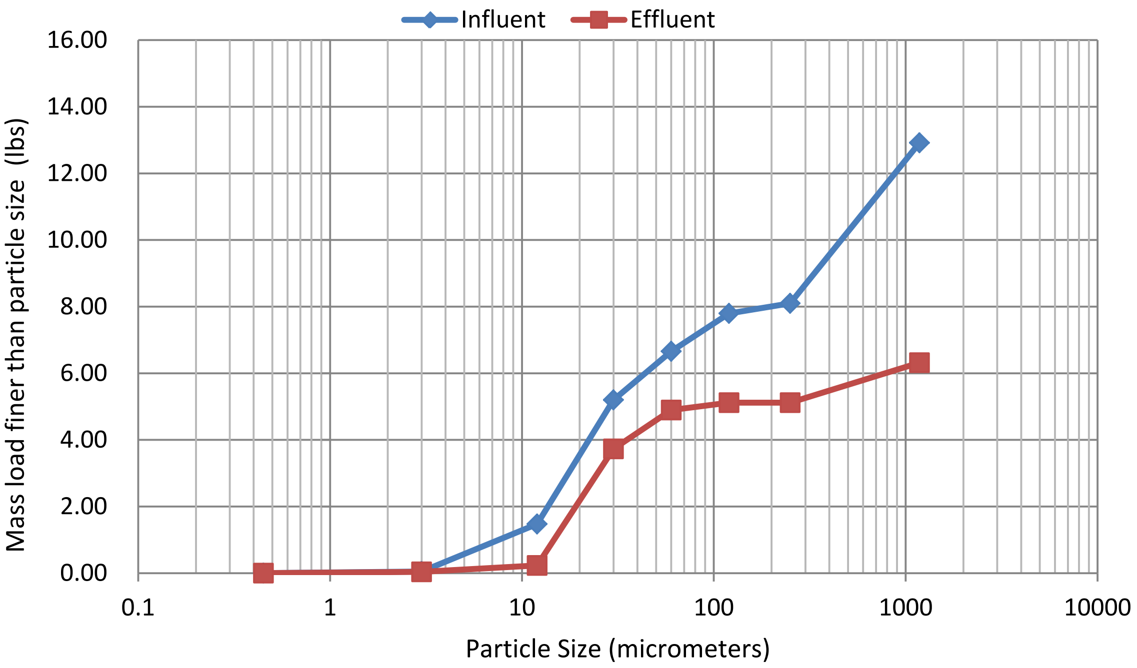


Figure 17-6. December 10, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 μm)



Not shown: The influent sample had 0.68 lbs larger than 1180 μm and the effluent had 0.25 lbs larger than 1180 μm (4.97% and 3.79% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 17-10. December 10, 2012 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.10	0.10	0.34	0.59	0.05	0.04	0.01	17.16
3 to 12	3.11	0.49	10.49	2.89	1.43	0.19	1.24	86.69
12 to 30	8.13	9.06	27.43	53.29	3.73	3.50	0.23	6.09
30 to 60	3.17	3.02	10.71	17.78	1.46	1.17	0.29	19.78
60 to 120	2.48	0.57	8.37	3.36	1.14	0.22	0.92	80.62
120 to 250	0.66	0.00	2.23	0.00	0.30	0.00	0.30	100.00
250 to 1180	10.51	3.11	35.46	18.30	4.82	1.20	3.62	75.07
>1180	1.47	0.64	4.97	3.79	0.68	0.25	0.43	63.12
Total	30	17	100.00	100.00	13.59	6.57	7.02	51.68

Table 17-11. December 10, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.34	0.59	0.05	0.04
<12	10.84	3.48	1.47	0.23
<30	38.26	56.77	5.20	3.73
<60	48.97	74.55	6.66	4.90
<120	57.34	77.91	7.79	5.12
<250	59.57	77.91	8.10	5.12
<1180	95.03	96.21	12.92	6.32
>1180	100.00	100.00	13.59	6.57

Figure 17-7. December 10, 2012 Rain Event
Temperature vs. Rain Intensity

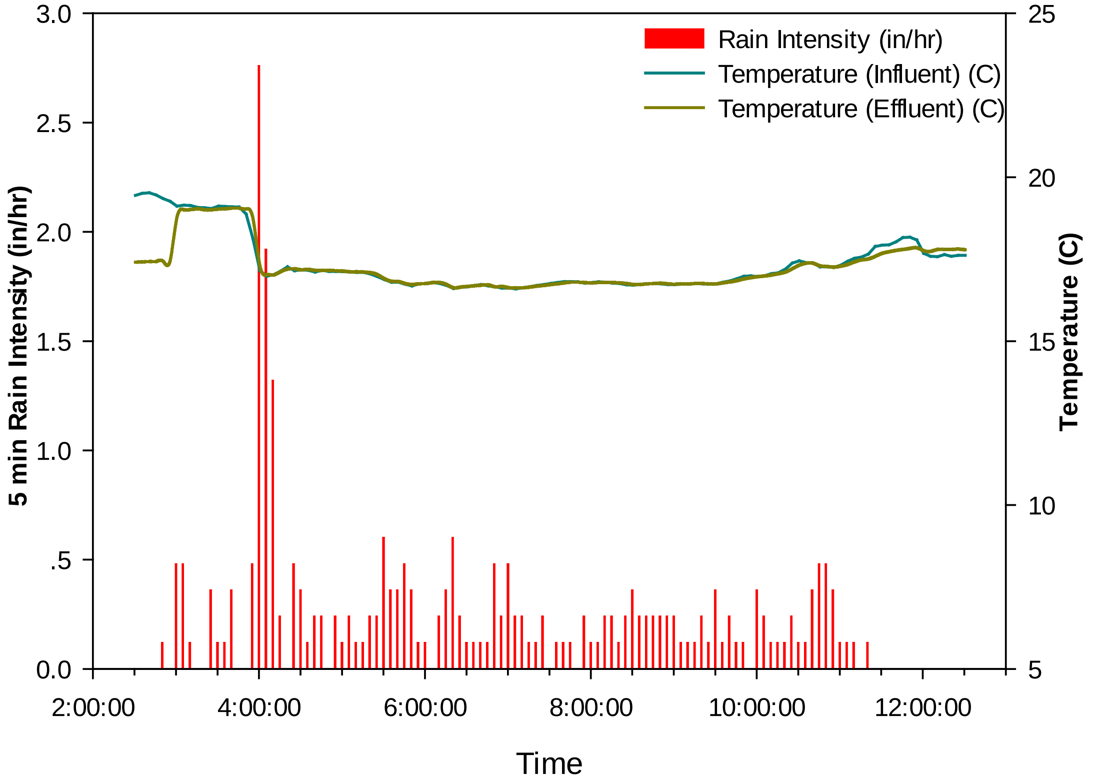
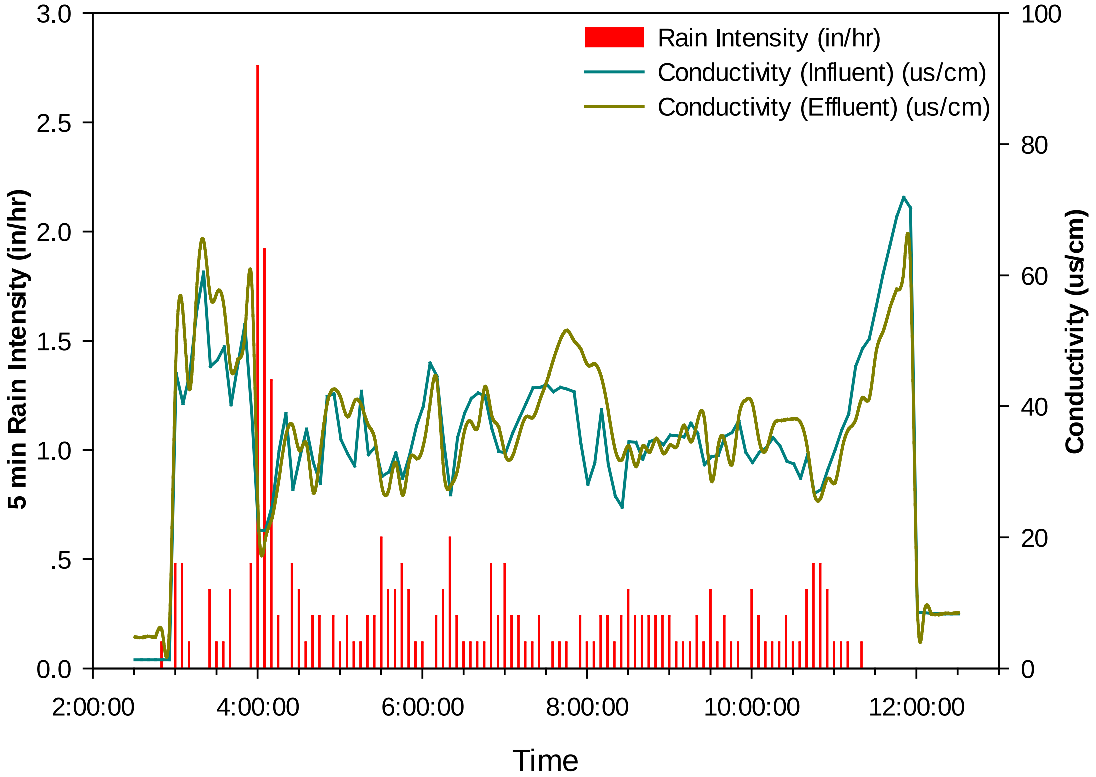


Figure 17-8. December 10, 2012 Rain Event
Conductivity vs. Rain Intensity



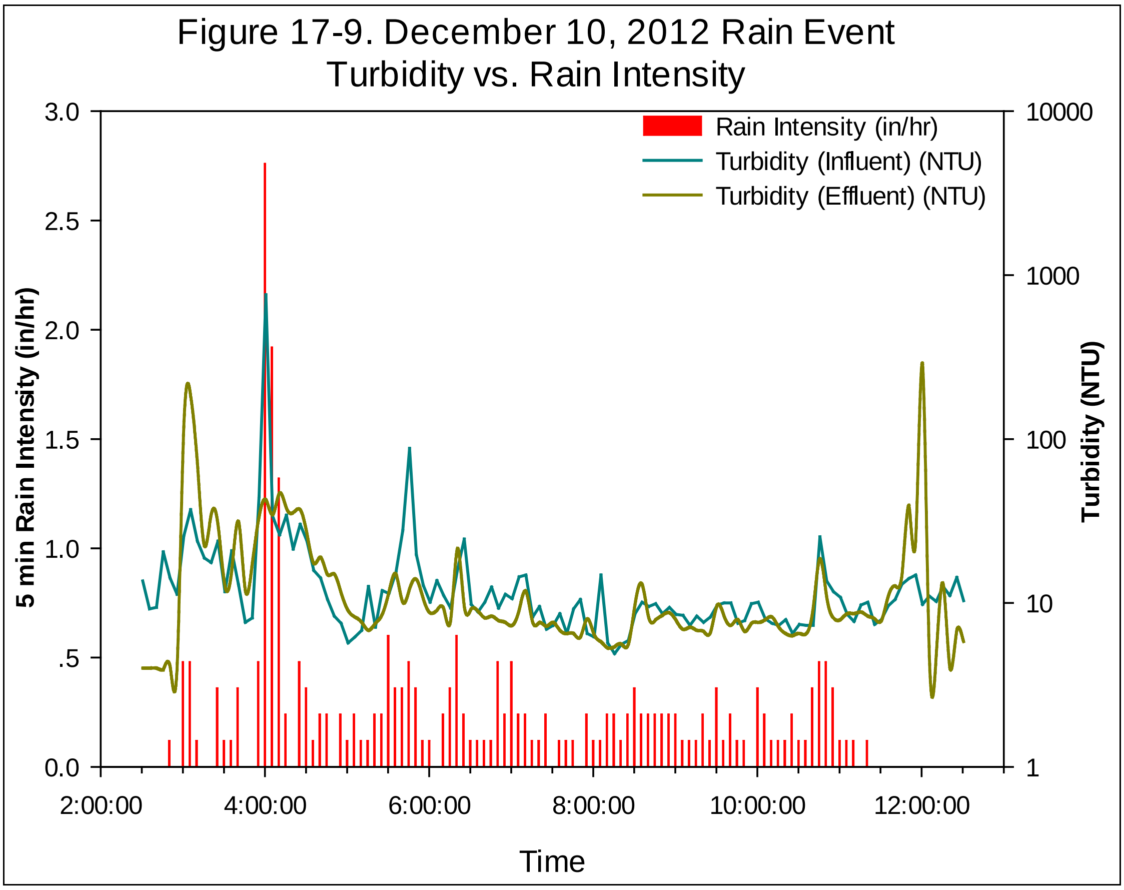
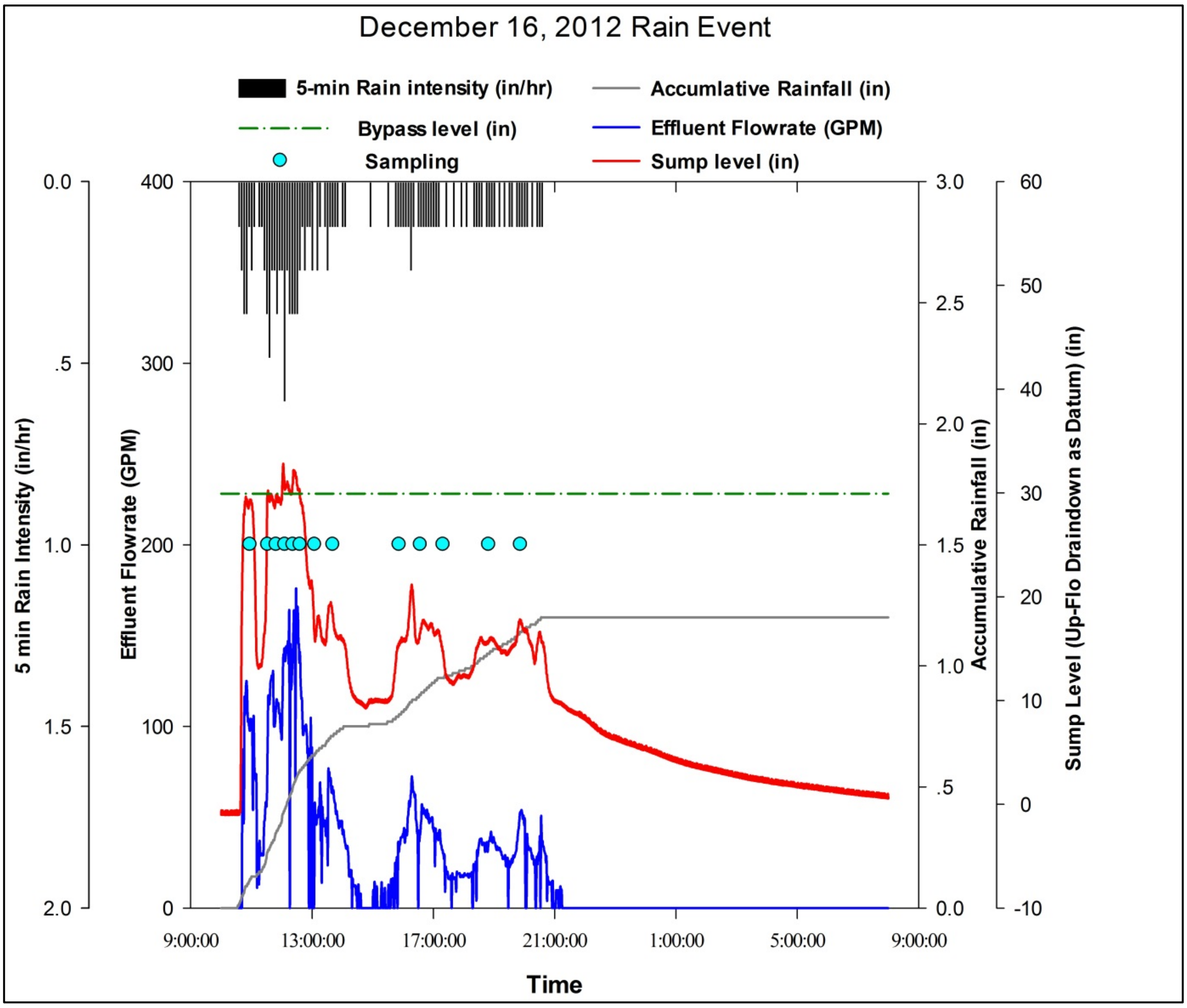


Figure 17-9. December 10, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
2:00:00
4:00:00
6:00:00
8:00:00
10:00:00
12:00:00

Appendix F.18: December 16, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 18-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.69
Volumetric Runoff Coefficient (Rv)	0.90

Table 18-2. December 16, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/12/16 10:33
Rain Event End Date/Time:			2012/12/16 20:33
Total Precipitation (inch):	≥ 0.1	1.20	
Total Runoff Depth (inch):	NA	1.08	
Total Outflow (gallon):	NA	27550	
Rain Duration (hours):	≥ 1	10.00	
Flow Start Date/Time:			2012/12/16 10:42
Flow End Date/Time:			2012/12/16 21:15
Flow Duration (hours):	NA	10.55	
Average Rain Intensity (in/hr):	NA	0.12	
Average Runoff Rate (gallons/min):	NA	44	
Peak 5-min Rain Intensity (in/hr):	NA	0.60	
Peak Runoff Rate (gallons/min):	NA	166	
Peak to Average Runoff Ratio:	NA	3.81	
Bypassed flow volume (gallon):	NA	433	
Percentage of Bypassed Flow (%):	NA	1.57	
Inter-Event Time since prior rain (hours)	≥ 6.0	143.2	

Table 18-3. December 16, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	13	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	3.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	2000	
Samples Coverage of total storm flow (%)	75.00	87.63	

Table 18-4. December 16, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	52	13	75.0	SM 2540D	1 mg/L	Stillbrook Lab
TSS	50	4	92.0	SM 2540D	1 mg/L	UA Lab
SSC	50	11	78.0	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	99	7	93.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	17	14	17.6	EPA 160.2	1 mg/L	UA Lab
VSS	6	3	50.0	SM 2540E	1 mg/L	UA Lab
Total N as N	0.4	0.4	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.4	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.06	0.06	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.40	0.28	30.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.18	0.18	0.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	0.21	BDL	> 90.5	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.011	BDL	> 54.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.018	0.009	50.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	15930	13287	16.6	IDEXX Method	<1	UA Lab
E. Coli	556	476	14.3	IDEXX Method	<1	UA Lab
Enterococci	358	261	27.2	IDEXX Method	<1	UA Lab
pH	6.85	6.89	-0.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	18.45	4.52	75.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	40.6	36.3	10.6	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	14.5	14.8	-2.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 18-5. December 16, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	50	NA*	NA*	11	NA*	NA*	78.0	NA*	NA*
UA Lab	64	35	99	6	1	7	90.5	98.2	93.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 18-6. December 16, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	18445	4497	17	2	0.9	0.4

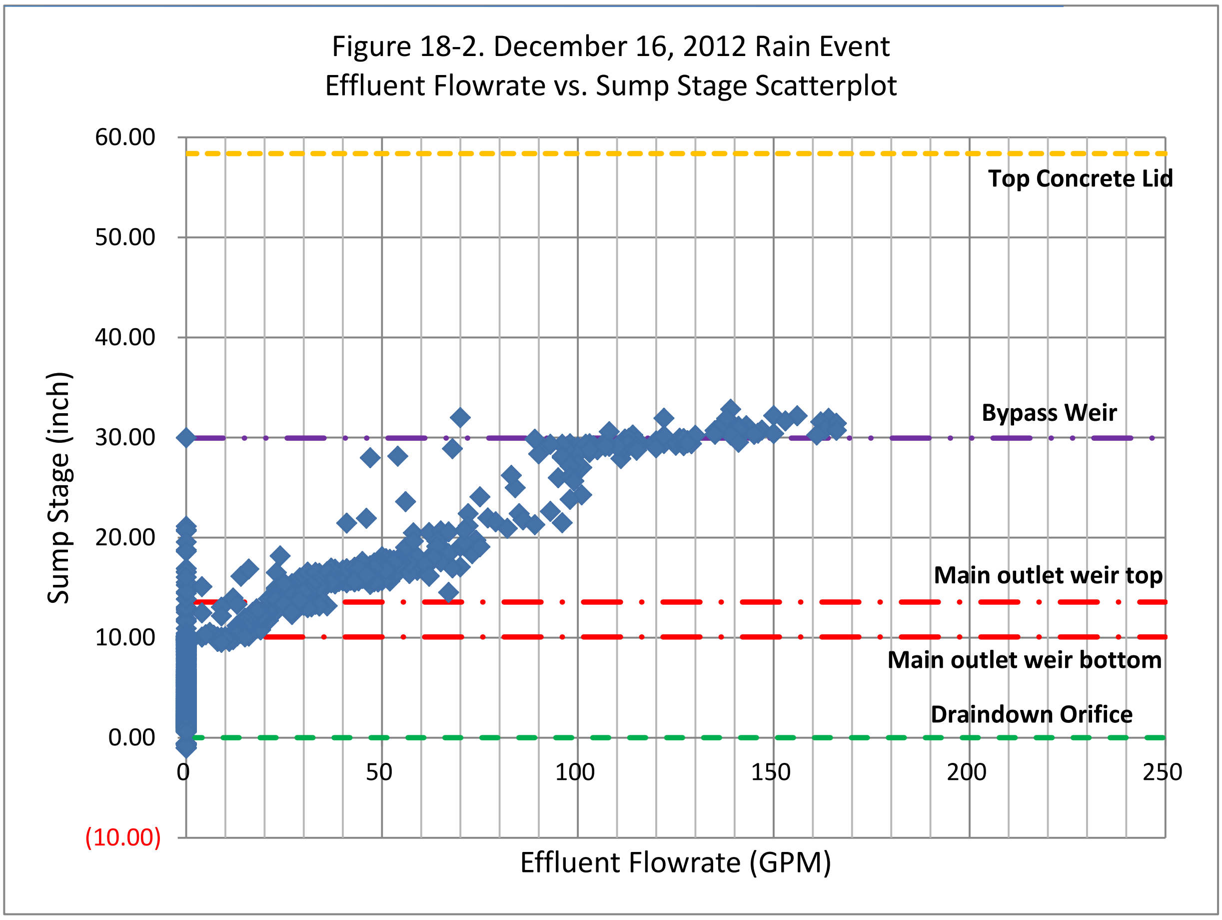
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 18-7. December 16, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	48	52	50	4	4	4
Millipore Membrane Filter, 0.45µm	BDL	BDL	BDL	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 18-8. December 16, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	15531	16328	15930	12,033	14540	13,287
E. Coli	457	654	556	422	530	476
Enterococci	496	220	358	201	320	261

Table 18-9. December 16, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	4	8	6	2	4	3



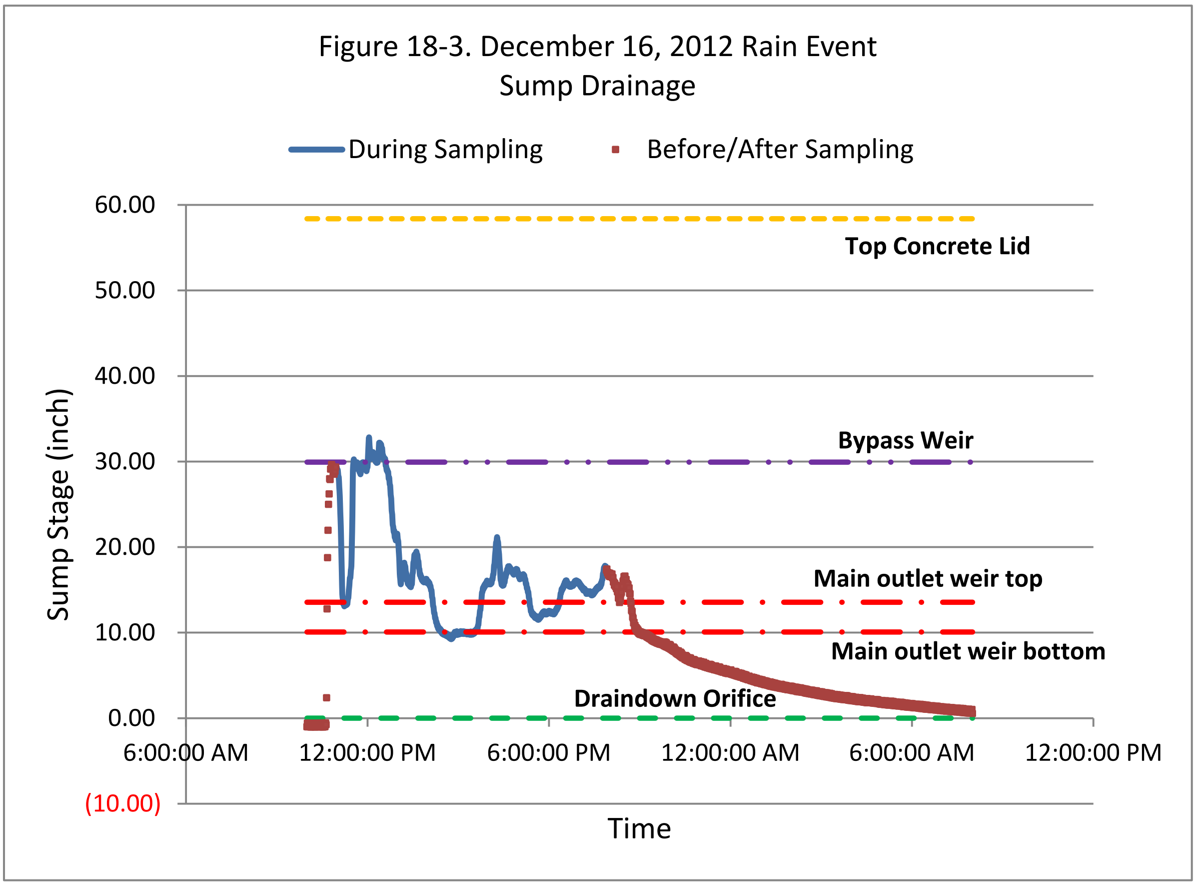


Figure 18-3. December 16, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
Time

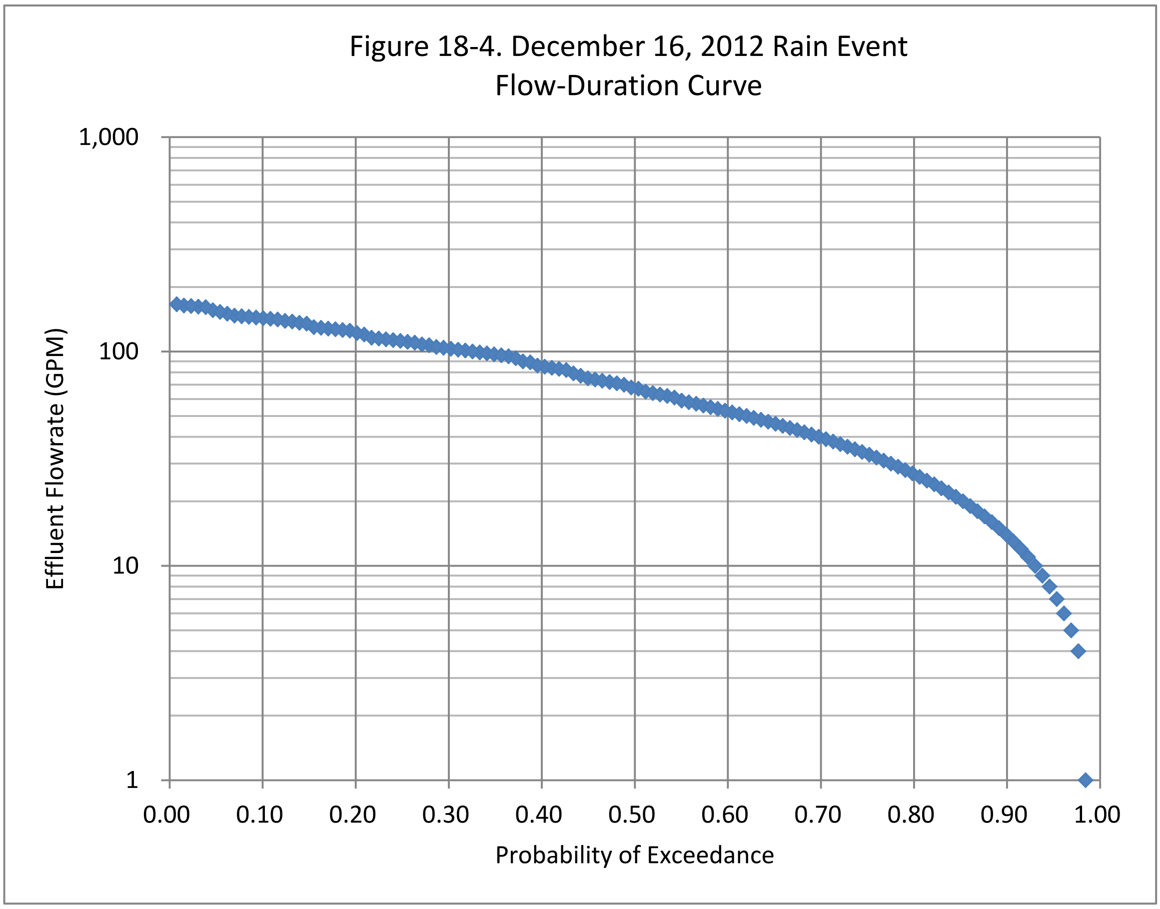


Figure 18-4. December 16, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 18-5. December 16, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

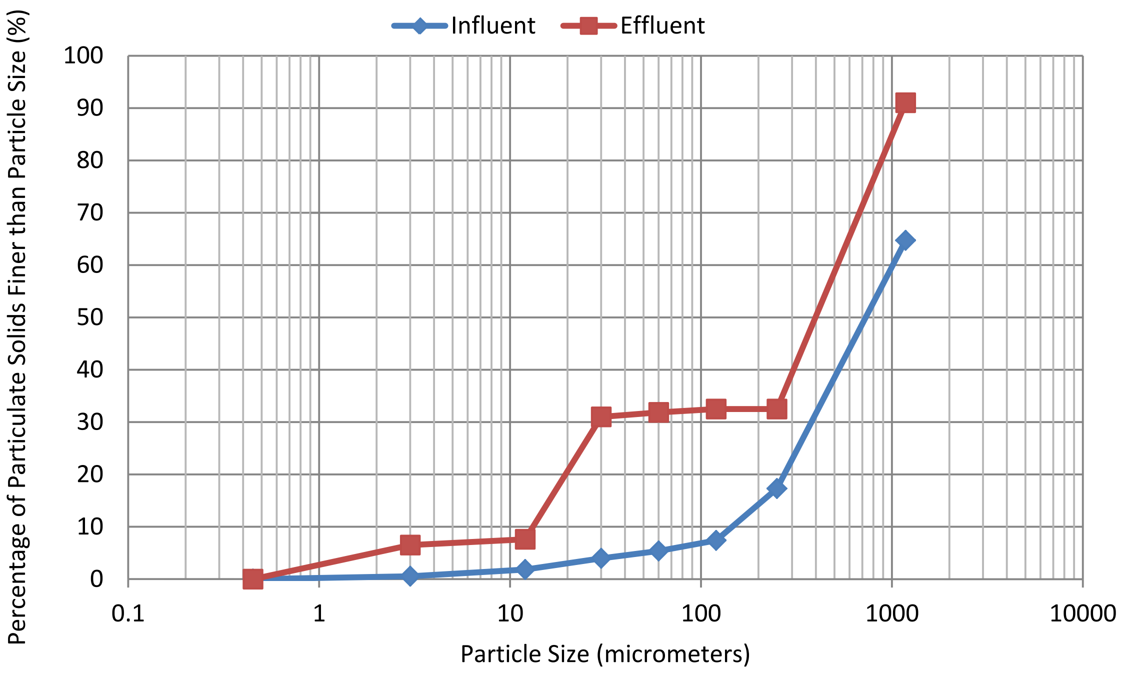
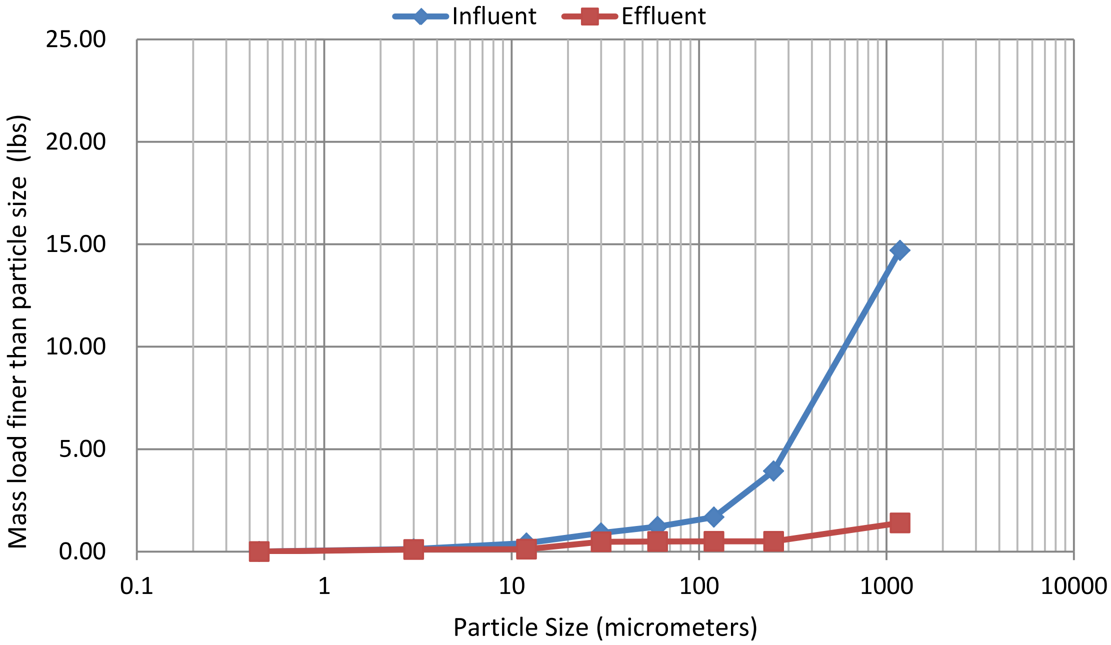


Figure 18-6. December 16, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 8.01 lbs larger than 1180 µm and the effluent had 0.14 lbs larger than 1180 µm (35.27% and 8.98% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 18-10. December 16, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.56	0.47	0.56	6.50	0.13	0.10	0.03	20.91
3 to 12	1.28	0.08	1.28	1.12	0.29	0.02	0.27	94.09
12 to 30	2.14	1.68	2.15	23.38	0.49	0.36	0.13	26.06
30 to 60	1.37	0.06	1.38	0.85	0.31	0.01	0.30	95.80
60 to 120	2.02	0.05	2.03	0.65	0.46	0.01	0.45	97.83
120 to 250	9.86	0.00	9.90	0.00	2.25	0.00	2.25	100.00
250 to 1180	47.22	4.21	47.43	58.51	10.77	0.90	9.87	91.63
>1180	35.11	0.65	35.27	8.98	8.01	0.14	7.87	98.27
Total	100	7	100.00	100.00	22.71	1.54	21.17	93.21

Table 18-11. December 16, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.56	6.50	0.13	0.10
<12	1.84	7.62	0.42	0.12
<30	3.99	31.00	0.91	0.48
<60	5.37	31.86	1.22	0.49
<120	7.40	32.51	1.68	0.50
<250	17.30	32.51	3.93	0.50
<1180	64.73	91.02	14.70	1.40
>1180	100.00	100.00	22.71	1.54

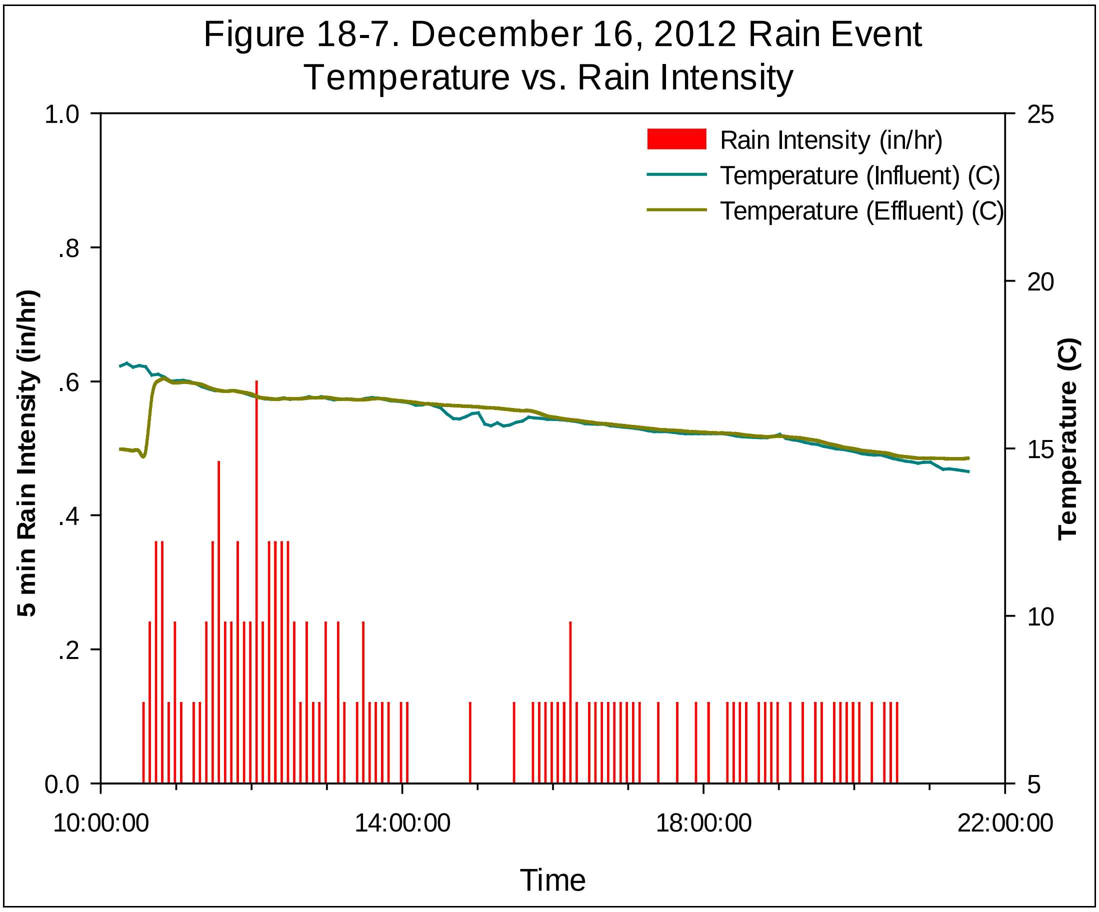


Figure 18-7. December 16, 2012 Rain Event
Temperature vs. Rain Intensity
5 min Rain Intensity (in/hr)
Temperature (C)
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
1.0
.8
.6
.4
.2
0.0
25
20
15
10
5
10:00:00
14:00:00
18:00:00
22:00:00
Time

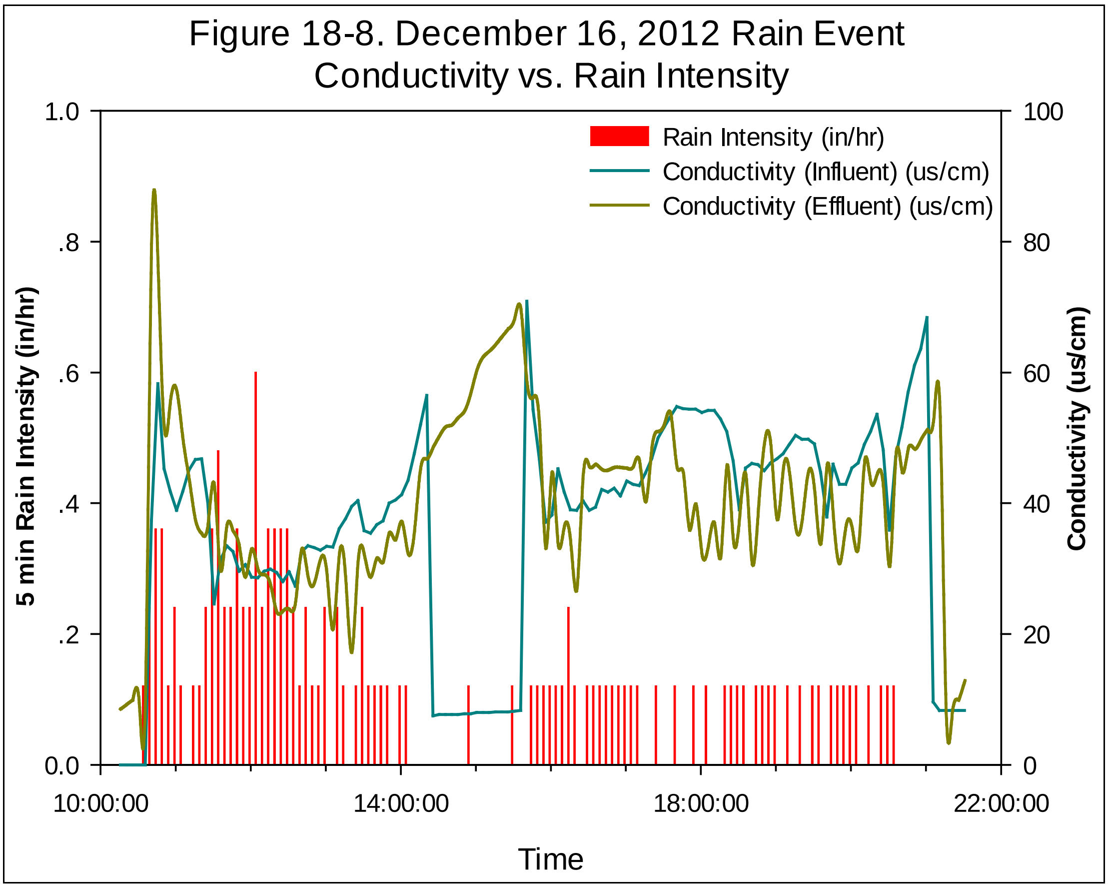


Figure 18-8. December 16, 2012 Rain Event
Conductivity vs. Rain Intensity
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
1.0
.8
.6
.4
.2
0.0
100
80
60
40
20
0
10:00:00
14:00:00
18:00:00
22:00:00
Time

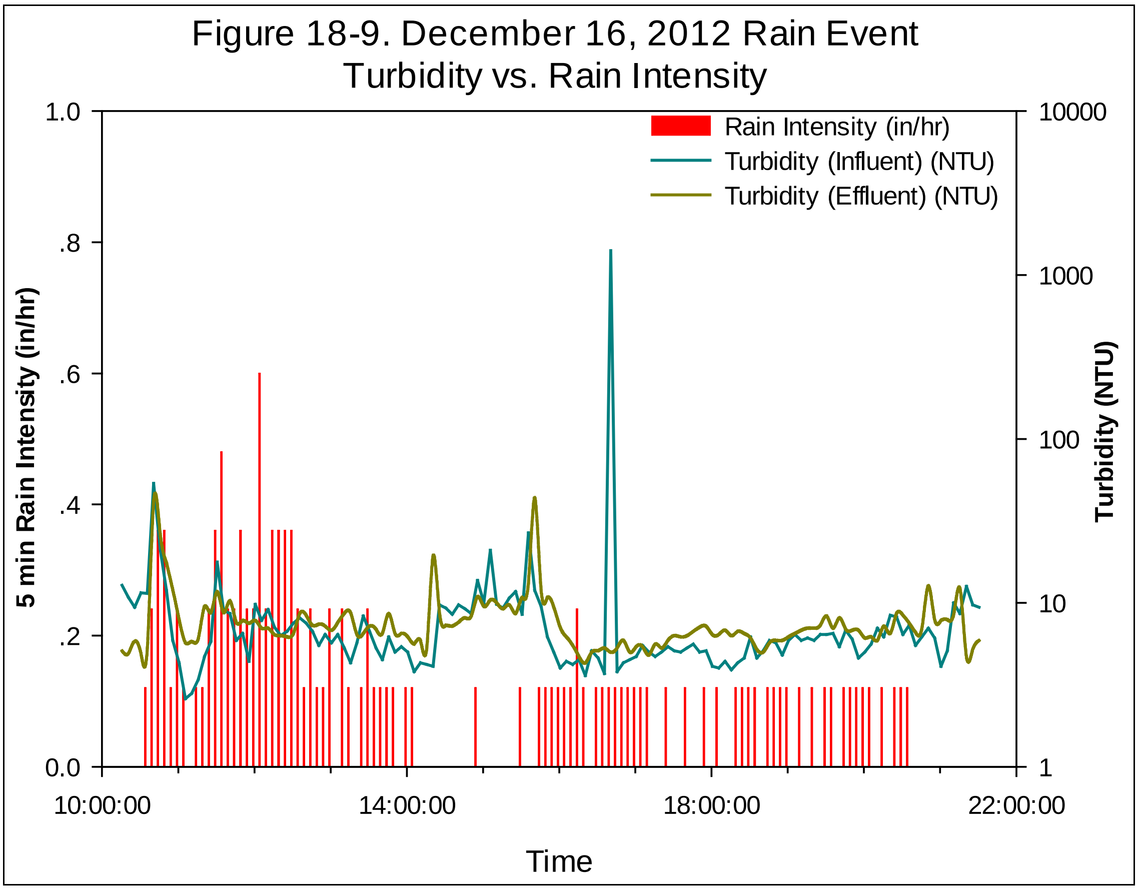
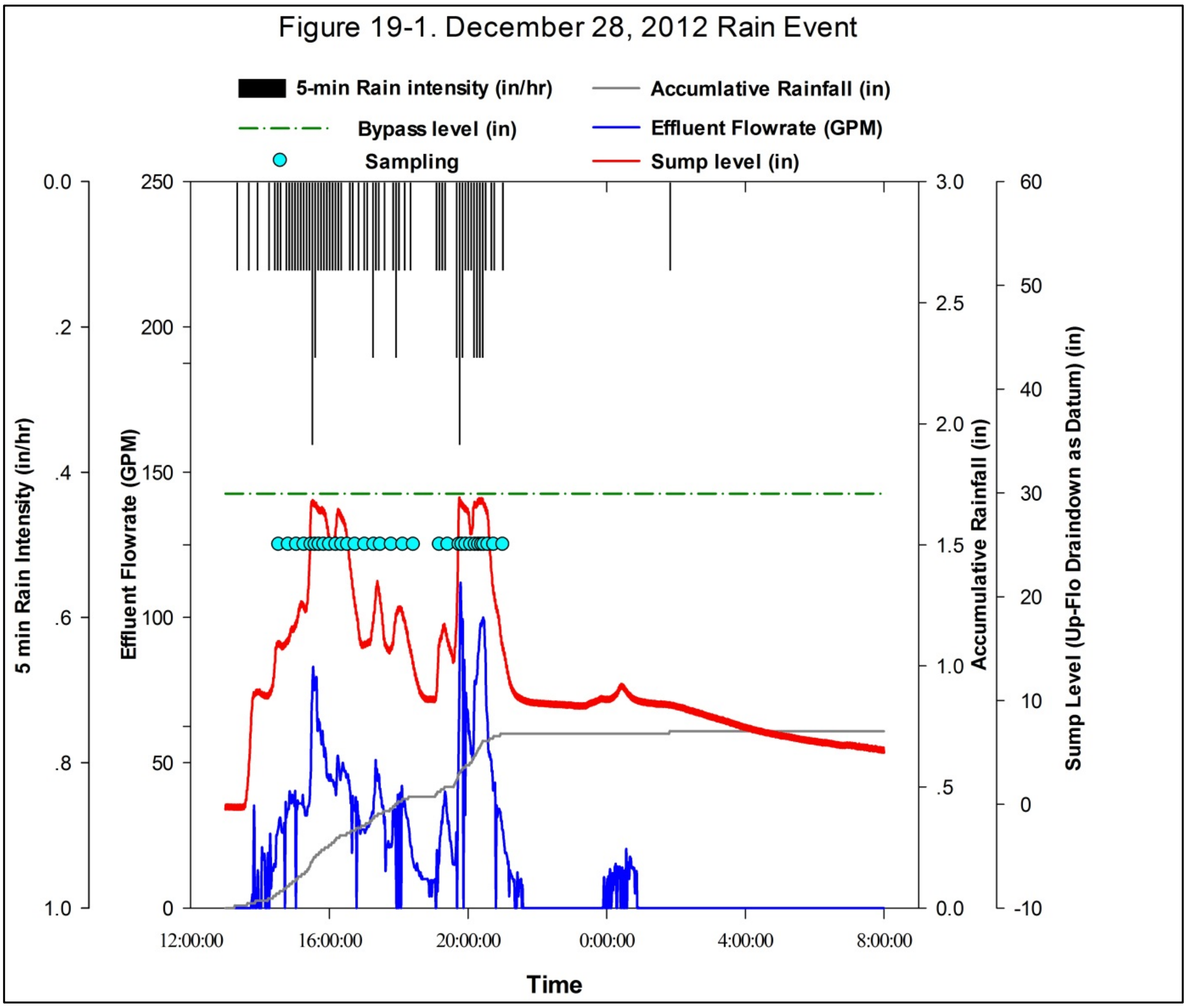


Figure 18-9. December 16, 2012 Rain Event
Turbidity vs. Rain Intensity
5 min Rain Intensity (in/hr)
1.0
.8
.6
.4
.2
0.0
Turbidity (NTU)
10000
1000
100
10
1
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
10:00:00
14:00:00
18:00:00
22:00:00
Time

Appendix F.19: December 28, 2012 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 19-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.78
Volumetric Runoff Coefficient (Rv)	1.04

Table 19-2. December 28, 2012 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2012/12/28 13:16
Rain Event End Date/Time:			2012/12/29 1:49
Total Precipitation (inch):	≥ 0.1	0.73	
Total Runoff Depth (inch):	NA	0.76	
Total Outflow (gallon):	NA	16242	
Rain Duration (hours):	≥ 1	12.55	
Flow Start Date/Time:			2012/12/28 13:45
Flow End Date/Time:			2012/12/29 0:53
Flow Duration (hours):	NA	11.13	
Average Rain Intensity (in/hr):	NA	0.06	
Average Runoff Rate (gallons/min):	NA	24	
Peak 5-min Rain Intensity (in/hr):	NA	0.36	
Peak Runoff Rate (gallons/min):	NA	112	
Peak to Average Runoff Ratio:	NA	4.61	
Bypassed flow volume (gallon):	NA	0	
Percentage of Bypassed Flow (%):	NA	0.00	
Inter-Event Time since prior rain (hours)	≥ 6.0	64.03	

Table 19-3. December 28, 2012 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	32	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	8.0	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	91.62	

Table 19-4. December 28, 2012 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	33	13	60.6	SM 2540D	1 mg/L	Stillbrook Lab
TSS	34	5	83.6	SM 2540D	1 mg/L	UA Lab
SSC	30	19	36.7	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	88	6	93.1	ASTM D3977-97B	1 mg/L	UA Lab
TDS	40	41	-1.2	EPA 160.2	1 mg/L	UA Lab
VSS	7	2	61.5	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.6	14.3	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.5	-25.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.07	0.09	-28.6	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.40	0.25	37.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.31	0.21	32.3	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.011	BDL	> 54.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.016	0.010	37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.006	BDL	> 16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	> 48,392	15532	> 67.9	IDEXX Method	<1	UA Lab
E. Coli	371	161	56.6	IDEXX Method	<1	UA Lab
Enterococci	173	176	-2.0	IDEXX Method	<1	UA Lab
pH	6.82	6.89	-1.0	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	8.38	5.86	30.1	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	44.0	47.9	-8.9	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.2	7.9	3.7	SM 212/ EPA 170.1	5 °C	UA Lab

Table 19-5. December 28, 2012 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	30	NA*	NA*	19	NA*	NA*	36.7	NA*	NA*
UA Lab	74	14	88	6	0	6	91.9	99.3	93.1

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 19-6. December 28, 2012 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	5933	5219	29	5	4.9	1.0

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

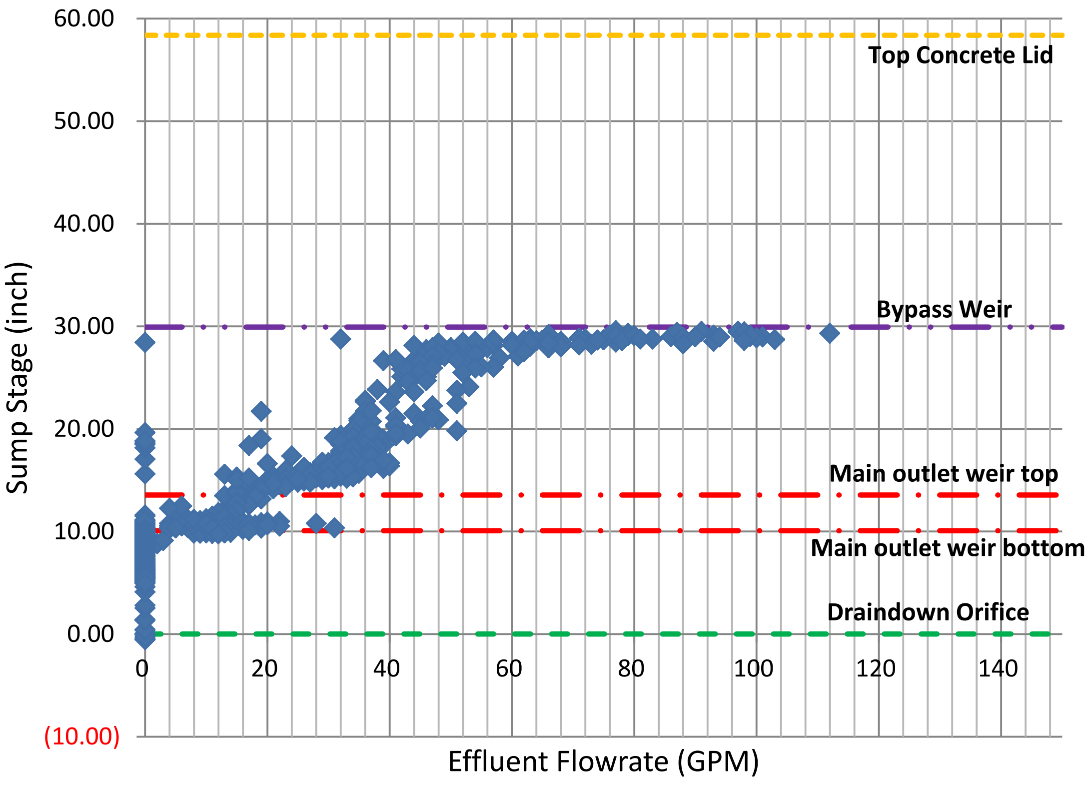
Table 19-7. December 28, 2012 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	28	39	34	6	5	5
Millipore Membrane Filter, 0.45µm	24	27	26	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 19-8. December 28, 2012 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	> 24,196	> 48,392	> 48,392	17,329	13734	15,532
E. Coli	426	316	371	132	190	161
Enterococci	153	192	173	226	126	176

Table 19-9. December 28, 2012 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	5	8	7	3	2	2

Figure 19-2. December 28, 2012 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



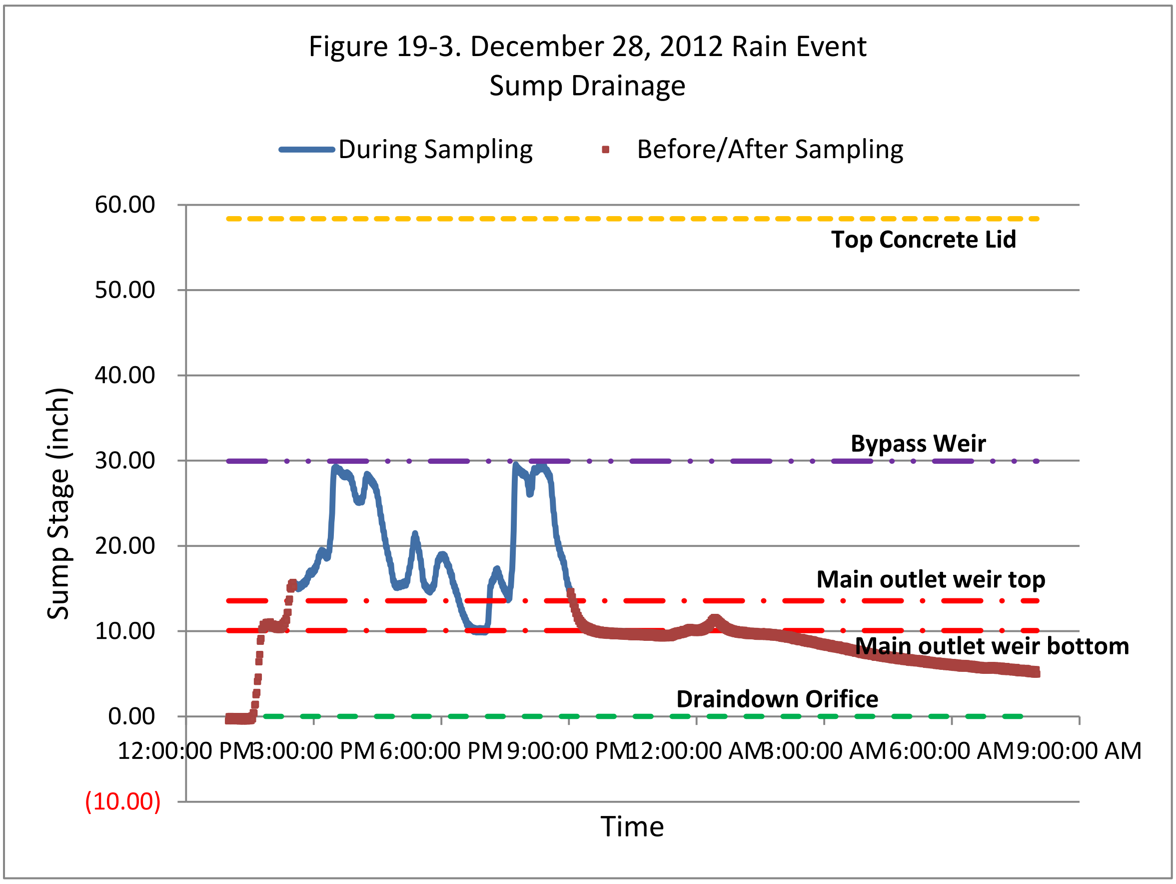


Figure 19-3. December 28, 2012 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
3:00:00 PM
6:00:00 PM
9:00:00 PM
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
Sump Stage (inch)
Time

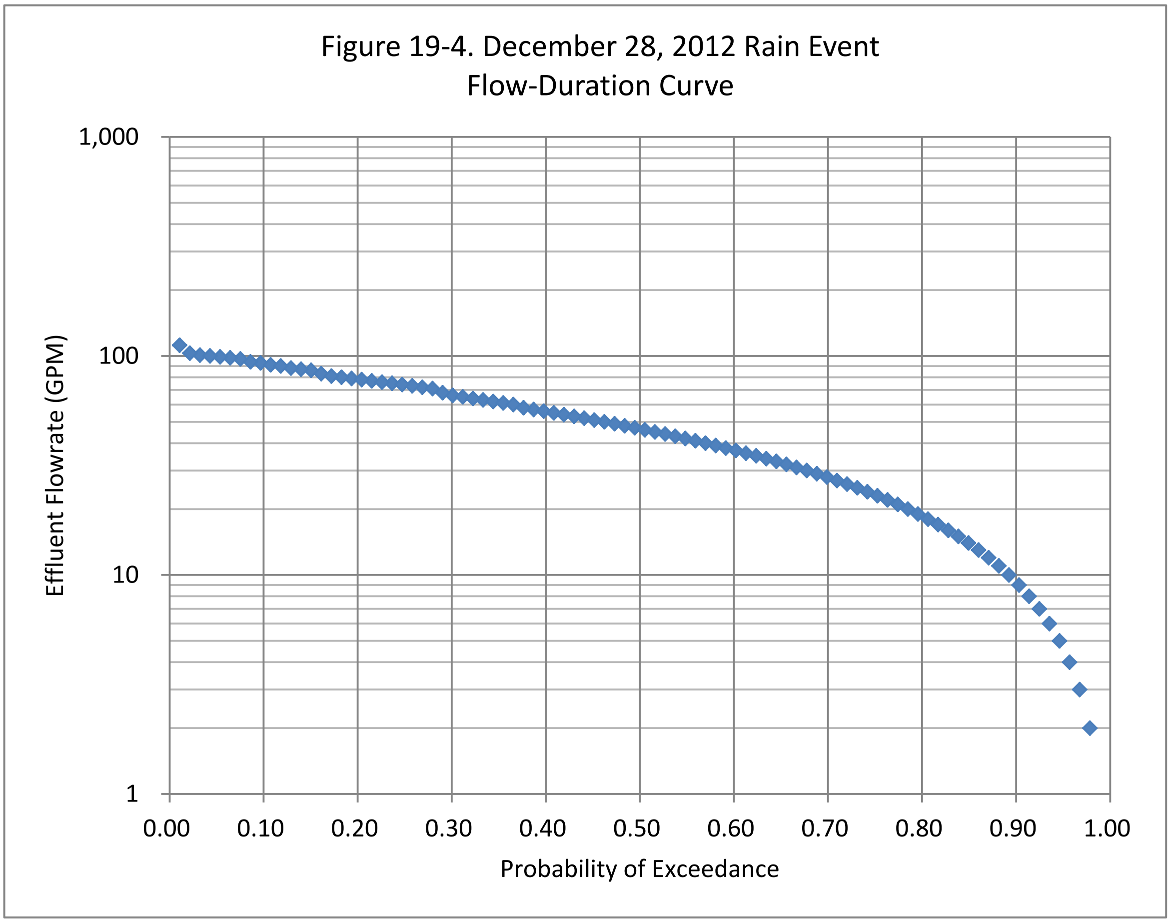


Figure 19-4. December 28, 2012 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 19-5. December 28, 2012 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

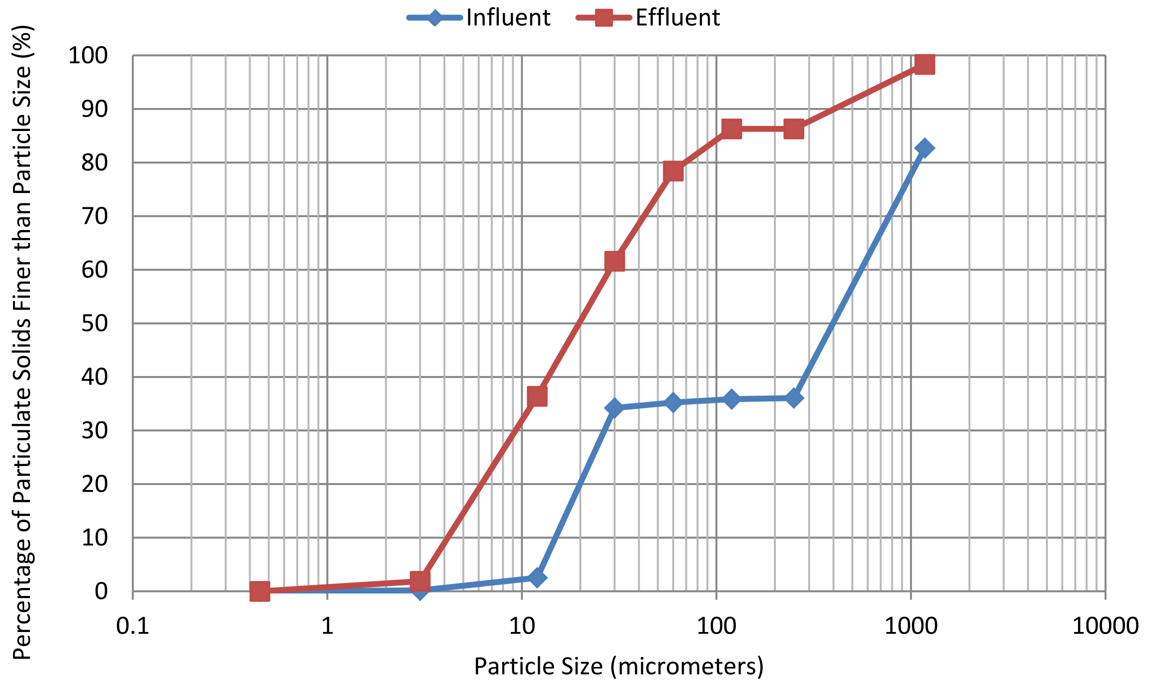
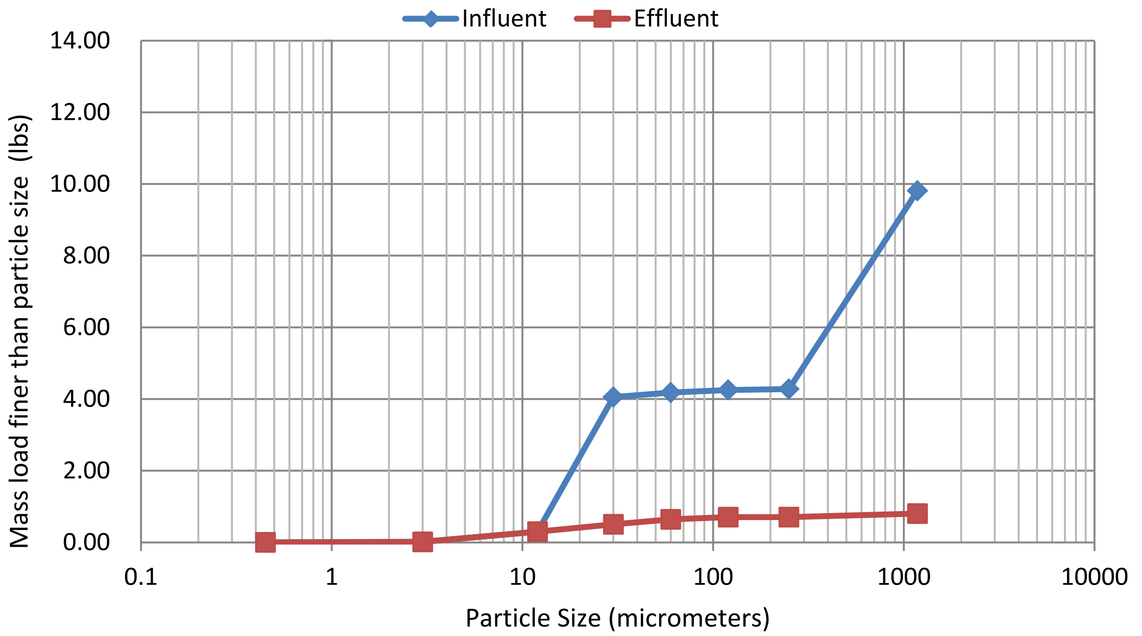


Figure 19-6. December 28, 2012 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 2.05 lbs larger than 1180 µm and the effluent had 0.01 lbs larger than 1180 µm (17.31% and 1.67% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 19-10. December 28, 2012 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.13	0.11	0.16	1.86	0.02	0.02	0.00	20.61
3 to 12	1.93	2.05	2.37	34.52	0.28	0.28	0.00	-0.26
12 to 30	25.71	1.50	31.67	25.22	3.76	0.21	3.55	94.51
30 to 60	0.83	1.00	1.02	16.83	0.12	0.14	-0.02	-13.87
60 to 120	0.51	0.47	0.63	7.84	0.07	0.06	0.01	13.76
120 to 250	0.18	0.00	0.23	0.00	0.03	0.00	0.03	100.00
250 to 1180	37.84	0.72	46.62	12.06	5.53	0.10	5.43	98.22
>1180	14.05	0.10	17.31	1.67	2.05	0.01	2.04	99.34
Total	81	6	100.00	100.00	11.86	0.82	11.05	93.11

Table 19-11. December 28, 2012 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.16	1.86	0.02	0.02
<12	2.53	36.38	0.30	0.30
<30	34.20	61.60	4.06	0.50
<60	35.22	78.43	4.18	0.64
<120	35.85	86.27	4.25	0.71
<250	36.07	86.27	4.28	0.71
<1180	82.69	98.33	9.81	0.80
>1180	100.00	100.00	11.86	0.82

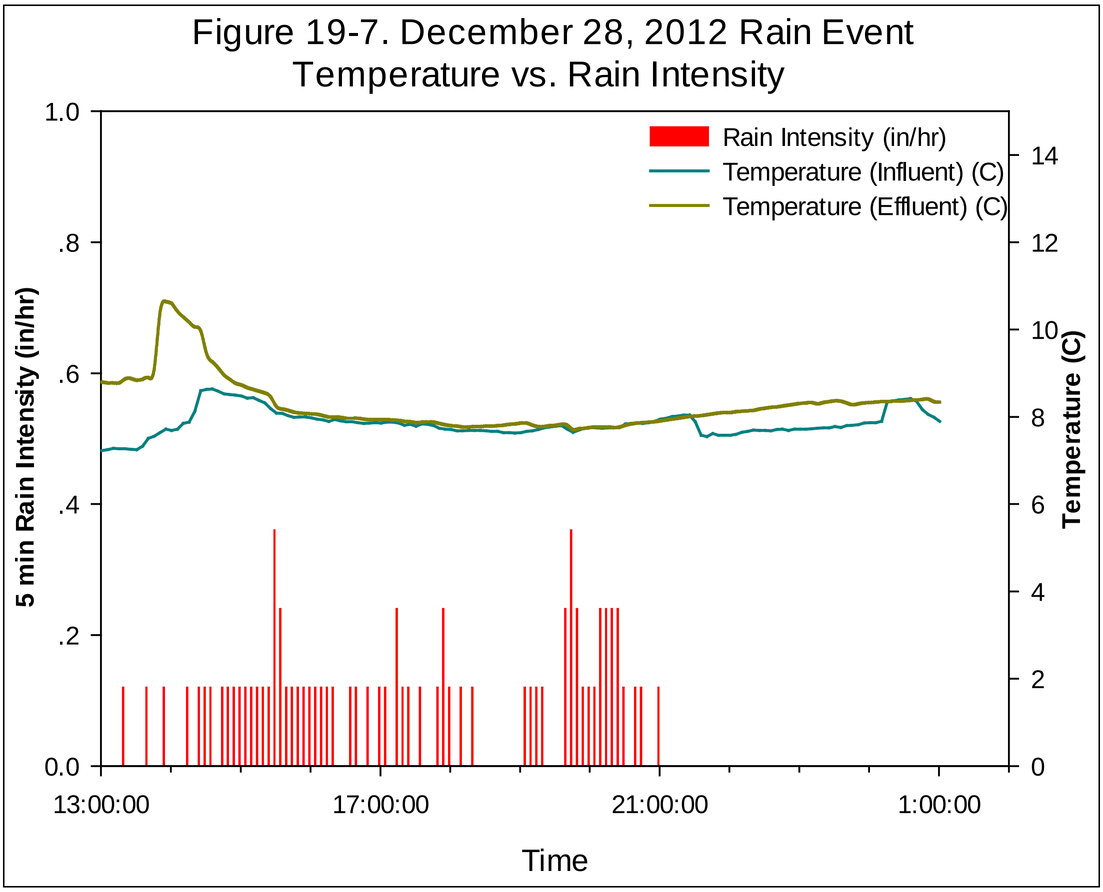


Figure 19-7. December 28, 2012 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
1.0
.8
.6
.4
.2
0.0
14
12
10
8
6
4
2
0
13:00:00
17:00:00
21:00:00
1:00:00
Time

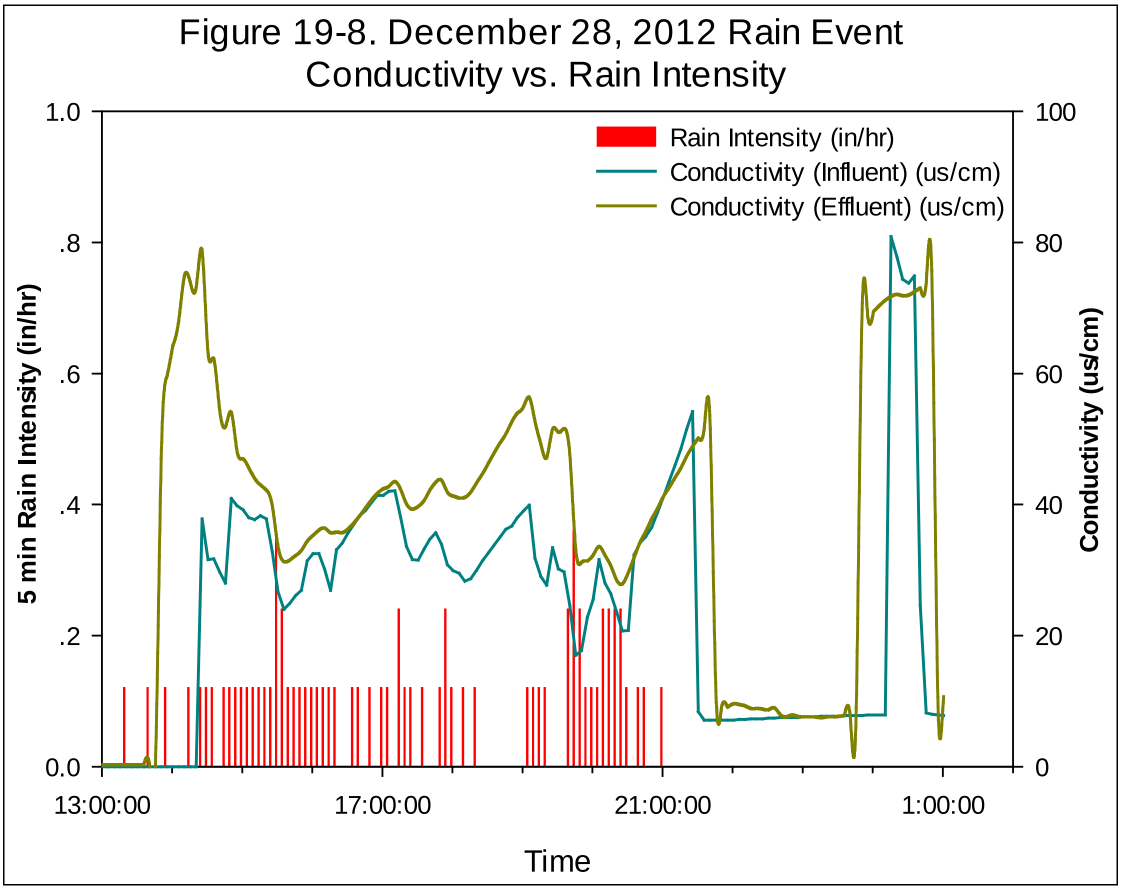


Figure 19-8. December 28, 2012 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
1.0
.8
.6
.4
.2
0.0
100
80
60
40
20
0
13:00:00
17:00:00
21:00:00
1:00:00
Time

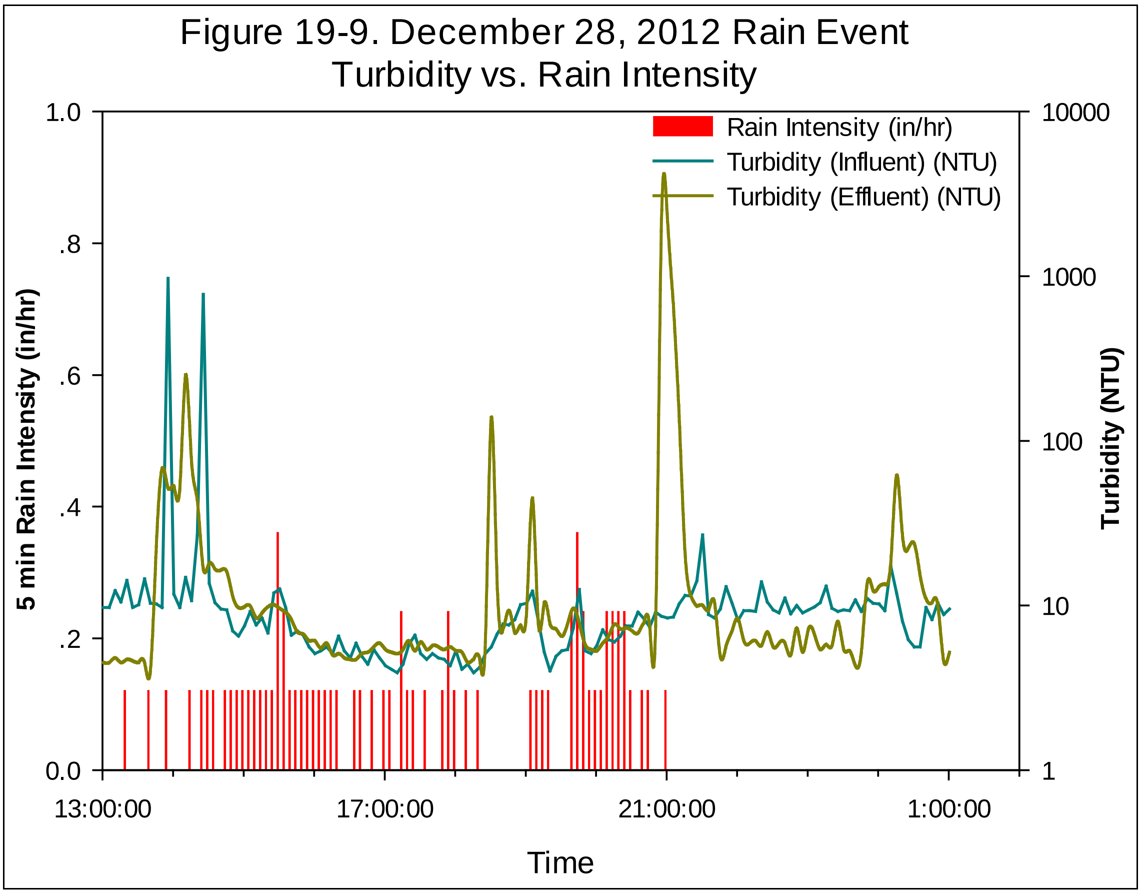
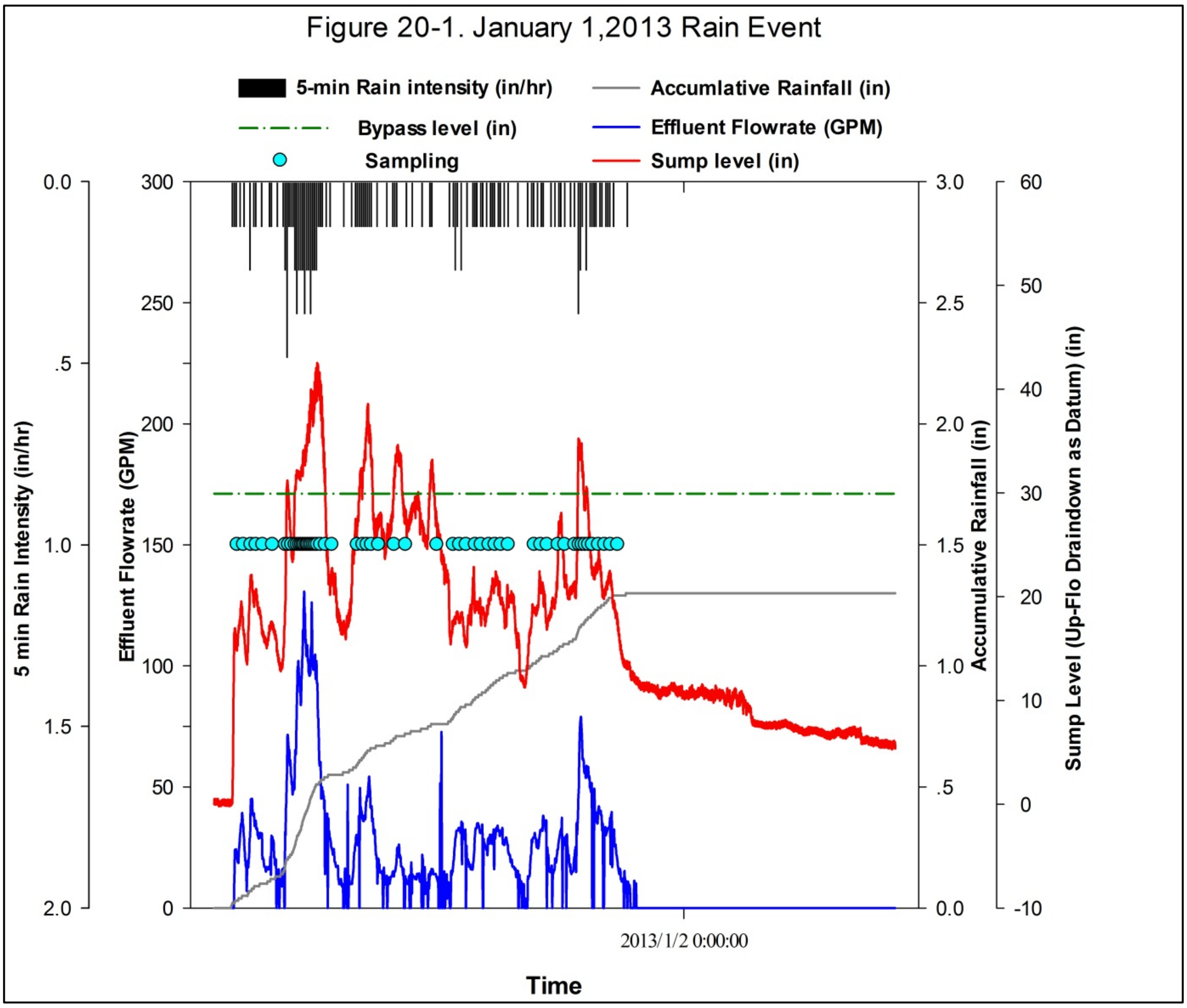


Figure 19-9. December 28, 2012 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
1.0
.8
.6
.4
.2
0.0
10000
1000
100
10
1
13:00:00
17:00:00
21:00:00
1:00:00
Time

Appendix F.20: January 1, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 5.7 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 20-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.68
Volumetric Runoff Coefficient (Rv)	0.91

Table 20-2. January 1, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/1/1 4:44
Rain Event End Date/Time:			2013/1/1 21:32
Total Precipitation (inch):	≥ 0.1	1.30	
Total Runoff Depth (inch):	NA	1.18	
Total Outflow (gallon):	NA	28886	
Rain Duration (hours):	≥ 1	16.80	
Flow Start Date/Time:			2013/1/1 4:51
Flow End Date/Time:			2013/1/1 21:59
Flow Duration (hours):	NA	17.13	
Average Rain Intensity (in/hr):	NA	0.08	
Average Runoff Rate (gallons/min):	NA	28	
Peak 5-min Rain Intensity (in/hr):	NA	0.48	
Peak Runoff Rate (gallons/min):	NA	130	
Peak to Average Runoff Ratio:	NA	4.63	
Bypassed flow volume (gallon):	NA	4511	
Percentage of Bypassed Flow (%):	NA	15.62	
Inter-Event Time since prior rain (hours)	≥ 6.0	74.92	

Table 20-3. January 1, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	57	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	14.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	98.13	

Table 20-4. January 1, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN/100 mL, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	39	25	35.9	SM 2540D	1 mg/L	Stillbrook Lab
TSS	11	3	72.7	SM 2540D	1 mg/L	UA Lab
SSC	41	29	29.3	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	29	3	88.8	ASTM D3977-97B	1 mg/L	UA Lab
TDS	31	35	-12.9	EPA 160.2	1 mg/L	UA Lab
VSS	3	2	33.3	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.4	20.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.07	0.08	-14.3	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.34	0.21	38.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.21	0.15	28.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.010	0.007	30.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	12543	14254	-13.6	IDEXX Method	<1	UA Lab
E. Coli	809	545	32.7	IDEXX Method	<1	UA Lab
Enterococci	614	384	37.4	IDEXX Method	<1	UA Lab
pH	6.76	6.86	-1.5	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	4.48	3.69	17.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	38.7	39.8	-2.8	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.2	7.9	3.7	SM 212/ EPA 170.1	5 °C	UA Lab

Table 20-5. January 1, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	41	NA*	NA*	29	NA*	NA*	29.3	NA*	NA*
UA Lab	27	2	29	3	0	3	87.9	100.0	88.8

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 20-6. January 1, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	3834	2673	11	3	3.0	1.2

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

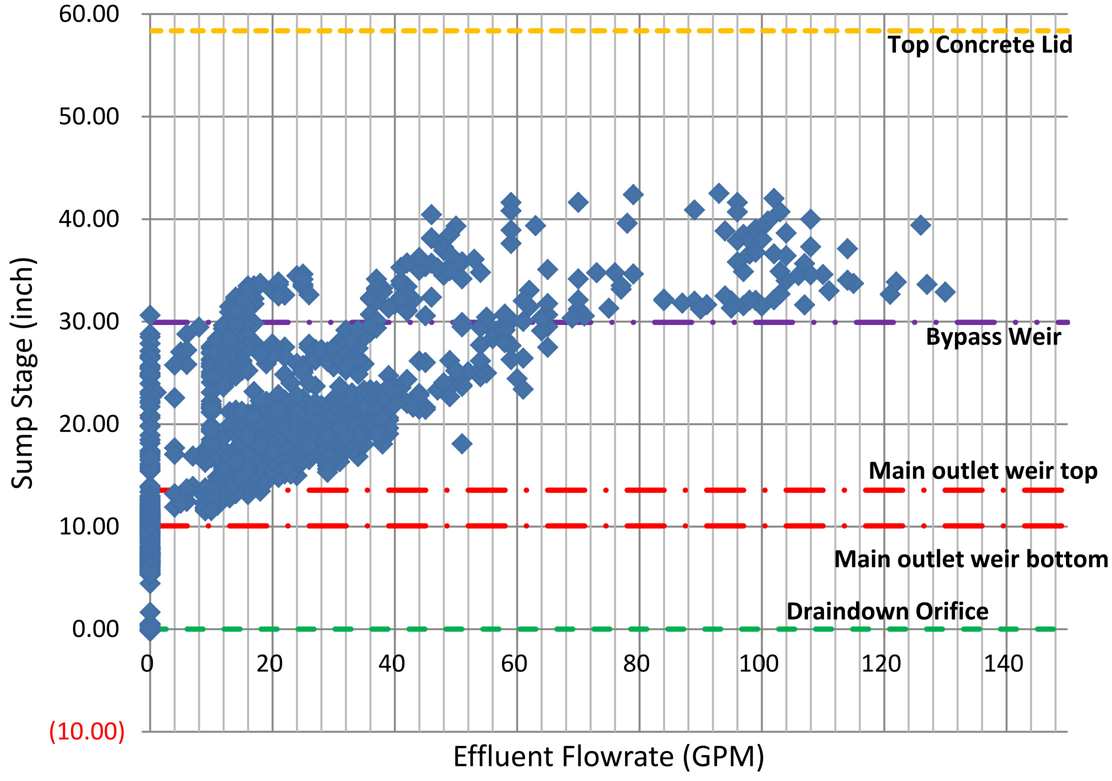
Table 20-7. January 1, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	10	12	11	3	3	3
Millipore Membrane Filter, 0.45µm	BDL	BDL	BDL	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 20-8. January 1, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	14136	10950	12,543	15,531	12976	14,254
E. Coli	754	864	809	583	506	545
Enterococci	683	544	614	448	320	384

Table 20-9. January 1, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	3	3	3	2	2	2

Figure 20-2. January 1, 2013 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



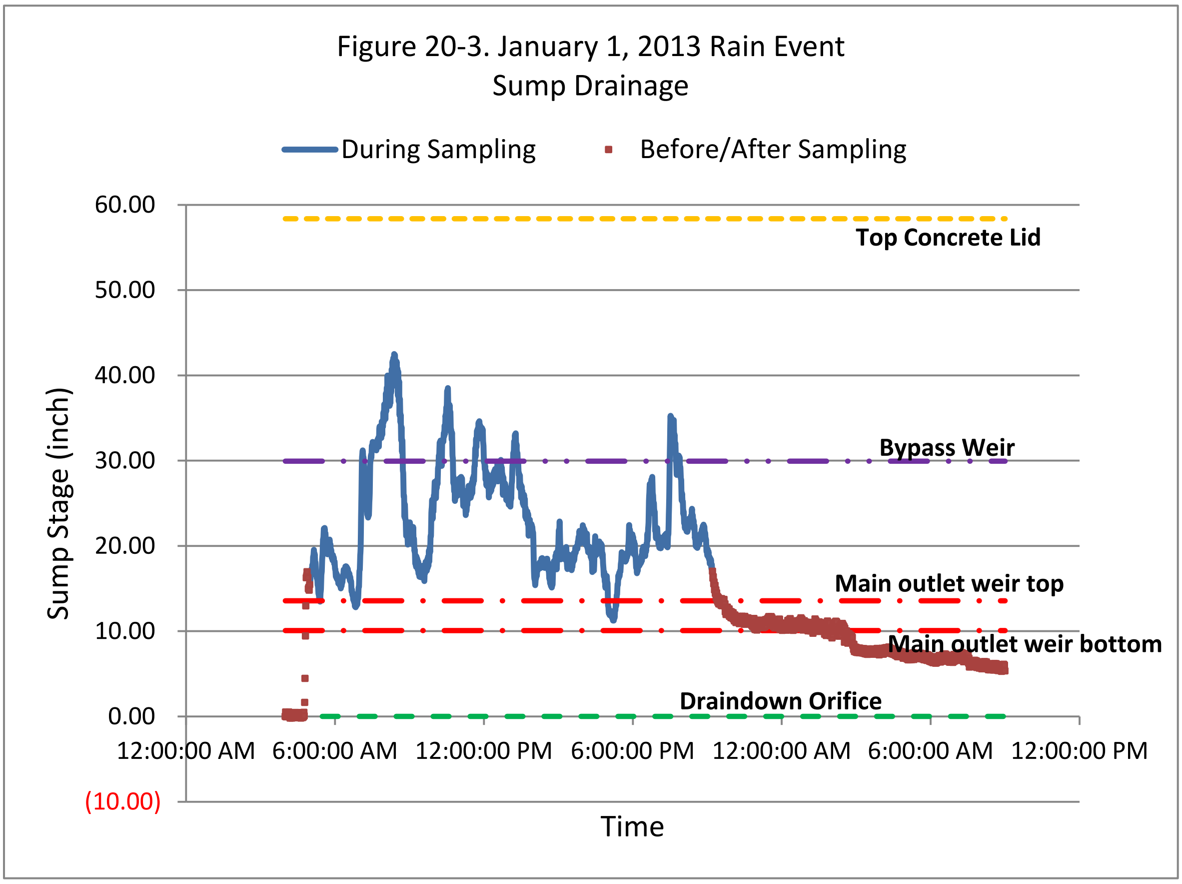


Figure 20-3. January 1, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
Time

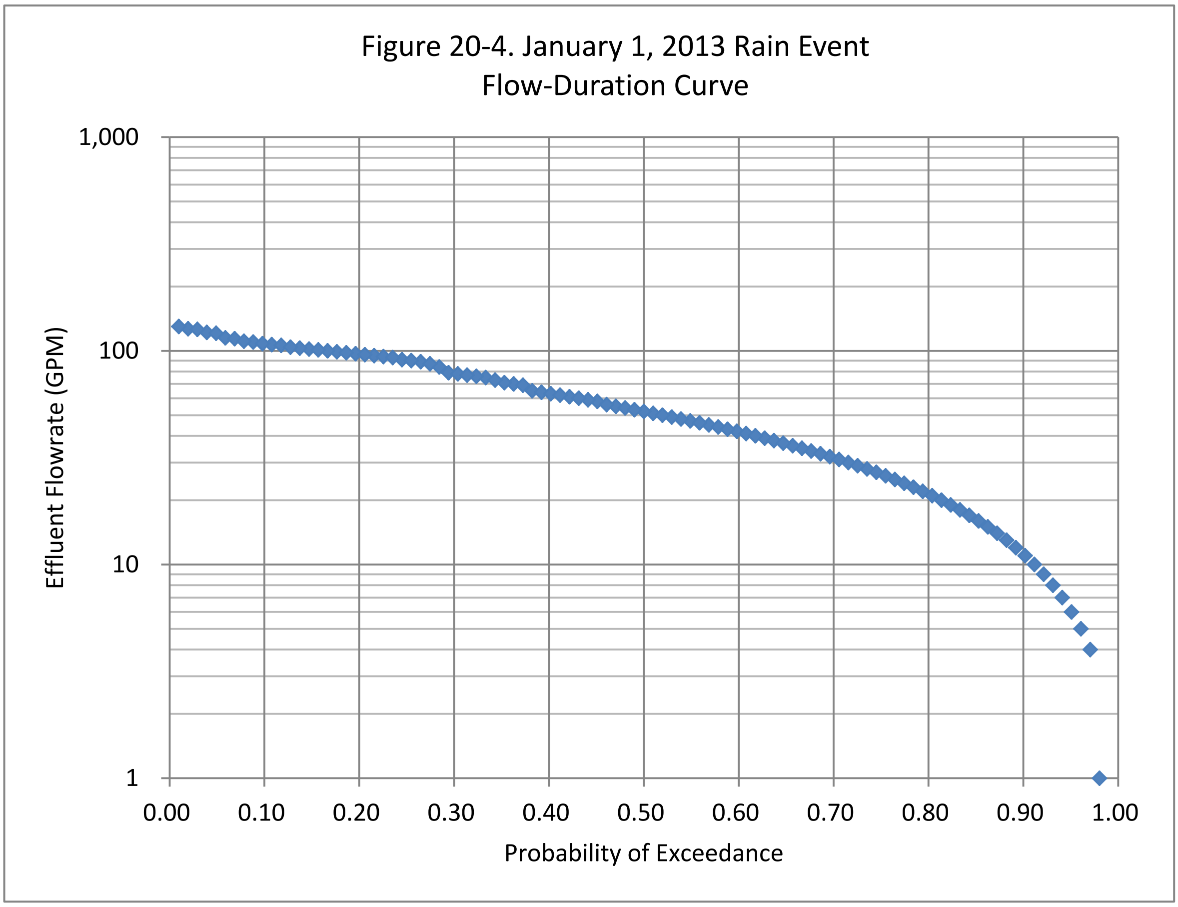
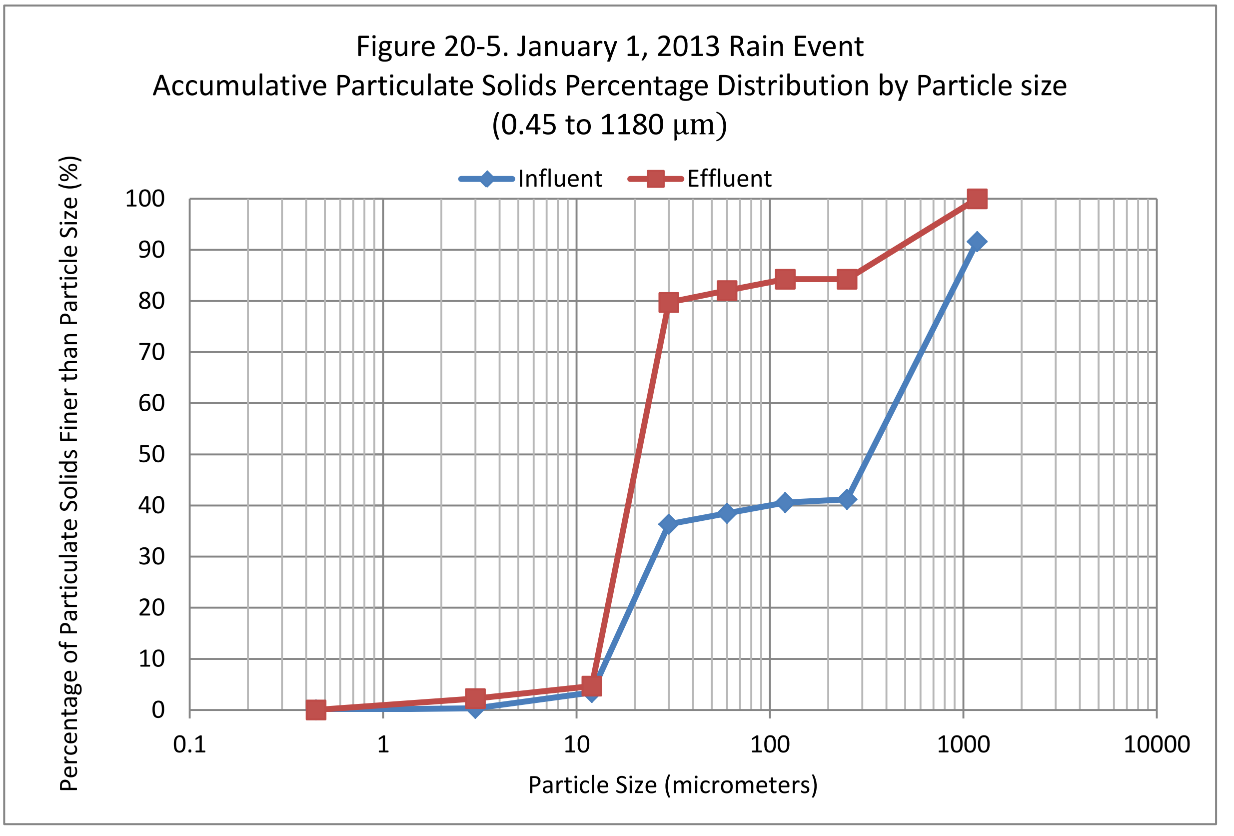
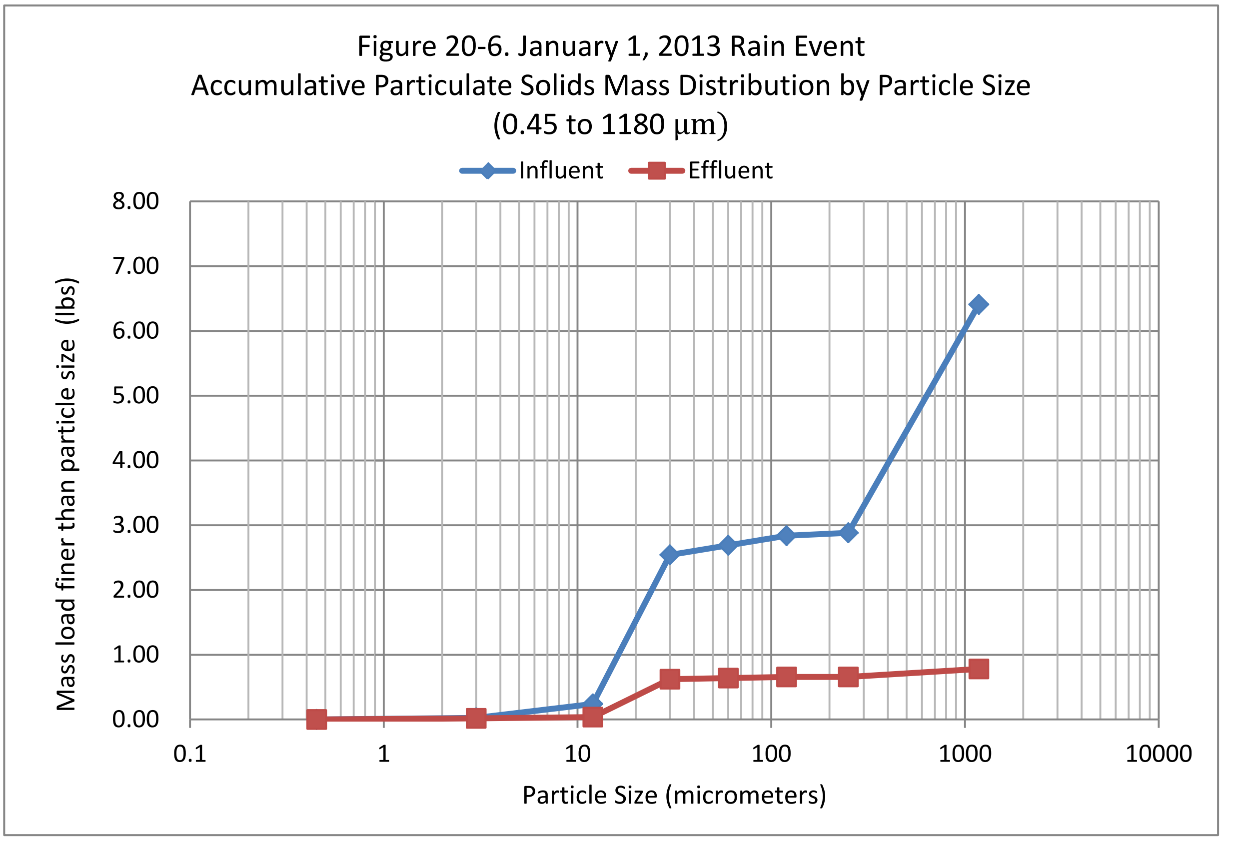


Figure 20-4. January 1, 2013 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 0.58 lbs larger than 1180 µm and the effluent had 0.00 lbs larger than 1180 µm (8.36% and 0.00% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 20-10. January 1, 2013 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.09	0.08	0.34	2.25	0.02	0.02	0.01	25.20
3 to 12	0.85	0.09	3.08	2.44	0.22	0.02	0.20	91.17
12 to 30	9.12	2.82	32.93	75.04	2.30	0.59	1.72	74.58
30 to 60	0.59	0.09	2.12	2.32	0.15	0.02	0.13	87.81
60 to 120	0.58	0.08	2.10	2.22	0.15	0.02	0.13	88.22
120 to 250	0.18	0.00	0.64	0.00	0.04	0.00	0.04	100.00
250 to 1180	13.97	0.59	50.43	15.73	3.53	0.12	3.40	96.52
>1180	2.32	0.00	8.36	0.00	0.58	0.00	0.58	100.00
Total	28	4	100.00	100.00	6.99	0.78	6.21	88.85

Table 20-11. January 1, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.34	2.25	0.02	0.02
<12	3.41	4.69	0.24	0.04
<30	36.34	79.73	2.54	0.62
<60	38.47	82.05	2.69	0.64
<120	40.57	84.27	2.84	0.66
<250	41.21	84.27	2.88	0.66
<1180	91.64	100.00	6.41	0.78
>1180	100.00	100.00	6.99	0.78

Figure 20-7. January 1, 2013 Rain Event
Temperature vs. Rain Intensity

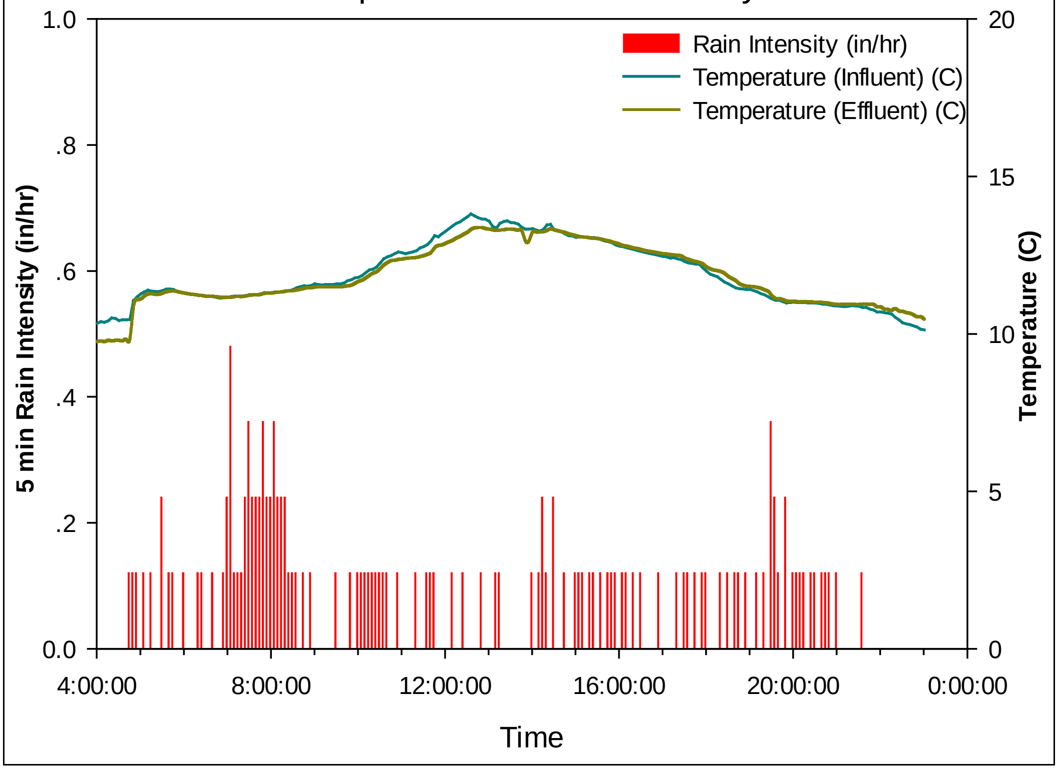
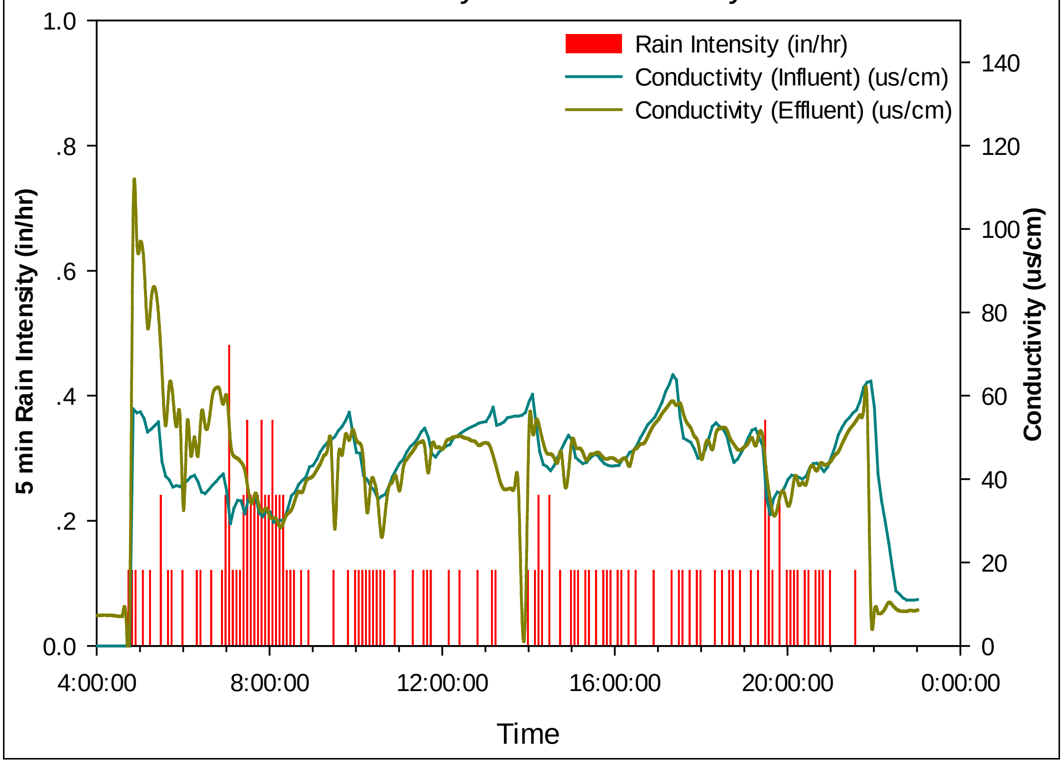


Figure 20-8. January 1, 2013 Rain Event
Conductivity vs. Rain Intensity



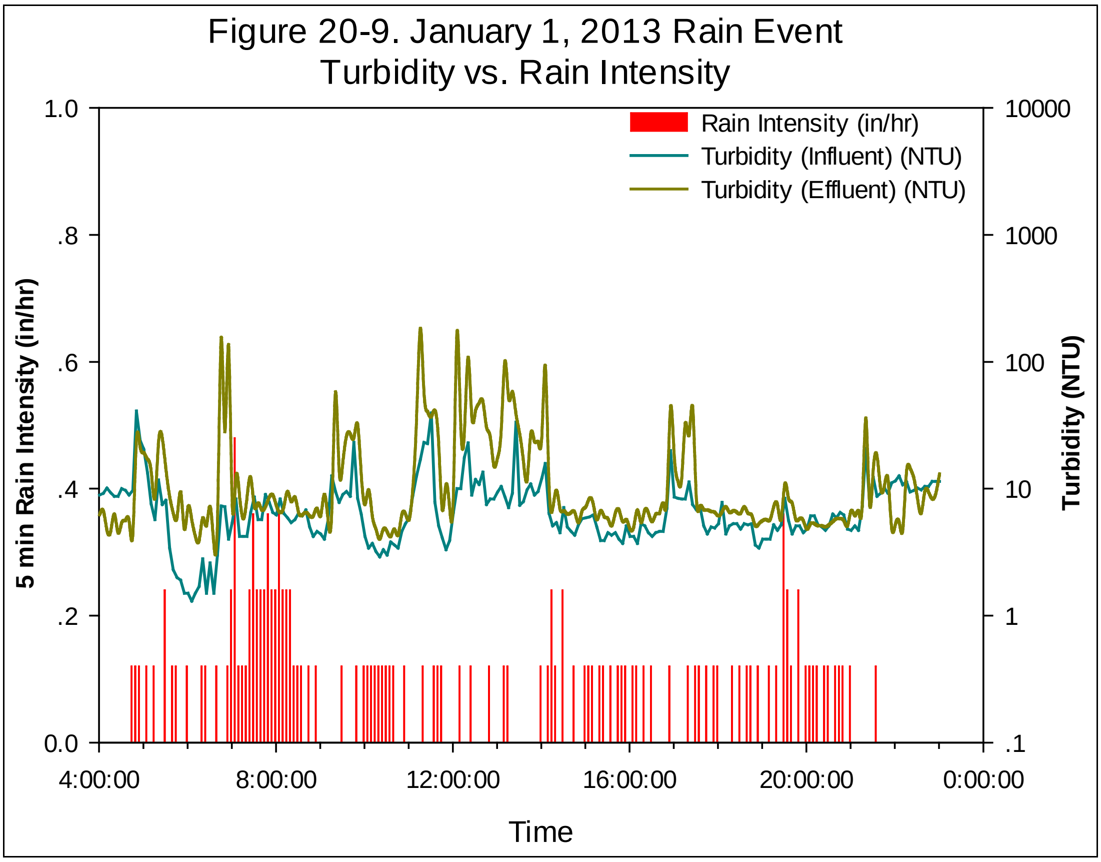
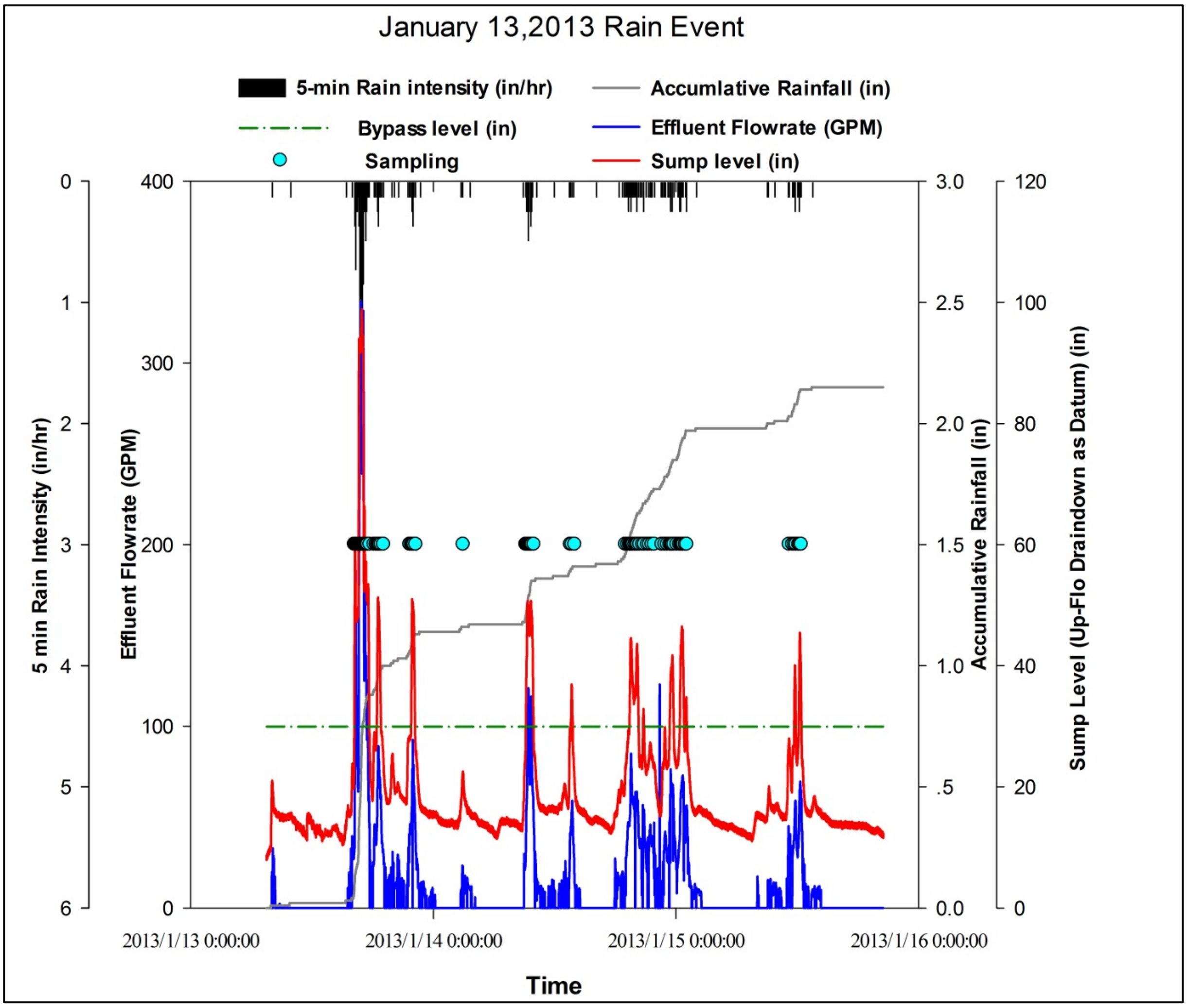


Figure 20-9. January 1, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
1.0
.8
.6
.4
.2
0.0
10000
1000
100
10
1
.1
4:00:00
8:00:00
12:00:00
16:00:00
20:00:00
0:00:00
Time

Appendix F.21: January 13, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 9.82 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 21-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.41
Volumetric Runoff Coefficient (Rv)	0.99

Table 21-2. January 13, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/1/13 7:55
Rain Event End Date/Time:			2013/1/15 13:25
Total Precipitation (inch):	≥ 0.1	2.15	
Total Runoff Depth (inch):	NA	2.14	
Total Outflow (gallon):	NA	52199	
Rain Duration (hours):	≥ 1	53.50	
Flow Start Date/Time:			2013/1/13 8:01
Flow End Date/Time:			2013/1/15 14:21
Flow Duration (hours):	NA	54.33	
Average Rain Intensity (in/hr):	NA	0.04	
Average Runoff Rate (gallons/min):	NA	16	
Peak 5-min Rain Intensity (in/hr):	NA	2.04	
Peak Runoff Rate (gallons/min):	NA	332	
Peak to Average Runoff Ratio:	NA	20.73	
Bypassed flow volume (gallon):	NA	13613	
Percentage of Bypassed Flow (%):	NA	26.08	
Inter-Event Time since prior rain (hours)	≥ 6.0	27.67	

Table 21-3. January 13, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	92	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	23.0	The actual volumes of both samples were visually only about 16 liter
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.19	As the plastic tray at influent was wash off during peak rainfall, the volume of influent sample was only about 5 liter, so the sample coverage of influent is only about 19%

Table 21-4. January 13, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	58	27	53.4	SM 2540D	1 mg/L	Stillbrook Lab
TSS	79	23	70.7	SM 2540D	1 mg/L	UA Lab
SSC	77	24	68.8	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	401	27	93.3	ASTM D3977-97B	1 mg/L	UA Lab
TDS	23	26	-10.6	EPA 160.2	1 mg/L	UA Lab
VSS	23	8	67.4	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.4	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.04	0.07	-75.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.43	0.37	14.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.34	0.25	26.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.012	BDL	>58.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.008	BDL	>37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.027	0.017	37.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	25095	9706	61.3	IDEXX Method	<1	UA Lab
E. Coli	1917	4446	-131.9	IDEXX Method	<1	UA Lab
Enterococci	775	290	62.6	IDEXX Method	<1	UA Lab
pH	6.71	6.79	-1.2	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	18.8	14.4	23.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	32.5	38.5	-18.5	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.2	7.8	4.9	SM 212/ EPA 170.1	5 °C	UA Lab

Table 21-5. January 13, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	77	NA*	NA*	24	NA*	NA*	68.8	NA*	NA*
UA Lab	276	125	401	25	2	27	90.9	98.7	93.3

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 21-6. January 13, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	13594	13226	55	21	4.1	1.6

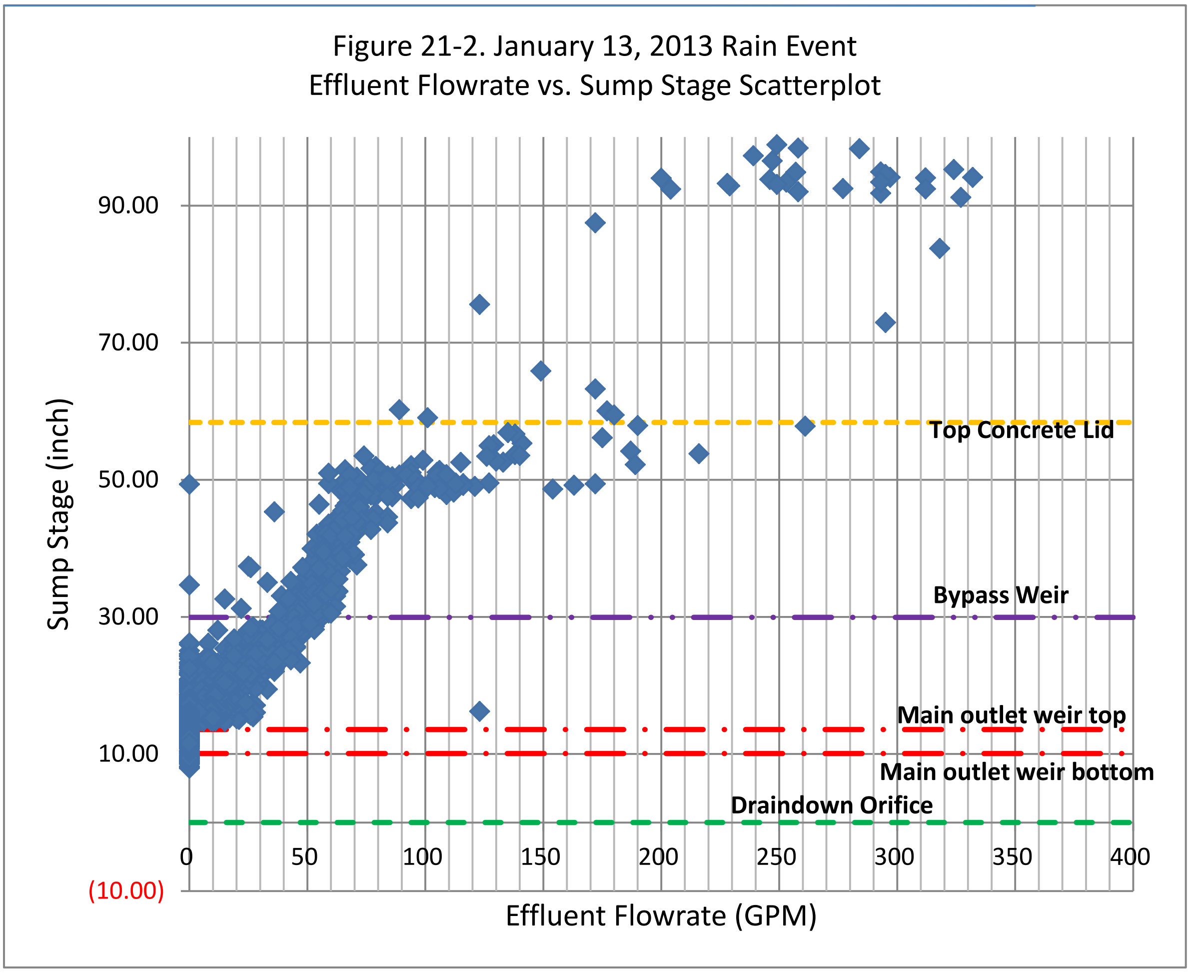
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 21-7. January 13, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	80	77	79	24	22	23
Millipore Membrane Filter, 0.45µm	79	70	74	12	10	11

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 21-8. January 13, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	24196	25994	25,095	11,199	8212	9,706
E. Coli	1,968	1,866	1,917	5,172	3,720	4,446
Enterococci	733	816	775	311	268	290

Table 21-9. January 13, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	29	17	23	8	7	8



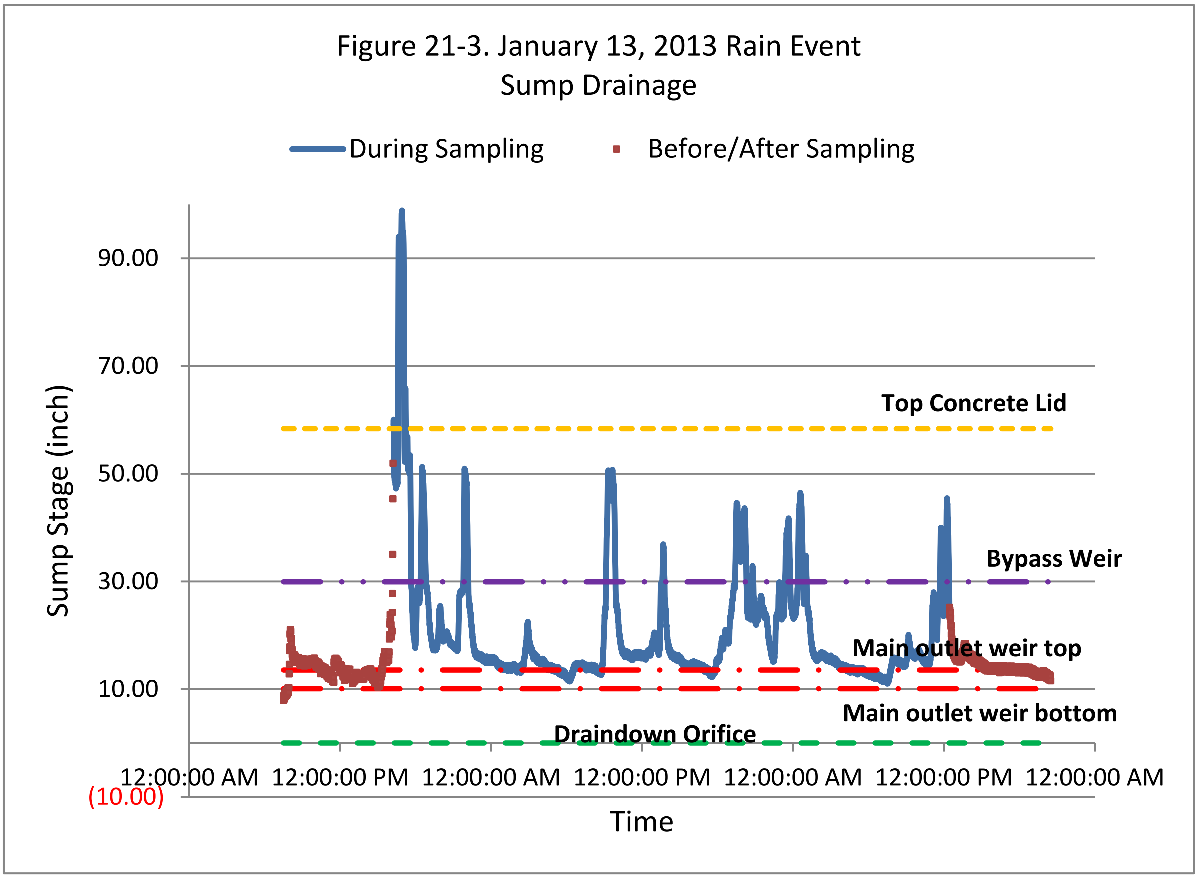


Figure 21-3. January 13, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Sump Stage (inch)
90.00
70.00
50.00
30.00
10.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
12:00:00 PM
12:00:00 AM
12:00:00 PM
12:00:00 AM
12:00:00 PM
12:00:00 AM
Time

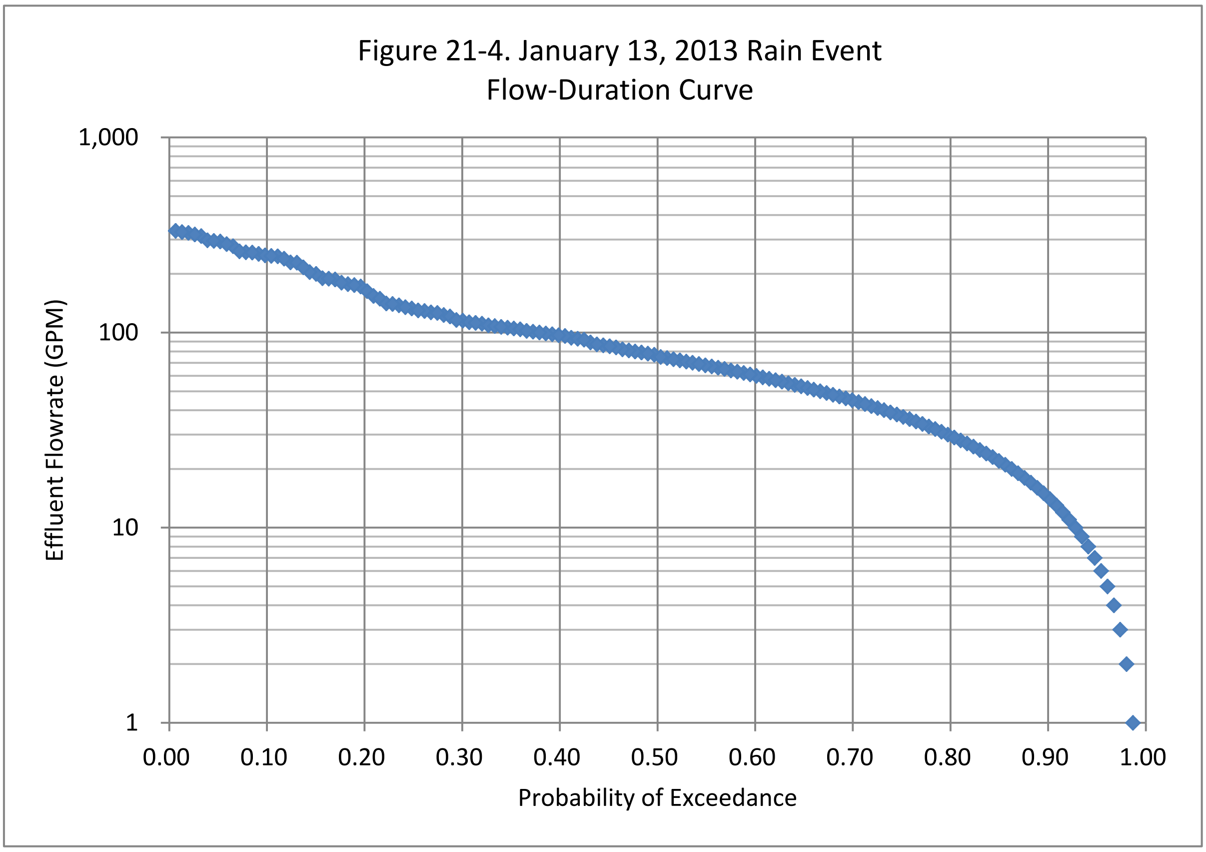


Figure 21-4. January 13, 2013 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance

Figure 21-5. January 13, 2013 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 μm)

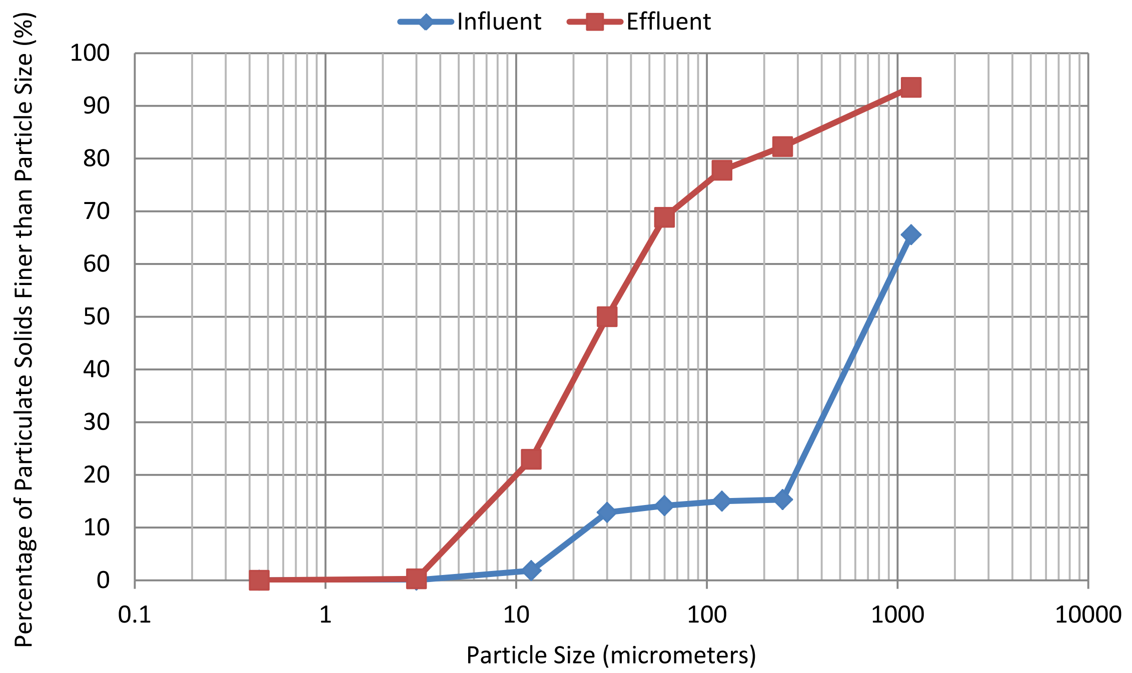
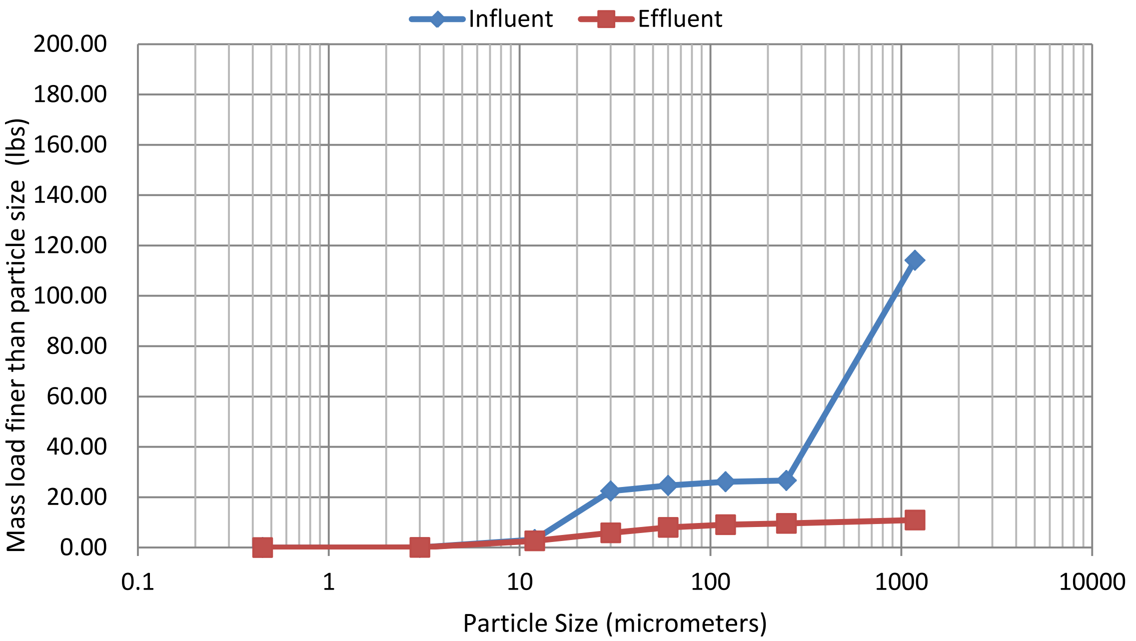


Figure 21-6. January 13, 2013 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 μm)



Not shown: The influent sample had 60.0 lbs larger than 1180 μm and the effluent had 0.76 lbs larger than 1180 μm (34.46% and 6.50% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 21-10. January 13, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.14	0.08	0.04	0.30	0.07	0.03	0.03	49.94
3 to 12	6.49	5.83	1.79	22.65	3.12	2.64	0.48	15.27
12 to 30	40.06	6.96	11.05	27.04	19.25	3.15	16.09	83.61
30 to 60	4.61	4.86	1.27	18.87	2.21	2.20	0.01	0.57
60 to 120	3.07	2.30	0.85	8.92	1.48	1.04	0.43	29.45
120 to 250	1.07	1.16	0.30	4.49	0.52	0.52	-0.01	-1.45
250 to 1180	182.09	2.89	50.24	11.23	87.49	1.31	86.18	98.50
>1180	124.89	1.67	34.46	6.50	60.00	0.76	59.25	98.74
Total	362	26	100.00	100.00	174.13	11.66	162.47	93.30

Table 21-11. January 13, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.04	0.30	0.07	0.03
<12	1.83	22.95	3.19	2.68
<30	12.88	49.99	22.43	5.83
<60	14.15	68.86	24.65	8.03
<120	15.00	77.79	26.12	9.07
<250	15.30	82.28	26.64	9.60
<1180	65.54	93.50	114.13	10.91
>1180	100.00	100.00	174.13	11.66

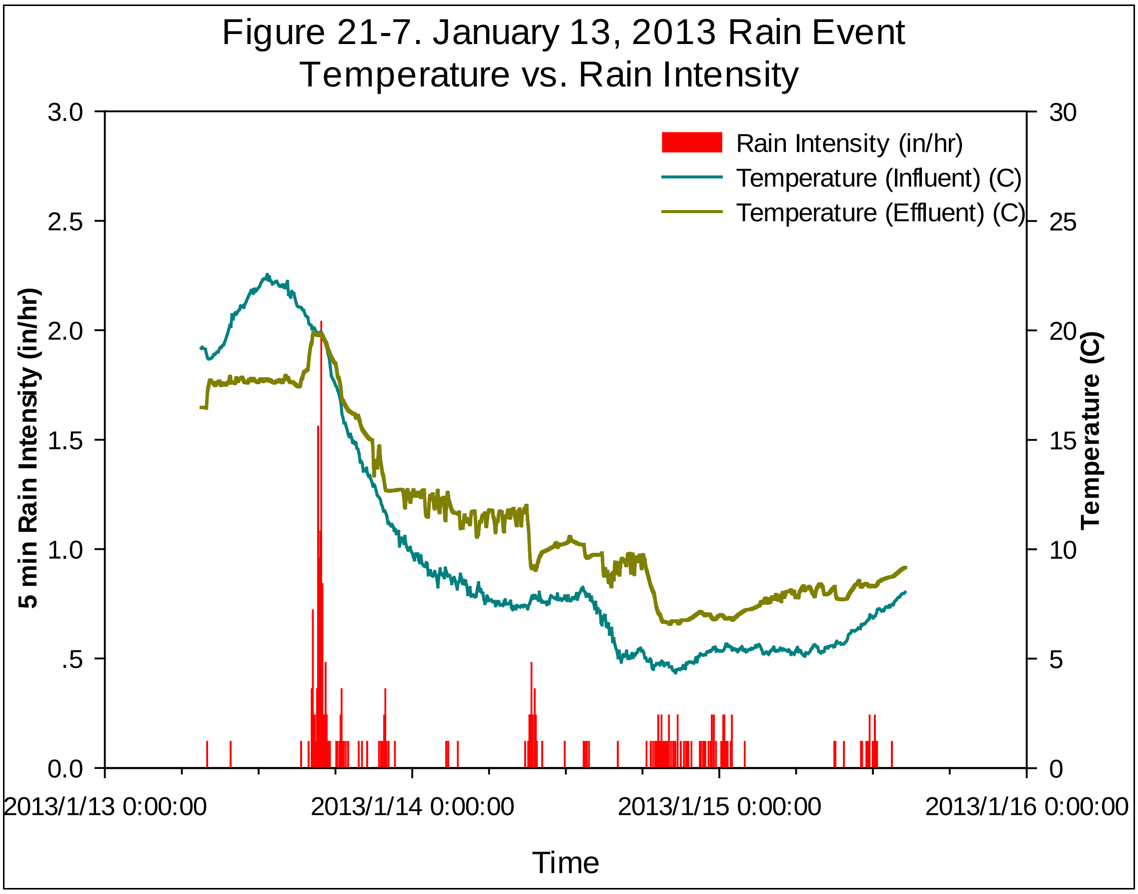


Figure 21-7. January 13, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
30
25
20
15
10
5
0
2013/1/13 0:00:00
2013/1/14 0:00:00
2013/1/15 0:00:00
2013/1/16 0:00:00
Time

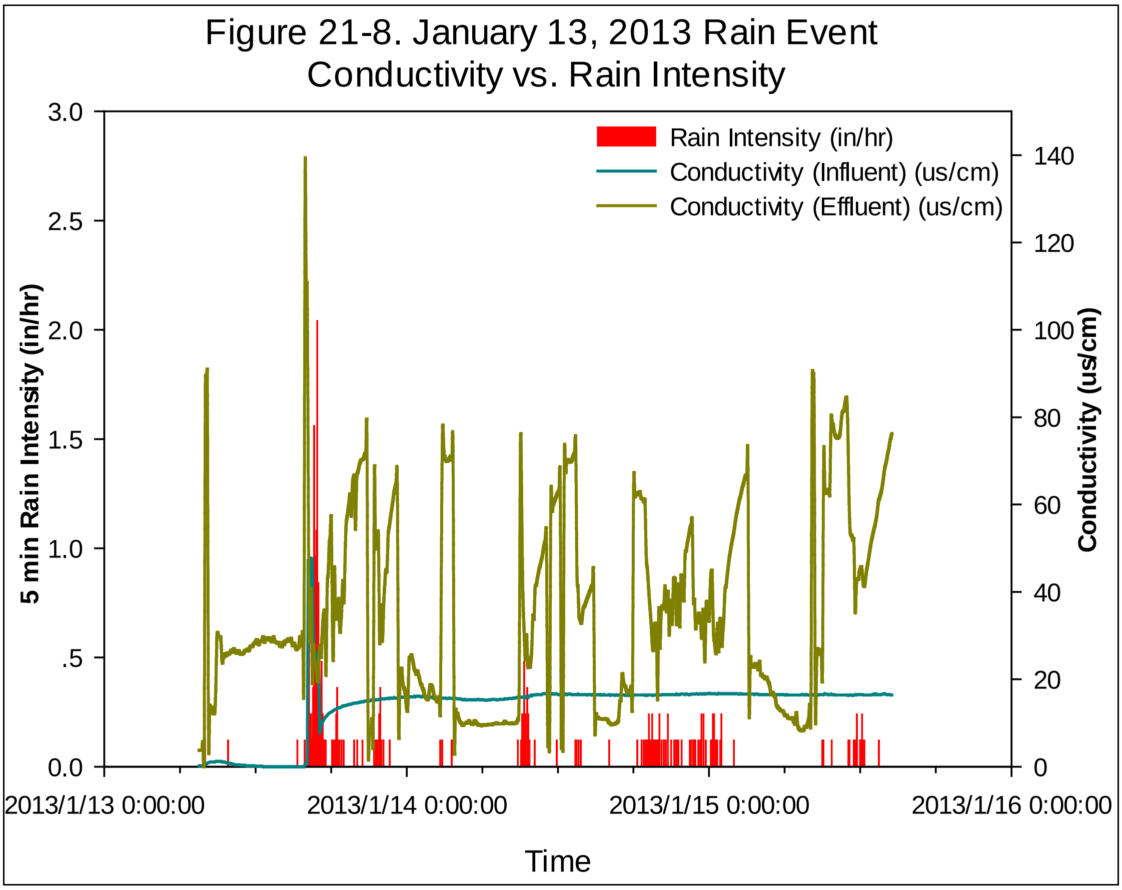


Figure 21-8. January 13, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
140
120
100
80
60
40
20
0
2013/1/13 0:00:00
2013/1/14 0:00:00
2013/1/15 0:00:00
2013/1/16 0:00:00
Time

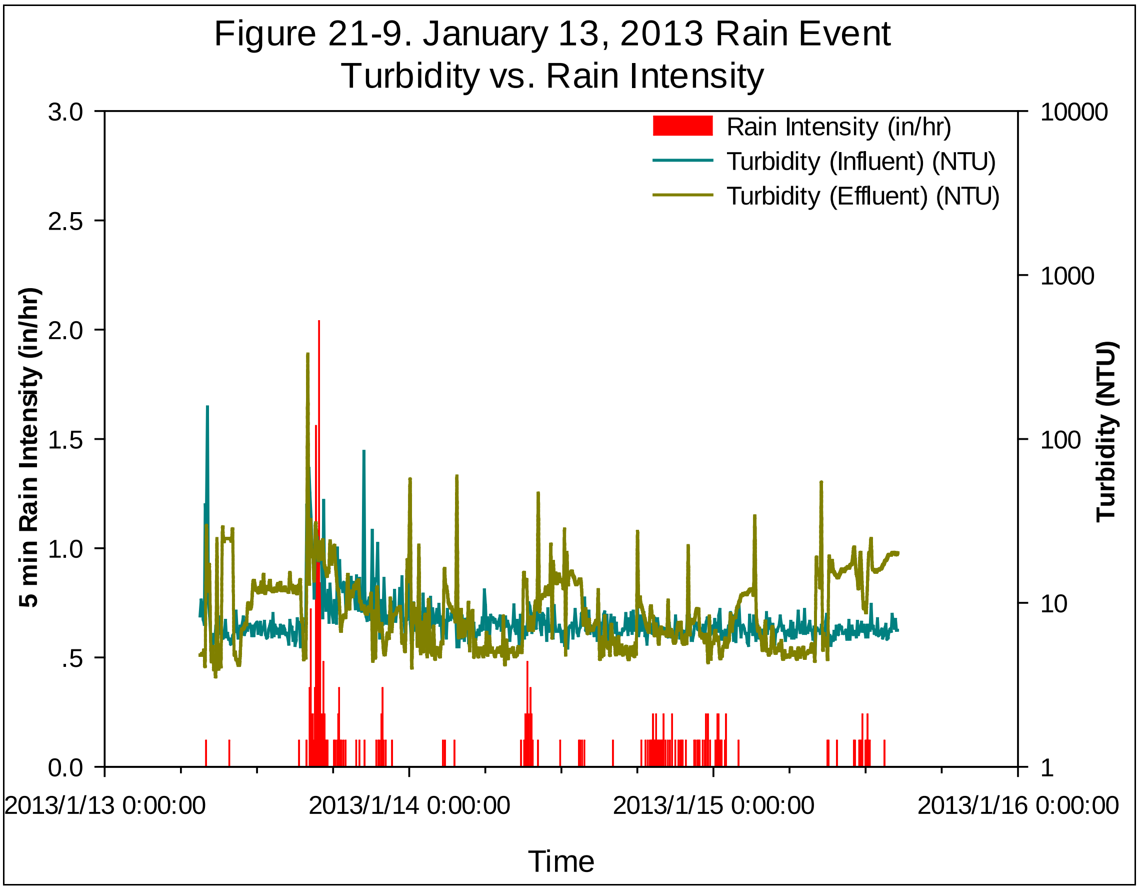
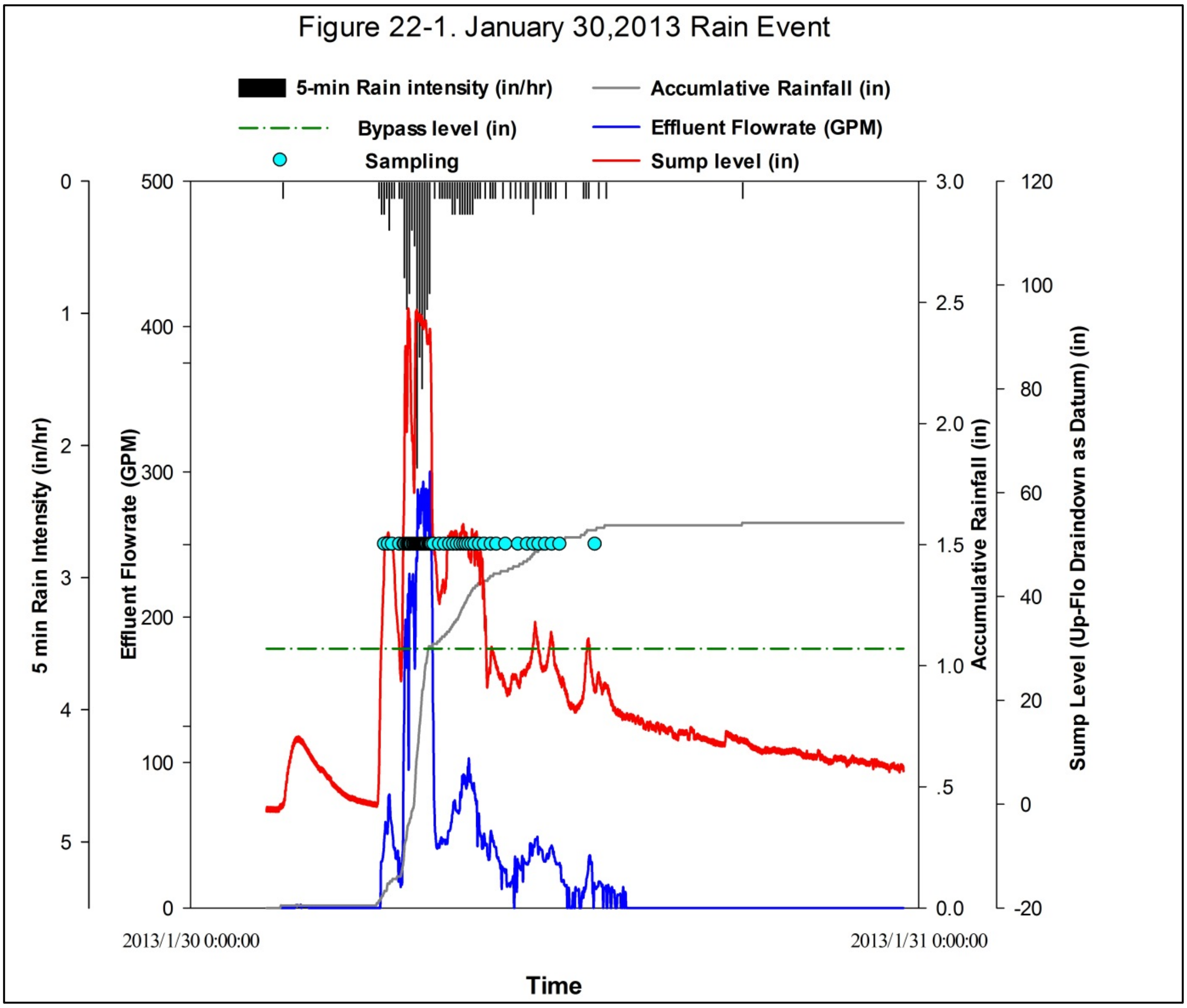


Figure 21-9. January 13, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
2013/1/13 0:00:00
2013/1/14 0:00:00
2013/1/15 0:00:00
2013/1/16 0:00:00
Time

Appendix F.22: January 30, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 9.05 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 22-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.34
Volumetric Runoff Coefficient (Rv)	1.05

Table 22-2. January 30, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/1/30 2:58
Rain Event End Date/Time:			2013/1/30 18:11
Total Precipitation (inch):	≥ 0.1	1.59	
Total Runoff Depth (inch):	NA	1.66	
Total Outflow (gallon):	NA	28721	
Rain Duration (hours):	≥ 1	15.22	
Flow Start Date/Time:			2013/1/30 3:27
Flow End Date/Time:			2013/1/30 14:22
Flow Duration (hours):	NA	10.92	
Average Rain Intensity (in/hr):	NA	0.10	
Average Runoff Rate (gallons/min):	NA	44	
Peak 5-min Rain Intensity (in/hr):	NA	2.16	
Peak Runoff Rate (gallons/min):	NA	297	
Peak to Average Runoff Ratio:	NA	6.77	
Bypassed flow volume (gallon):	NA	14429	
Percentage of Bypassed Flow (%):	NA	50.24	
Inter-Event Time since prior rain (hours)	≥ 6.0	99.12	

Table 22-3. January 30, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	57	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	14.3	The actual volumes of both samples were visually consistent with the programmed ones
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.92	

Table 22-4. January 30, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	81	42	48.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	313	40	87.4	SM 2540D	1 mg/L	UA Lab
SSC	82	44	46.3	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	2655	47	98.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	53	31	41.1	EPA 160.2	1 mg/L	UA Lab
VSS	42	11	74.1	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.4	20.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.06	0.06	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.58	0.37	36.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.40	0.25	37.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.087	BDL	>94.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.181	0.042	76.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	0.018	0.014	22.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.046	0.014	69.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	0.006	0.005	16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.157	0.046	70.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.007	0.006	14.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	>48392	NA	IDEXX Method	<1	UA Lab
E. Coli	3048	2815	7.6	IDEXX Method	<1	UA Lab
Enterococci	2400	784	67.4	IDEXX Method	<1	UA Lab
pH	6.76	6.86	-1.5	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	4.48	3.69	17.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	38.7	39.8	-2.8	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.2	7.9	3.7	SM 212/ EPA 170.1	5 °C	UA Lab

Table 22-5. January 30, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	0	NA*	NA*	0	NA*	NA*	#DIV/0!	NA*	NA*
UA Lab	1795	861	2655	45	2	47	97.5	99.7	98.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 22-6. January 30, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	34232	18117	139	35	4.1	1.9

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 22-7. January 30, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	269	358	313	38	41	40
Millipore Membrane Filter, 0.45µm	438	553	496	30	33	32

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 22-8. January 30, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	>48392	>48392
E. Coli	2,755	3,340	3,048	3,654	1,976	2,815
Enterococci	3,654	1,146	2,400	905	662	784

Table 22-9. January 30, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	45	40	42	10	12	11

Figure 22-2. January 30, 2013 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot

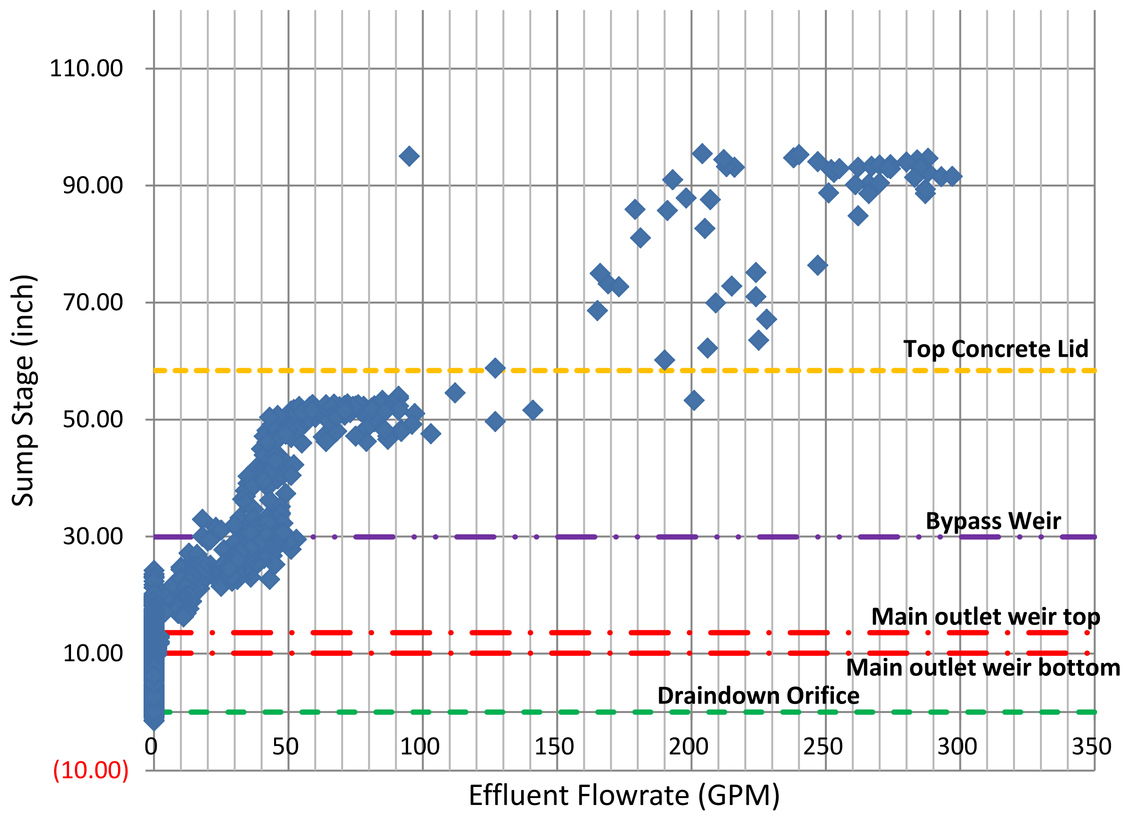


Figure 22-3. January 30, 2013 Rain Event
Sump Drainage

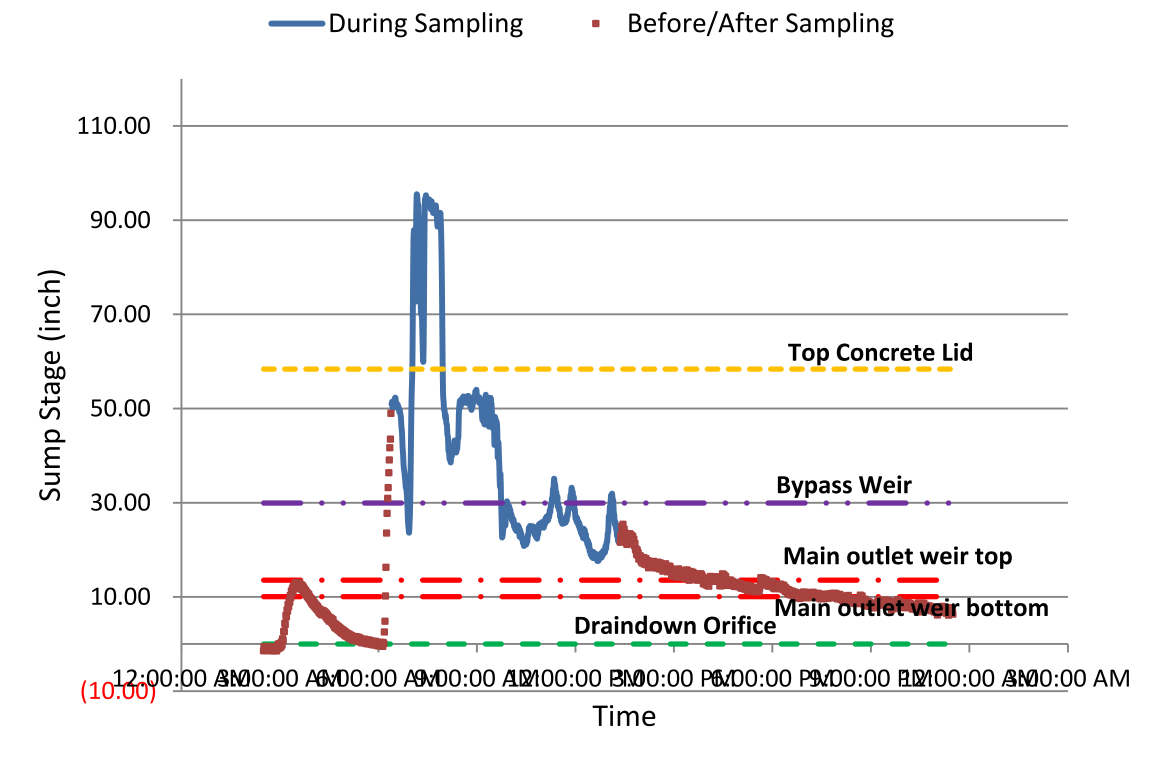


Figure 22-4. January 30, 2013 Rain Event
Flow-Duration Curve

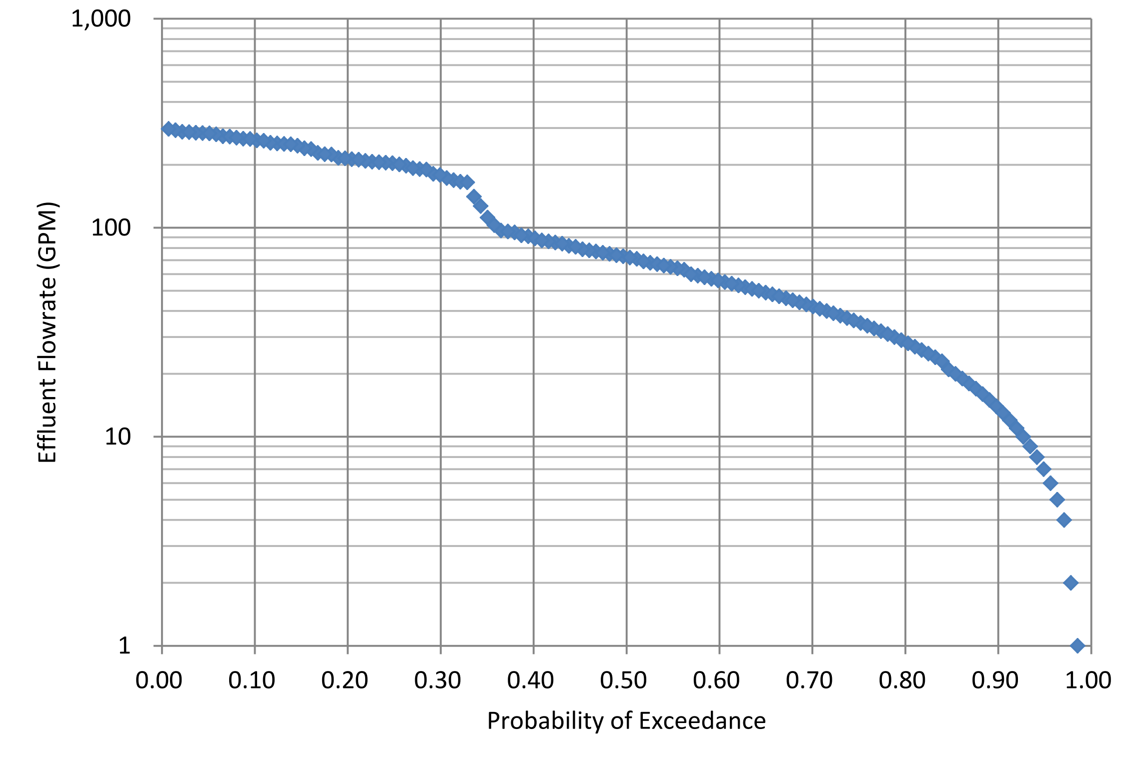


Figure 22-5. January 30, 2013 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size
(0.45 to 1180 µm)

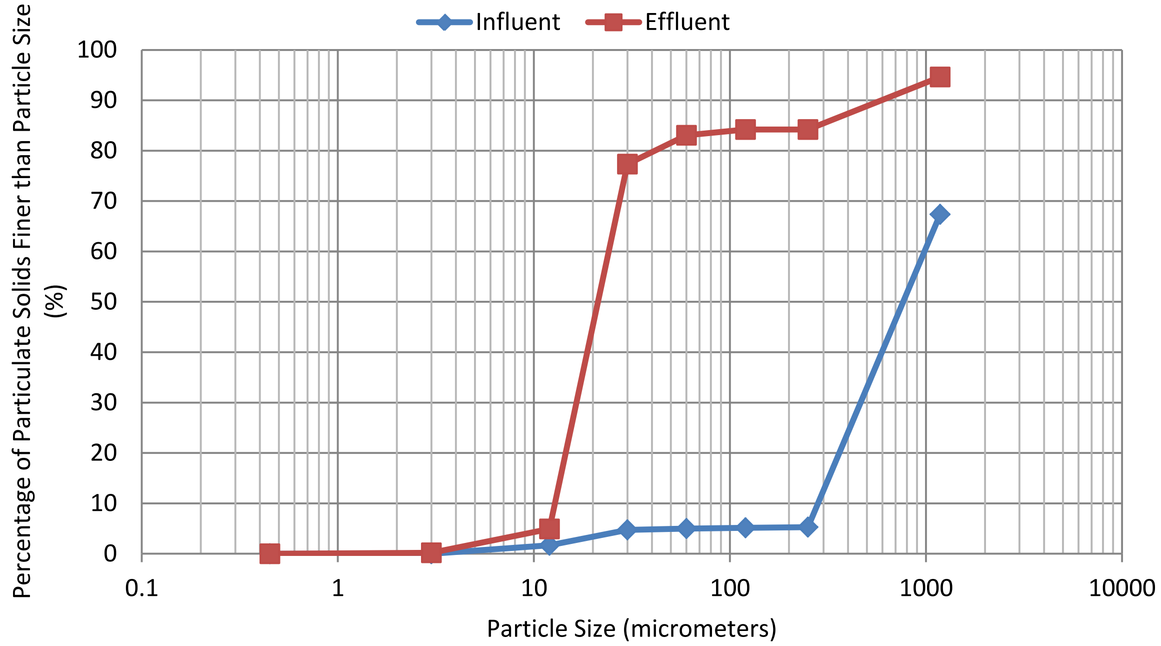
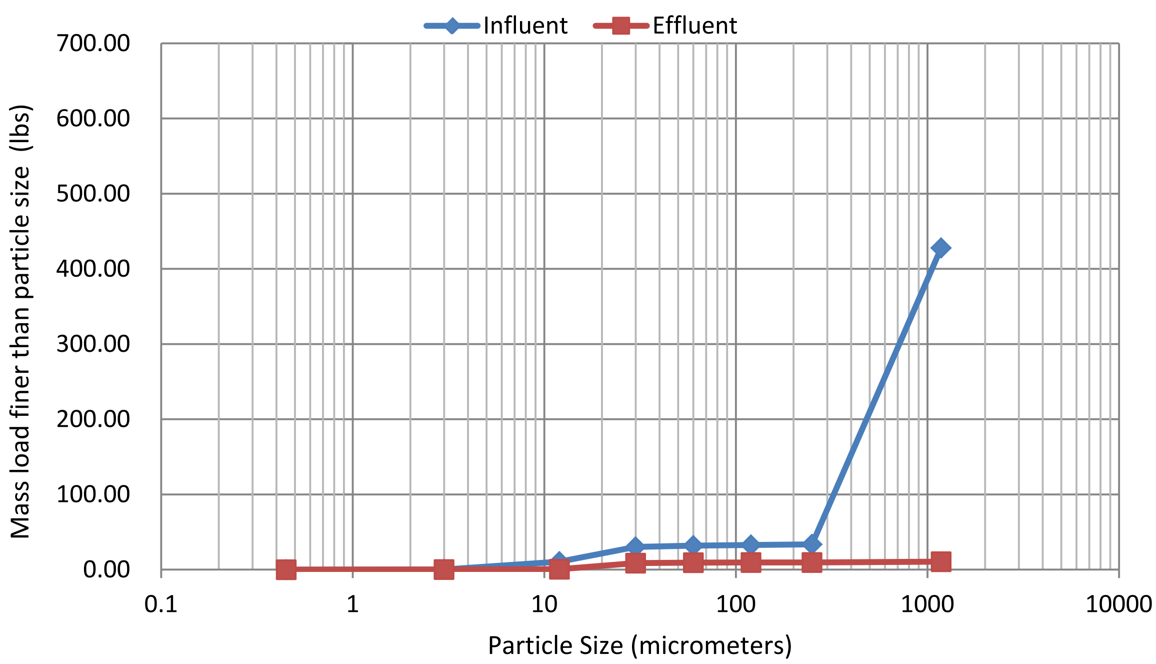


Figure 22-6. January 30, 2013 Rain Event
Accumulative Particulate Solids Mass Distribution by Particle Size
(0.45 to 1180 µm)



Not shown: The influent sample had 207.4 lbs larger than 1180 µm and the effluent had 0.60 lbs larger than 1180 µm (32.65% and 5.38% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 22-10. January 30, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.08	0.07	0.00	0.18	0.02	0.02	0.00	0.20
3 to 12	43.90	1.99	1.67	4.75	10.58	0.53	10.05	94.96
12 to 30	81.12	30.41	3.08	72.42	19.55	8.14	11.41	58.37
30 to 60	6.69	2.40	0.25	5.72	1.61	0.64	0.97	60.10
60 to 120	4.15	0.48	0.16	1.14	1.00	0.13	0.87	87.21
120 to 250	3.22	0.00	0.12	0.00	0.78	0.00	0.78	100.00
250 to 1180	1636.01	4.37	62.07	10.42	394.20	1.17	393.03	99.70
>1180	860.76	2.26	32.65	5.38	207.40	0.60	206.80	99.71
Total	2636	42	100.00	100.00	635.14	11.24	623.90	98.23

Table 22-11. January 30, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.00	0.18	0.02	0.02
<12	1.67	4.92	10.60	0.55
<30	4.75	77.34	30.14	8.69
<60	5.00	83.07	31.76	9.33
<120	5.16	84.21	32.76	9.46
<250	5.28	84.21	33.53	9.46
<1180	67.35	94.62	427.73	10.63
>1180	100.00	100.00	635.14	11.24

Figure 22-7. January 30, 2013 Rain Event
Temperature vs. Rain Intensity

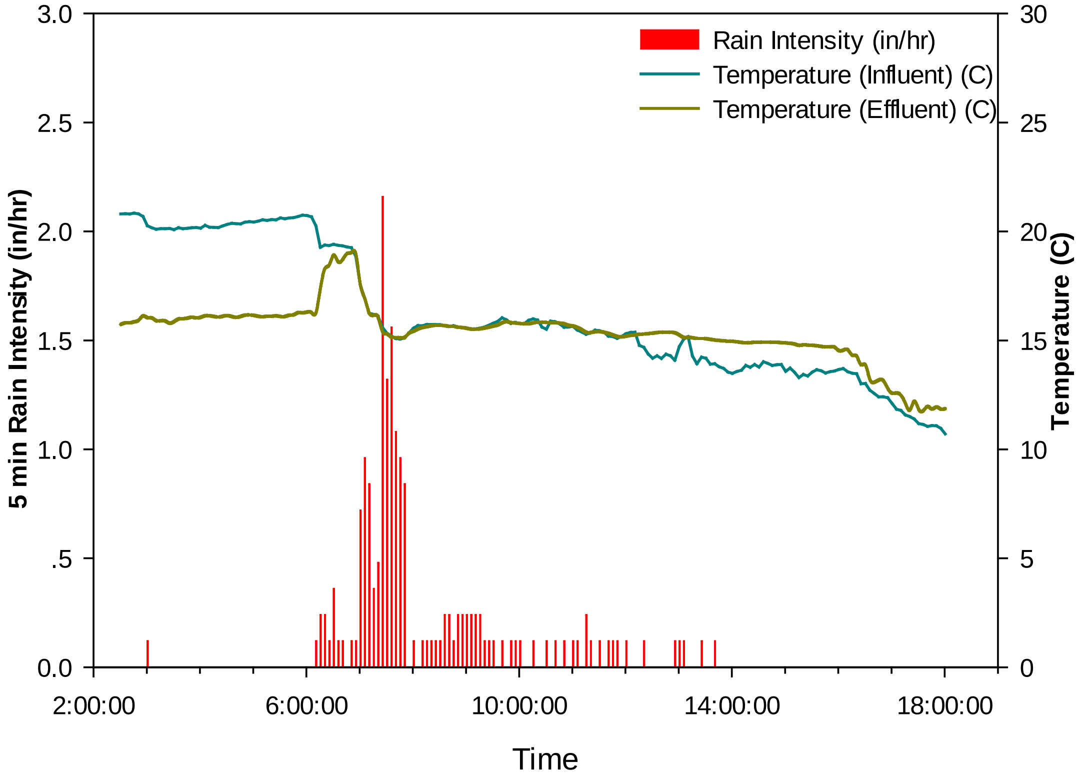
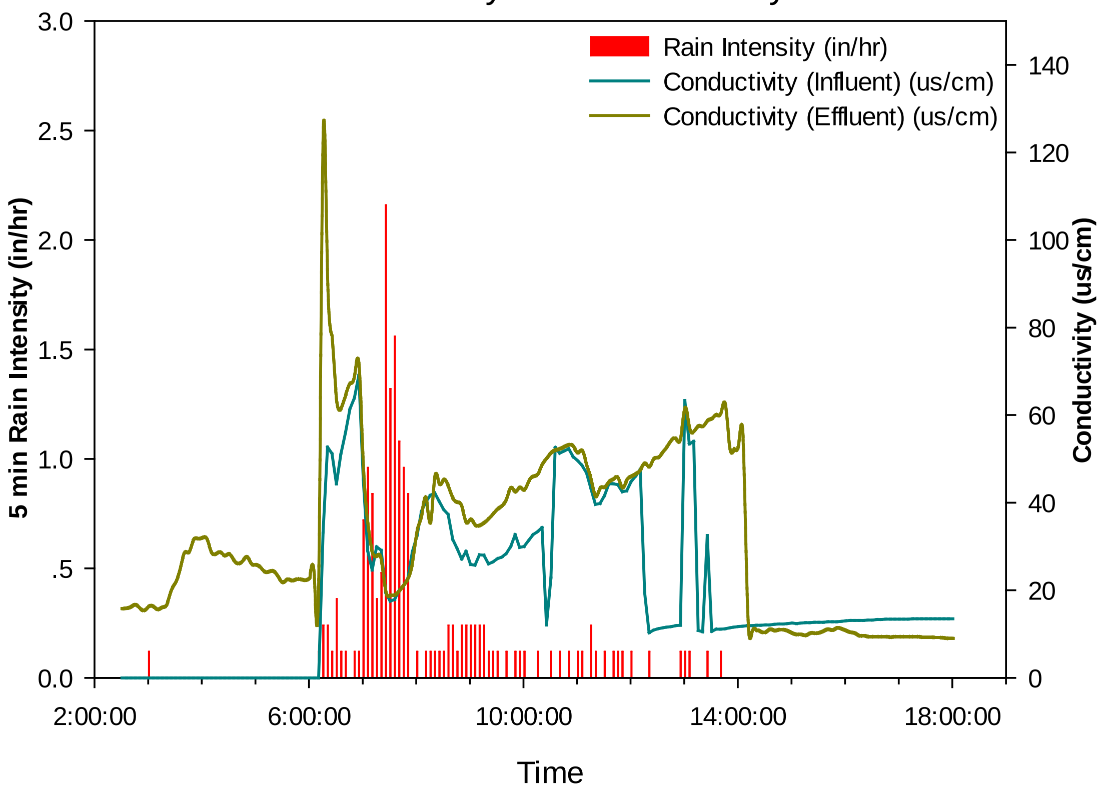


Figure 22-8. January 30, 2013 Rain Event
Conductivity vs. Rain Intensity



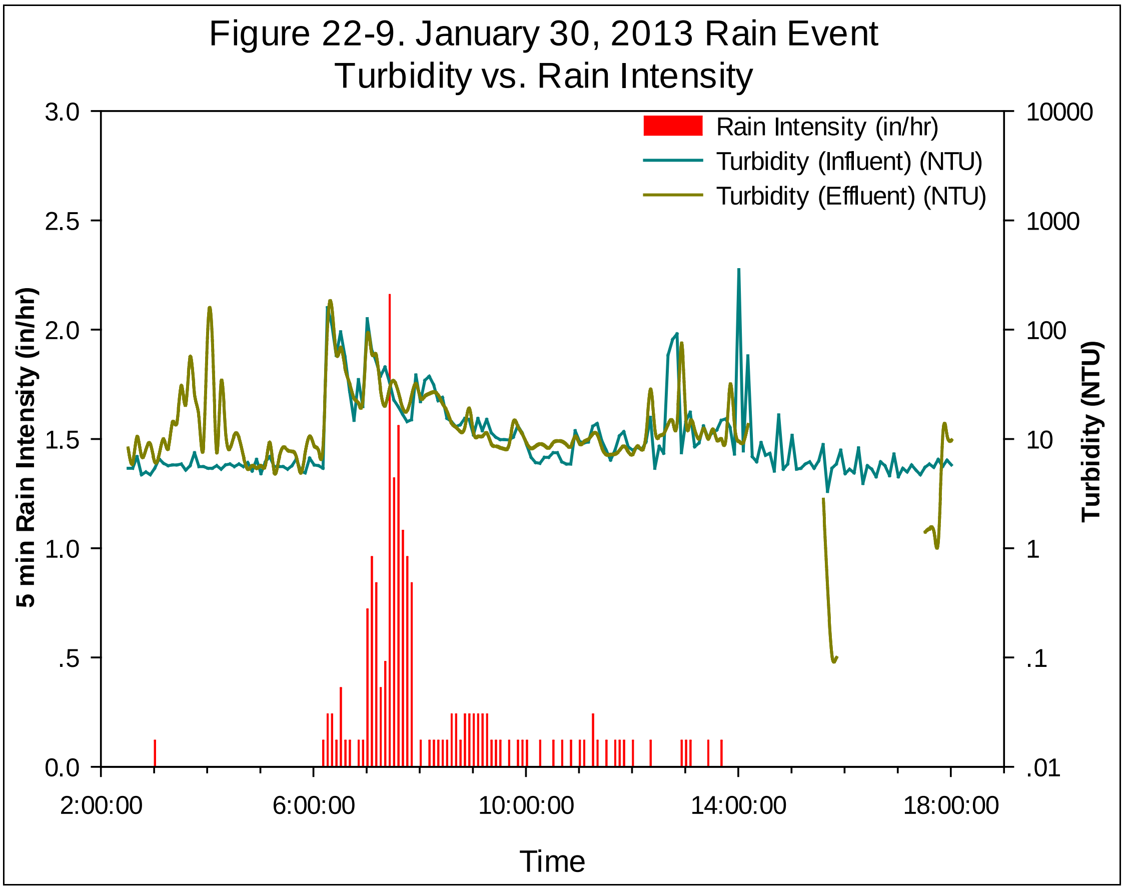
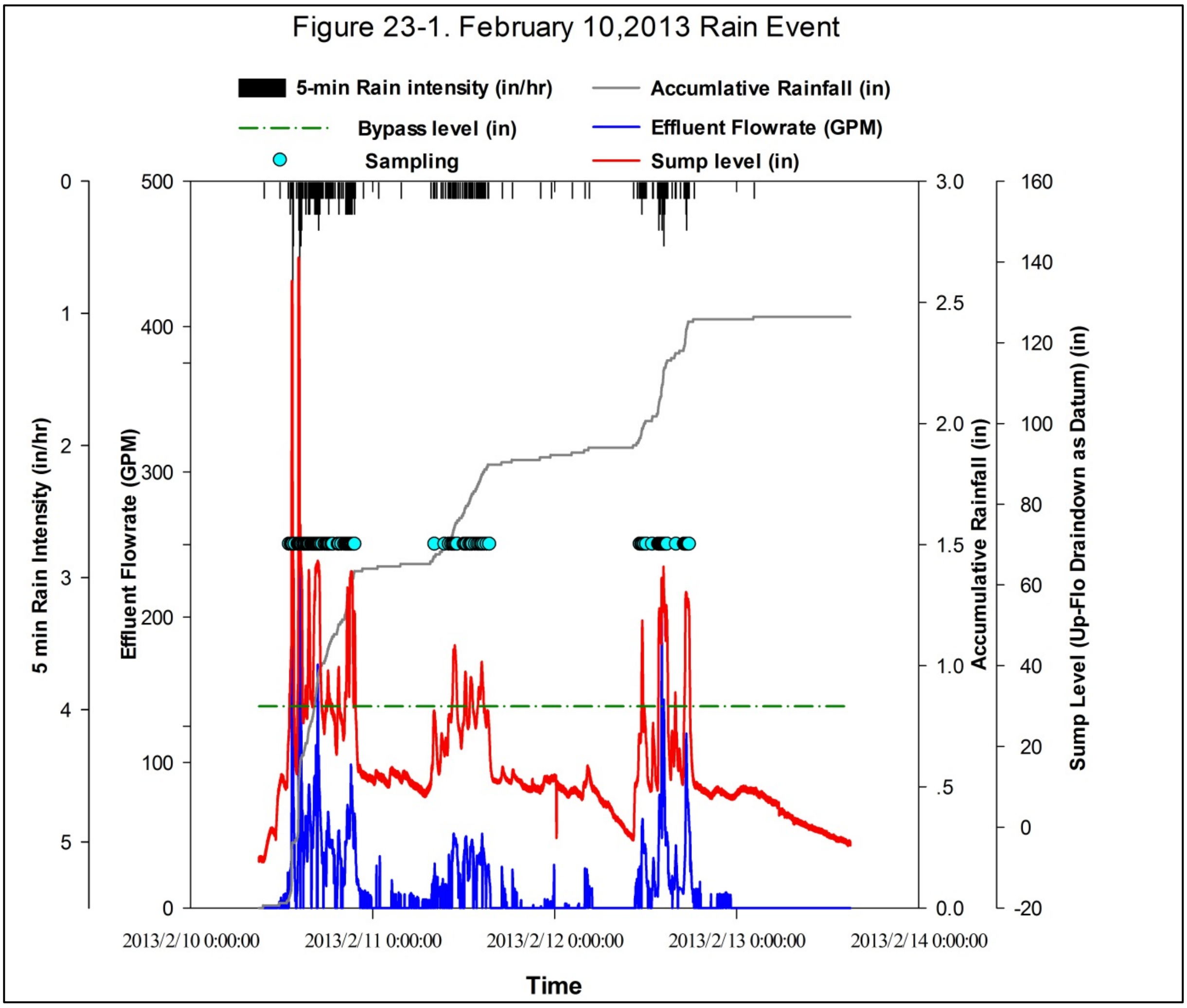


Figure 22-9. January 30, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
10000
1000
100
10
1
.1
.01
2:00:00
6:00:00
10:00:00
14:00:00
18:00:00
Time

Appendix F.23: February 10, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 27.86 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 23-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.32
Volumetric Runoff Coefficient (Rv)	1.00

Table 23-2. February 10, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/2/10 9:31
Rain Event End Date/Time:			2013/2/13 2:12
Total Precipitation (inch):	≥ 0.1	2.44	
Total Runoff Depth (inch):	NA	2.75	
Total Outflow (gallon):	NA	61131	
Rain Duration (hours):	≥ 1	64.68	
Flow Start Date/Time:			2013/2/10 11:26
Flow End Date/Time:			2013/2/12 23:13
Flow Duration (hours):	NA	59.78	
Average Rain Intensity (in/hr):	NA	0.04	
Average Runoff Rate (gallons/min):	NA	17	
Peak 5-min Rain Intensity (in/hr):	NA	2.28	
Peak Runoff Rate (gallons/min):	NA	290	
Peak to Average Runoff Ratio:	NA	17.02	
Bypassed flow volume (gallon):	NA	14552	
Percentage of Bypassed Flow (%):	NA	23.80	
Inter-Event Time since prior rain (hours)	≥ 6.0	79.10	

Table 23-3. February 10, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	109	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	27.3	The actual volumes of both samples were visually only about 16 liters
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120	480	
	Moderate Event: 480		
	Large Event: 2000		
Samples Coverage of total storm flow (%)	75.00	96.83	

Table 23-4. February 10, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	88	21	76.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	354	25	92.9	SM 2540D	1 mg/L	UA Lab
SSC	91	23	74.7	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	1864	29	98.4	ASTM D3977-97B	1 mg/L	UA Lab
TDS	52	29	45.7	EPA 160.2	1 mg/L	UA Lab
VSS	31	8	72.6	SM 2540E	1 mg/L	UA Lab
Total N as N	0.9	0.5	44.4	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.4	42.9	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.08	0.08	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.55	0.34	38.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.31	0.25	19.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.026	BDL	>80.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.031	0.018	41.9	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	0.011	0.008	27.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.042	0.020	52.4	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	17280	>64.3	IDEXX Method	<1	UA Lab
E. Coli	203	241	-18.8	IDEXX Method	<1	UA Lab
Enterococci	180	268	-48.9	IDEXX Method	<1	UA Lab
pH	6.68	6.79	-1.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	24.00	14.05	41.5	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	37.0	36.7	0.8	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.2	7.9	3.7	SM 212/ EPA 170.1	5 °C	UA Lab

Table 23-5. February 10, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	91	NA*	NA*	23	NA*	NA*	74.7	NA*	NA*
UA Lab	1373	491	1864	28	1	29	98.0	99.7	98.4

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 23-6. February 10, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	25351	12982	91	19	3.6	1.5

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

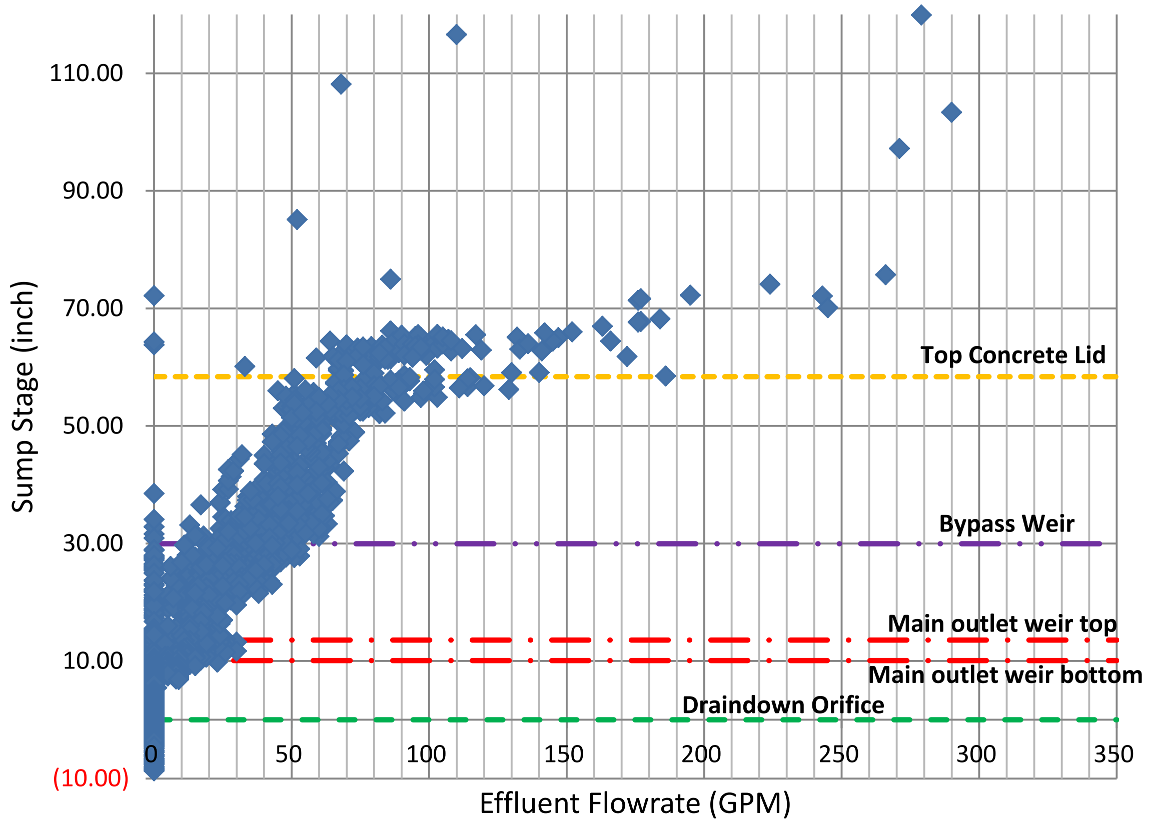
Table 23-7. February 10, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	320	387	354	24	26	25
Millipore Membrane Filter, 0.45µm	229	276	253	9	12	11

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 23-8. February 10, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	17280	17280
E. Coli	279	126	203	331	150	241
Enterococci	216	144	180	318	218	268

Table 23-9. February 10, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	30	32	31	9	8	8

Figure 23-2. February 10, 2013 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



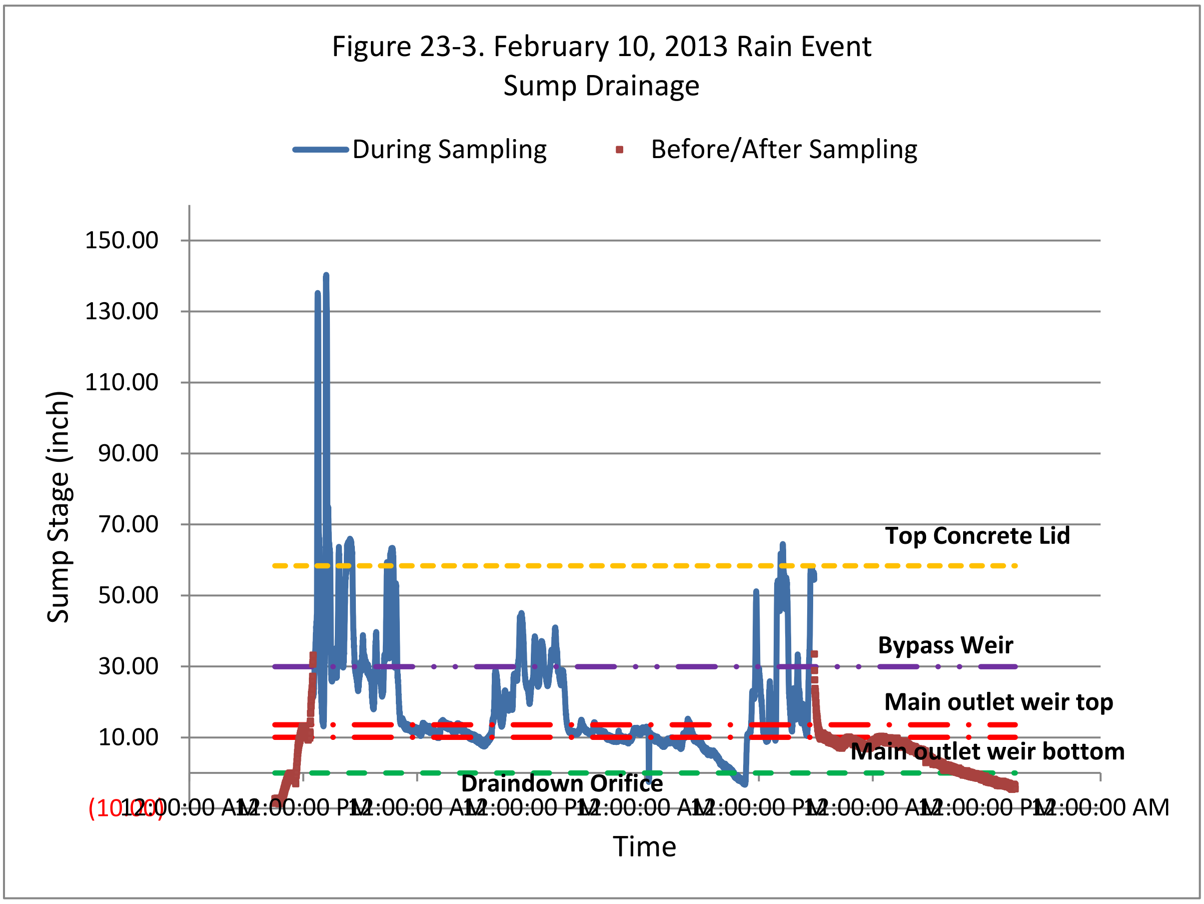


Figure 23-3. February 10, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Sump Stage (inch)
150.00
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
12:00:00 PM
Time

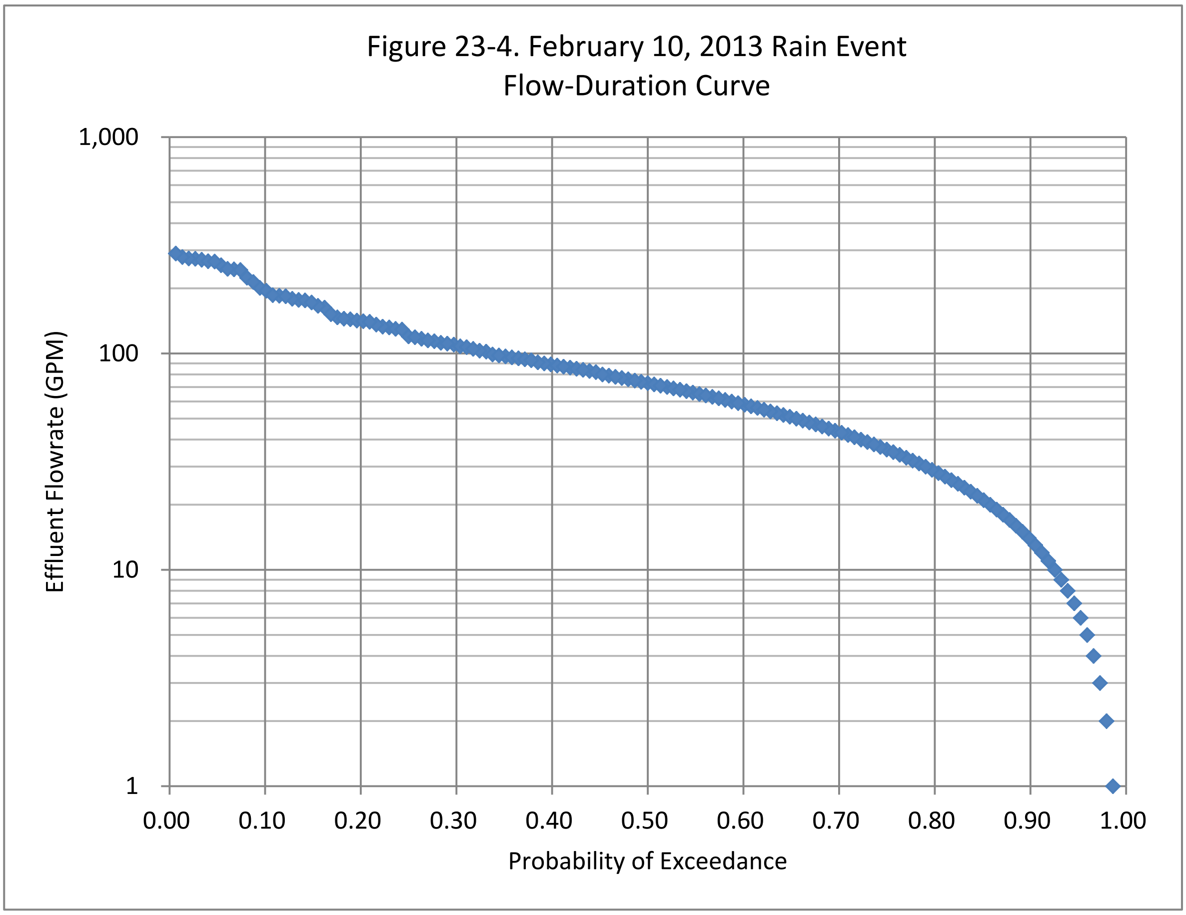
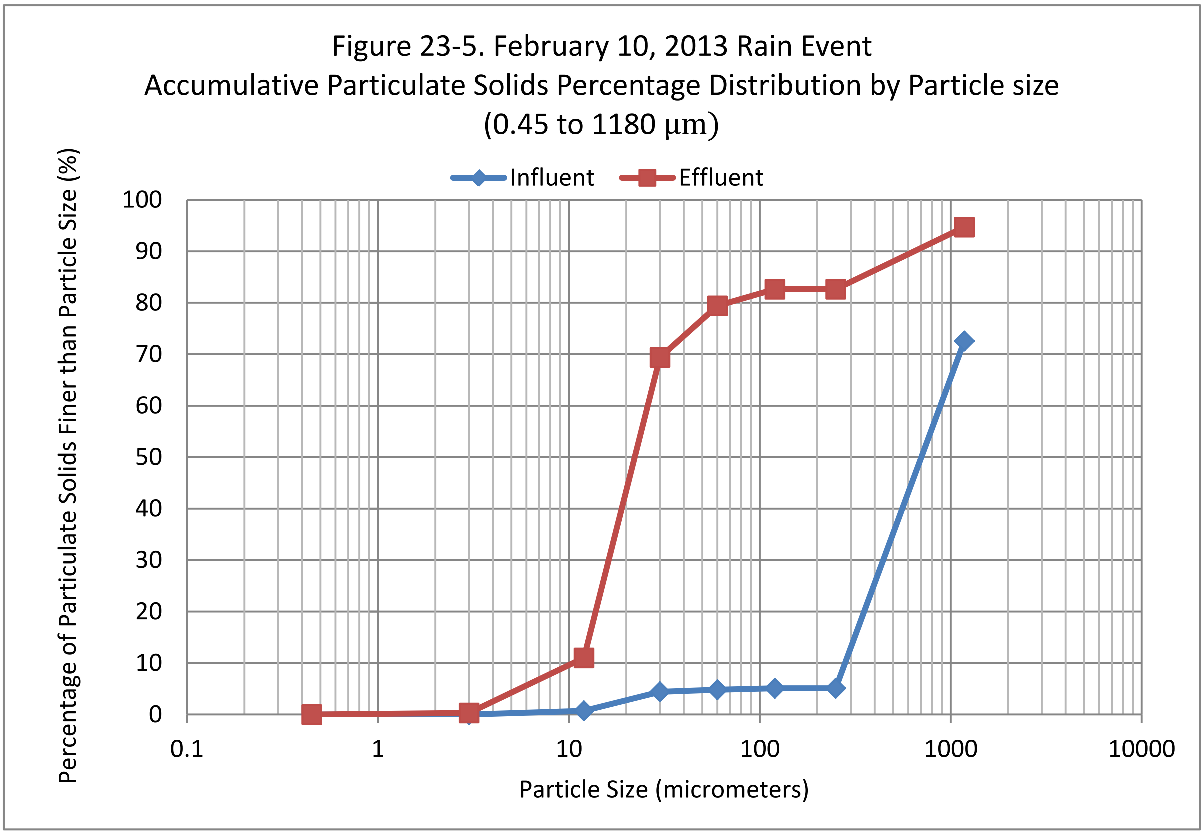
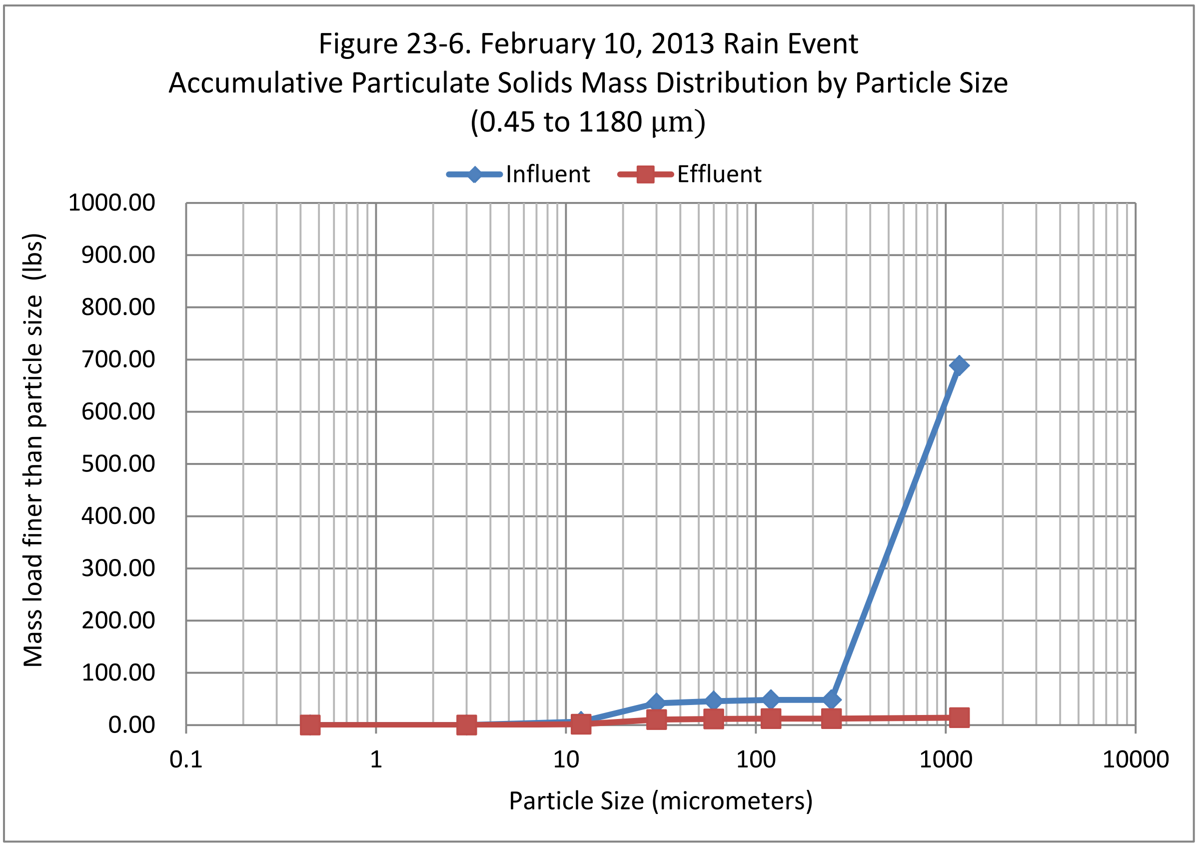


Figure 23-4. February 10, 2013 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 260.38 lbs larger than 1180 µm and the effluent had 0.79 lbs larger than 1180 µm (27.45% and 5.31% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 23-10. February 10, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.08	0.07	0.00	0.31	0.04	0.05	-0.01	-16.33
3 to 12	12.38	2.51	0.69	10.68	6.57	1.59	4.97	75.73
12 to 30	66.50	13.70	3.72	58.41	35.28	8.71	26.57	75.30
30 to 60	6.97	2.34	0.39	9.99	3.70	1.49	2.21	59.70
60 to 120	4.90	0.76	0.27	3.25	2.60	0.48	2.11	81.36
120 to 250	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
250 to 1180	1206.52	2.83	67.47	12.05	640.12	1.80	638.33	99.72
>1180	490.77	1.24	27.45	5.31	260.38	0.79	259.59	99.70
Total	1788	23	100.00	100.00	948.69	14.92	933.77	98.43

Table 23-11. February 10, 2013 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.00	0.31	0.04	0.05
<12	0.70	10.99	6.61	1.64
<30	4.42	69.40	41.89	10.35
<60	4.81	79.39	45.59	11.85
<120	5.08	82.64	48.19	12.33
<250	5.08	82.64	48.19	12.33
<1180	72.55	94.69	688.31	14.13
>1180	100.00	100.00	948.69	14.92

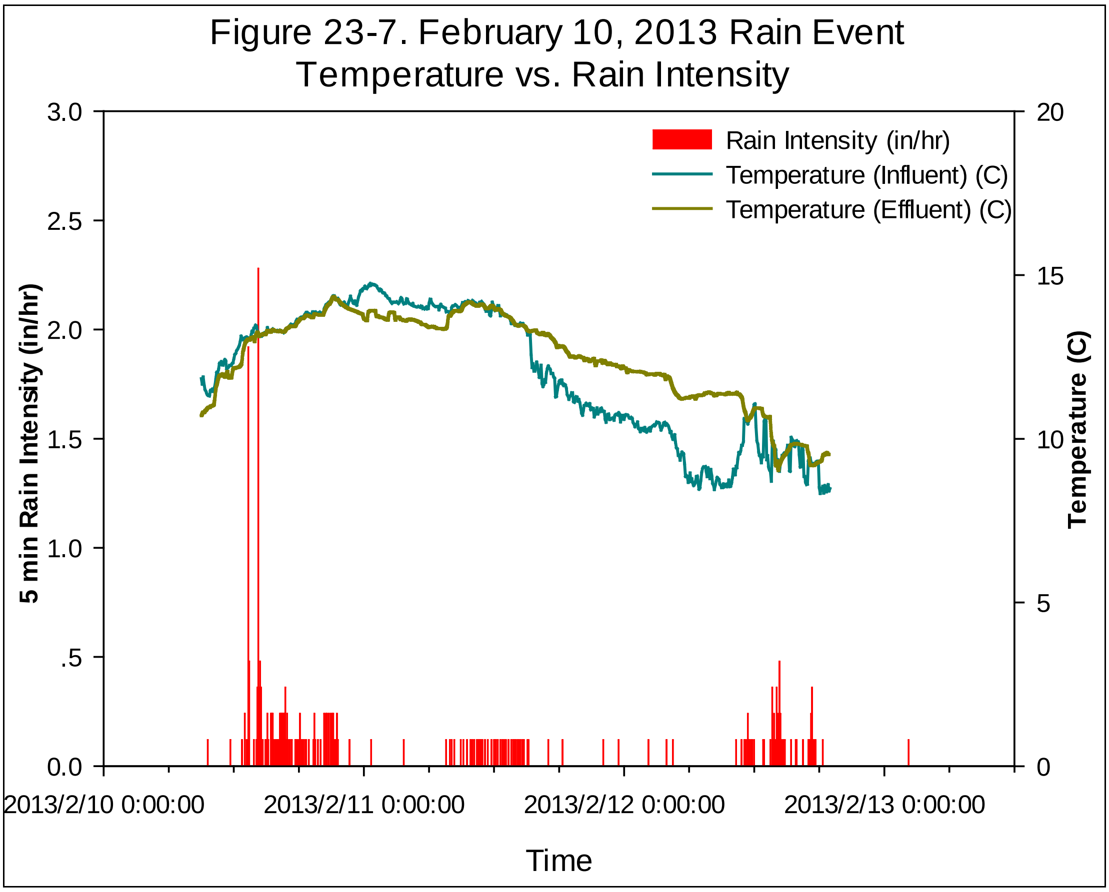


Figure 23-7. February 10, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
2013/2/10 0:00:00
2013/2/11 0:00:00
2013/2/12 0:00:00
2013/2/13 0:00:00
Time

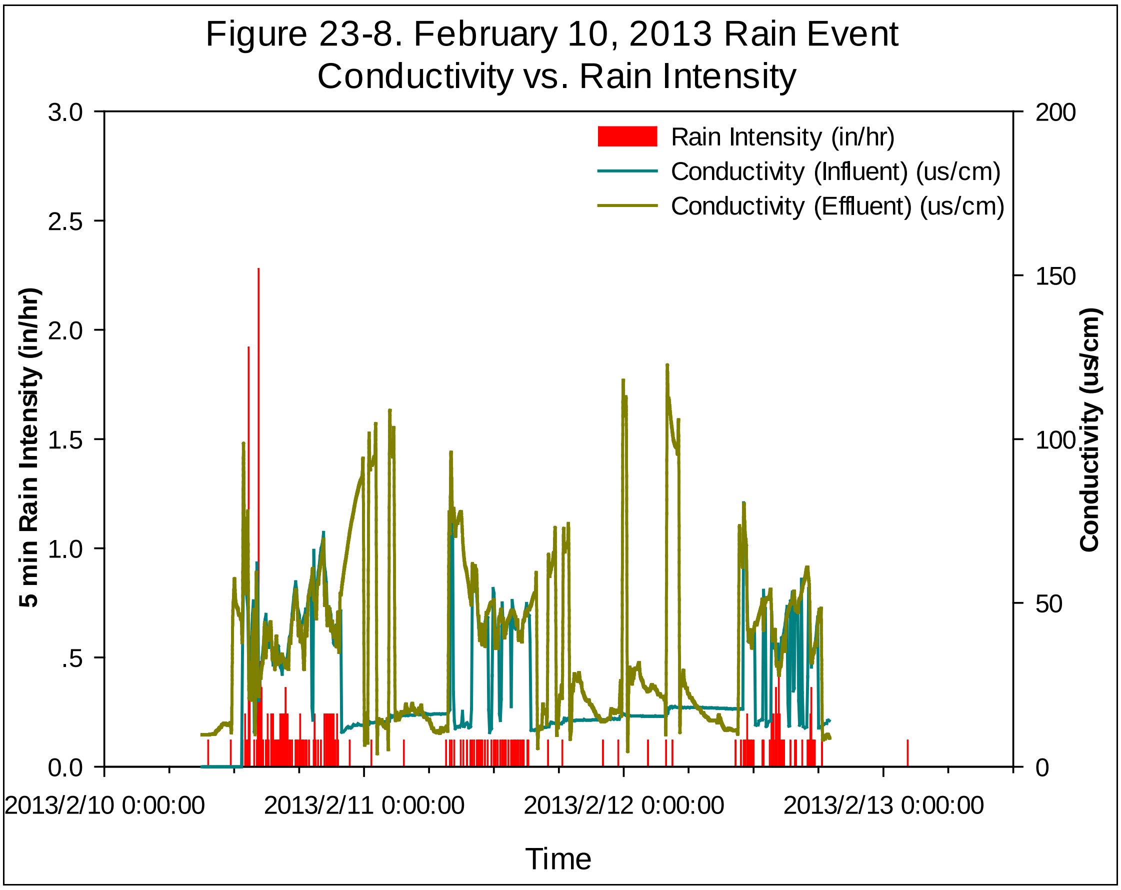


Figure 23-8. February 10, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
200
150
100
50
0
2013/2/10 0:00:00
2013/2/11 0:00:00
2013/2/12 0:00:00
2013/2/13 0:00:00
Time

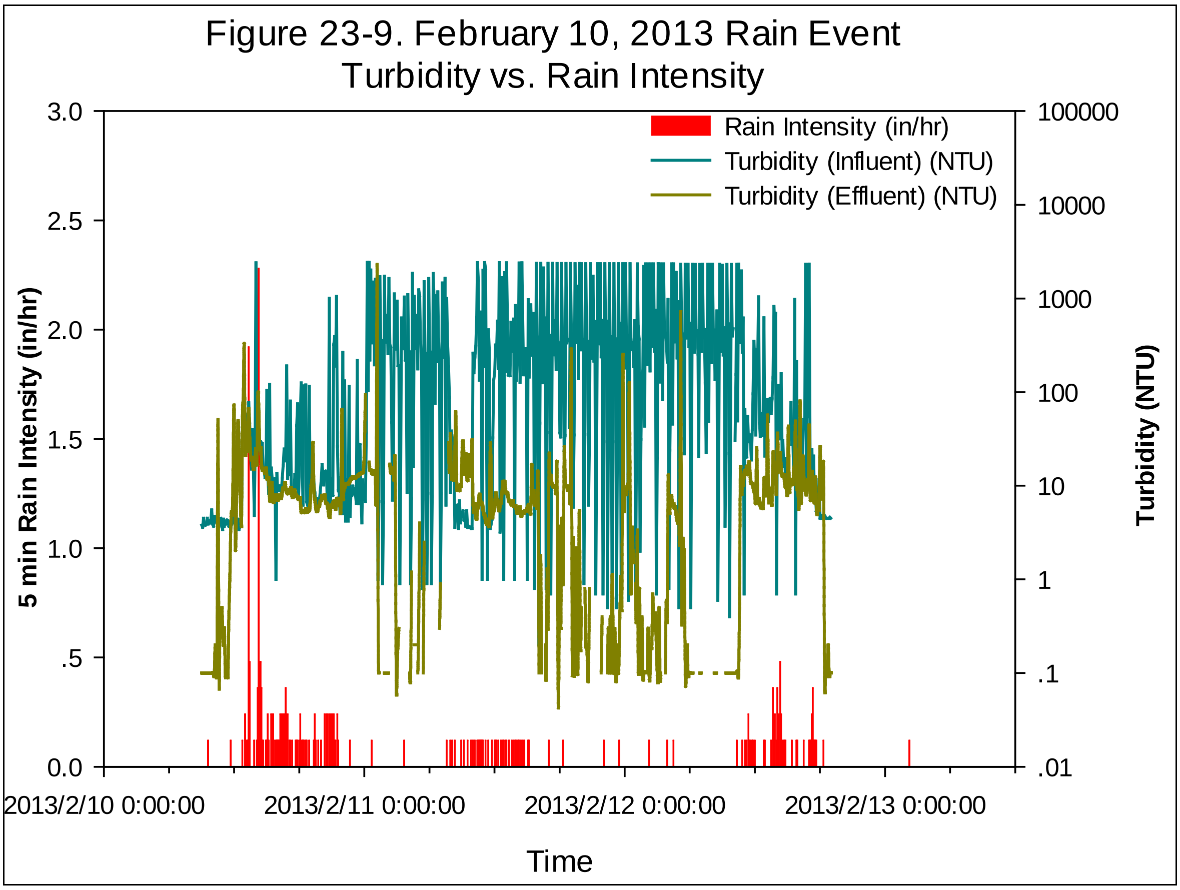
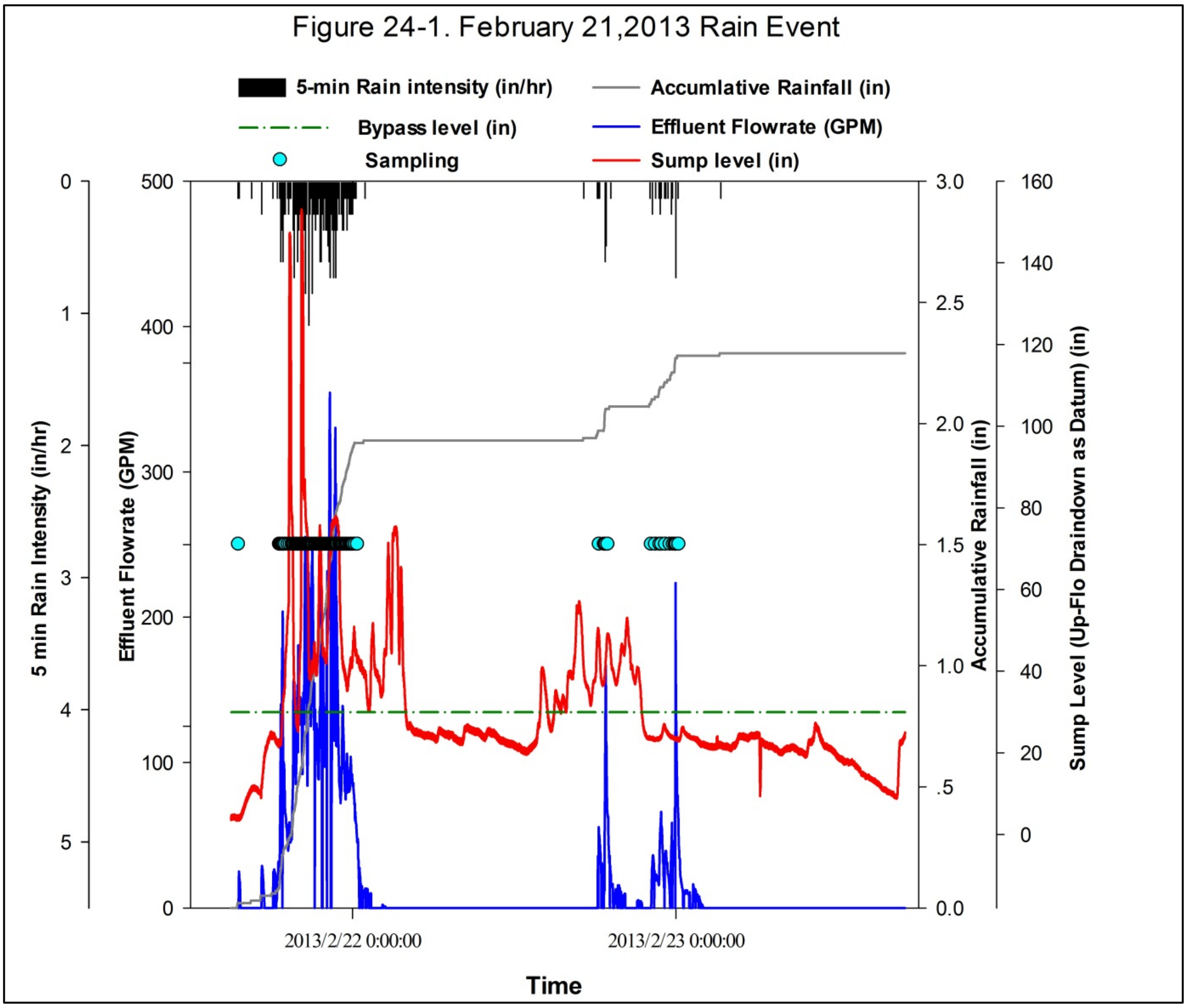


Figure 23-9. February 10, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
2013/2/10 0:00:00
2013/2/11 0:00:00
2013/2/12 0:00:00
2013/2/13 0:00:00
Time

Appendix F.24: February 21, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 15.81 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 24-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.82
Volumetric Runoff Coefficient (Rv)	1.00

Table 24-2. February 21, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/2/21 15:21
Rain Event End Date/Time:			2013/2/23 3:14
Total Precipitation (inch):	≥ 0.1	2.29	
Total Runoff Depth (inch):	NA	2.36	
Total Outflow (gallon):	NA	54490	
Rain Duration (hours):	≥ 1	35.88	
Flow Start Date/Time:			2013/2/21 15:34
Flow End Date/Time:			2013/2/23 2:01
Flow Duration (hours):	NA	34.45	
Average Rain Intensity (in/hr):	NA	0.06	
Average Runoff Rate (gallons/min):	NA	26	
Peak 5-min Rain Intensity (in/hr):	NA	1.08	
Peak Runoff Rate (gallons/min):	NA	353	
Peak to Average Runoff Ratio:	NA	13.39	
Bypassed flow volume (gallon):	NA	16145	
Percentage of Bypassed Flow (%):	NA	29.63	
Inter-Event Time since prior rain (hours)	≥ 6.0	56.58	

Table 24-3. February 21, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	110	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	27.5	The actual volumes of both samples were visually only about 16 liters
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	98.39	

Table 24-4. February 21, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	79	30	62.0	SM 2540D	1 mg/L	Stillbrook Lab
TSS	478	29	94.0	SM 2540D	1 mg/L	UA Lab
SSC	3780	22	99.4	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	6231	35	99.4	ASTM D3977-97B	1 mg/L	UA Lab
TDS	46	31	31.9	EPA 160.2	1 mg/L	UA Lab
VSS	42	10	77.1	SM 2540E	1 mg/L	UA Lab
Total N as N	0.8	0.5	37.5	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.4	20.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.10	0.11	-10.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	1.47	0.58	60.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.83	0.34	59.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.073	BDL	>93.2	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.008	BDL	>37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.006	BDL	>16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.059	0.019	67.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	11033	19736	-78.9	IDEXX Method	<1	UA Lab
E. Coli	26	20	21.6	IDEXX Method	<1	UA Lab
Enterococci	55	10	81.8	IDEXX Method	<1	UA Lab
pH	6.66	6.81	-2.3	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	22.40	9.15	59.2	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	53.9	35.2	34.7	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	8.5	8.0	5.9	SM 212/ EPA 170.1	5 °C	UA Lab

Table 24-5. February 21, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	3780	NA*	NA*	22	NA*	NA*	99.4	NA*	NA*
UA Lab	4478	1753	6231	31	4	35	99.3	99.8	99.4

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 24-6. February 21, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	26933	11073	195	20	7.2	1.8

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

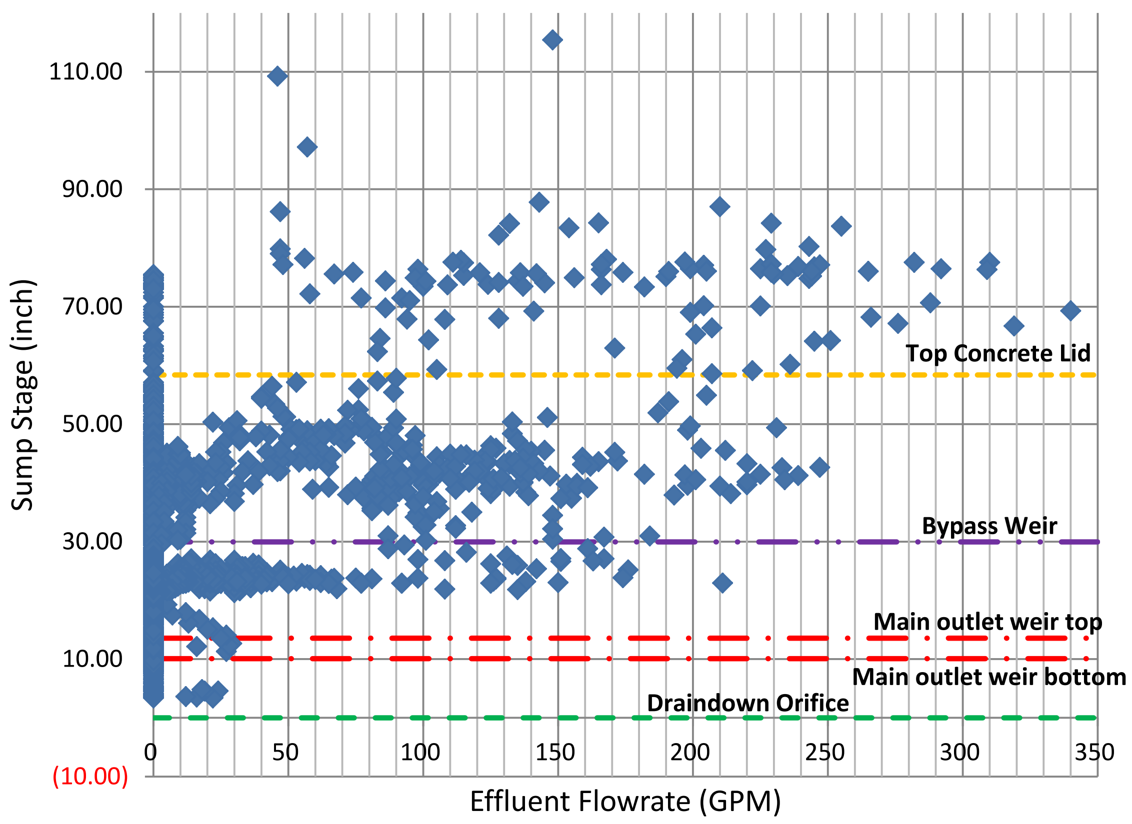
Table 24-7. February 21, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	463	493	478	30	27	29
Millipore Membrane Filter, 0.45µm	348	369	358	14	16	15

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 24-8. February 21, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	9804	12262	11,033	19863	19608	19,736
E. Coli	31	20	26	20	BDL	20
Enterococci	30	80	55	10	BDL	10

Table 24-9. February 21, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	39	44	42	11	8	10

Figure 24-2. February 21, 2013 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot



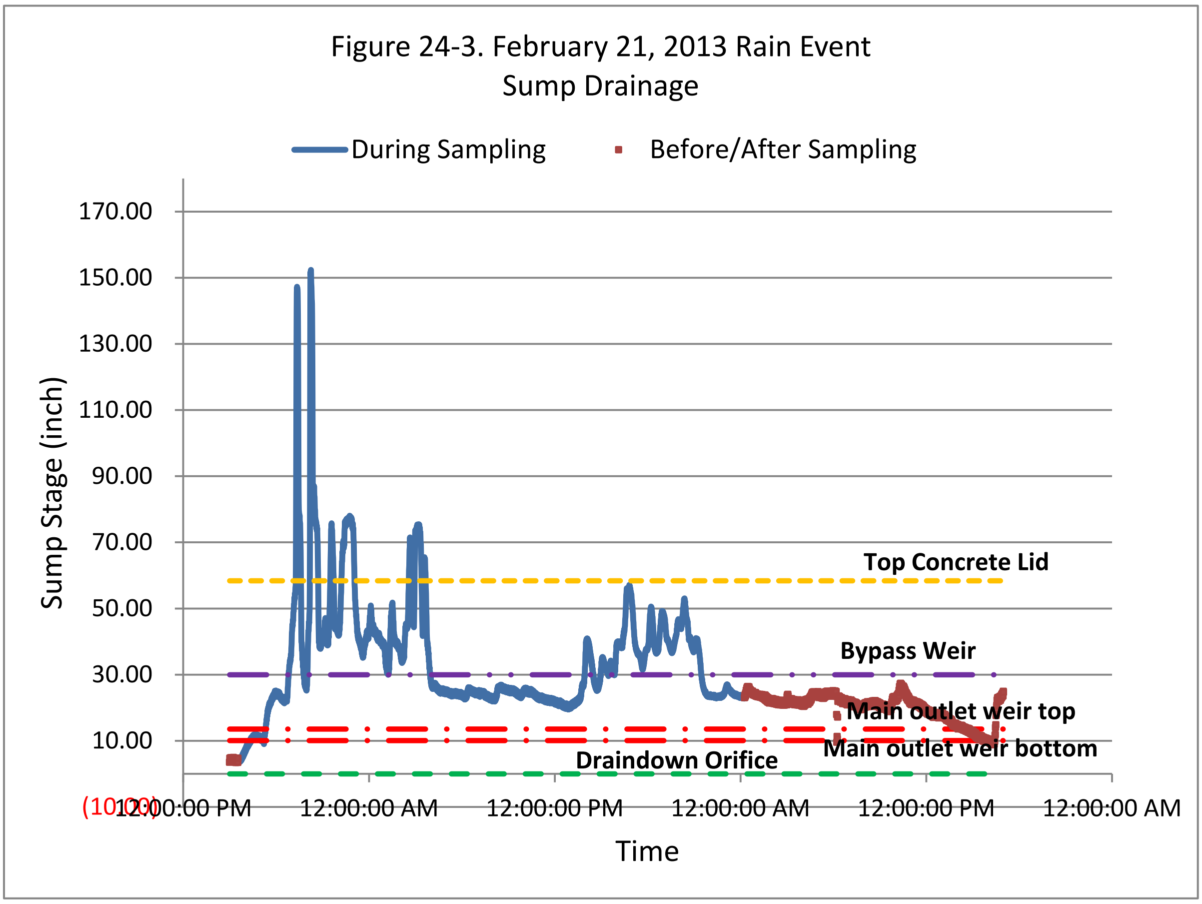


Figure 24-3. February 21, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Sump Stage (inch)
170.00
150.00
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
12:00:00 AM
12:00:00 PM
12:00:00 AM
12:00:00 PM
12:00:00 AM
Time

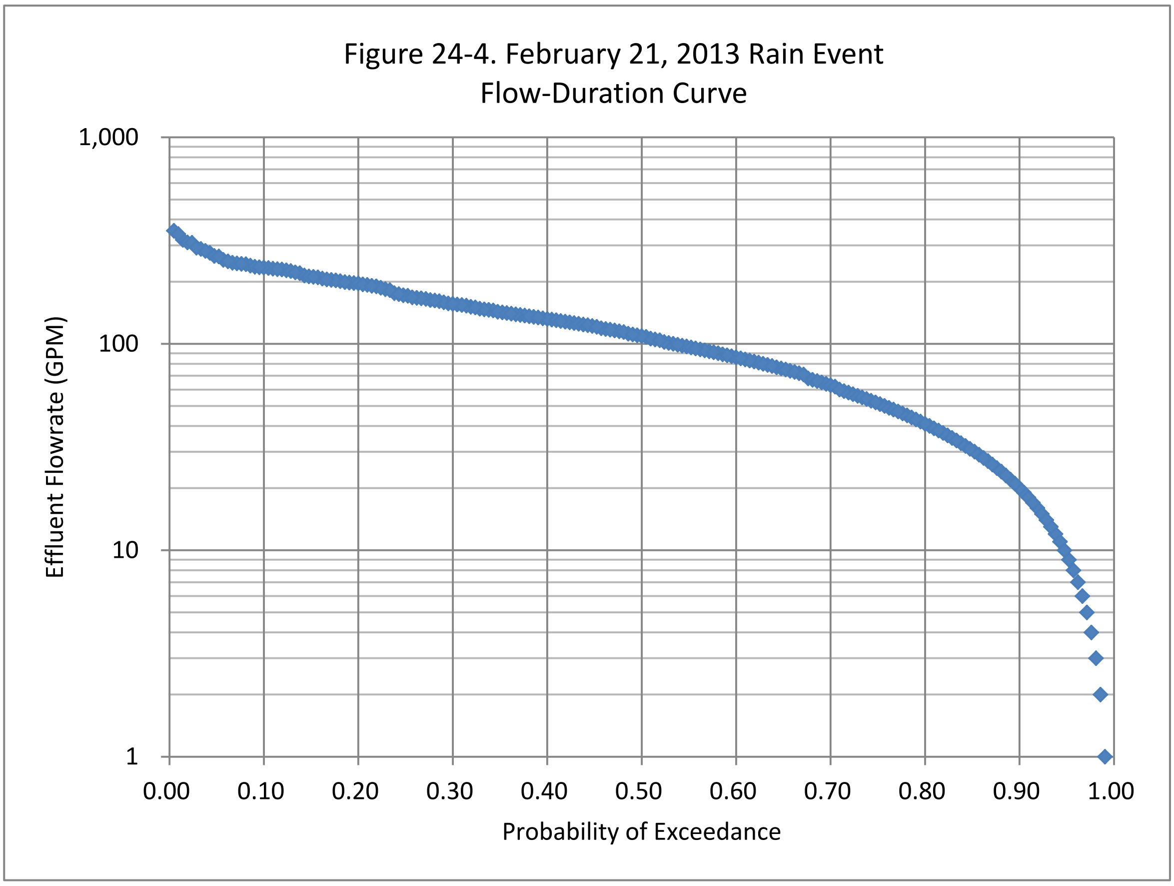
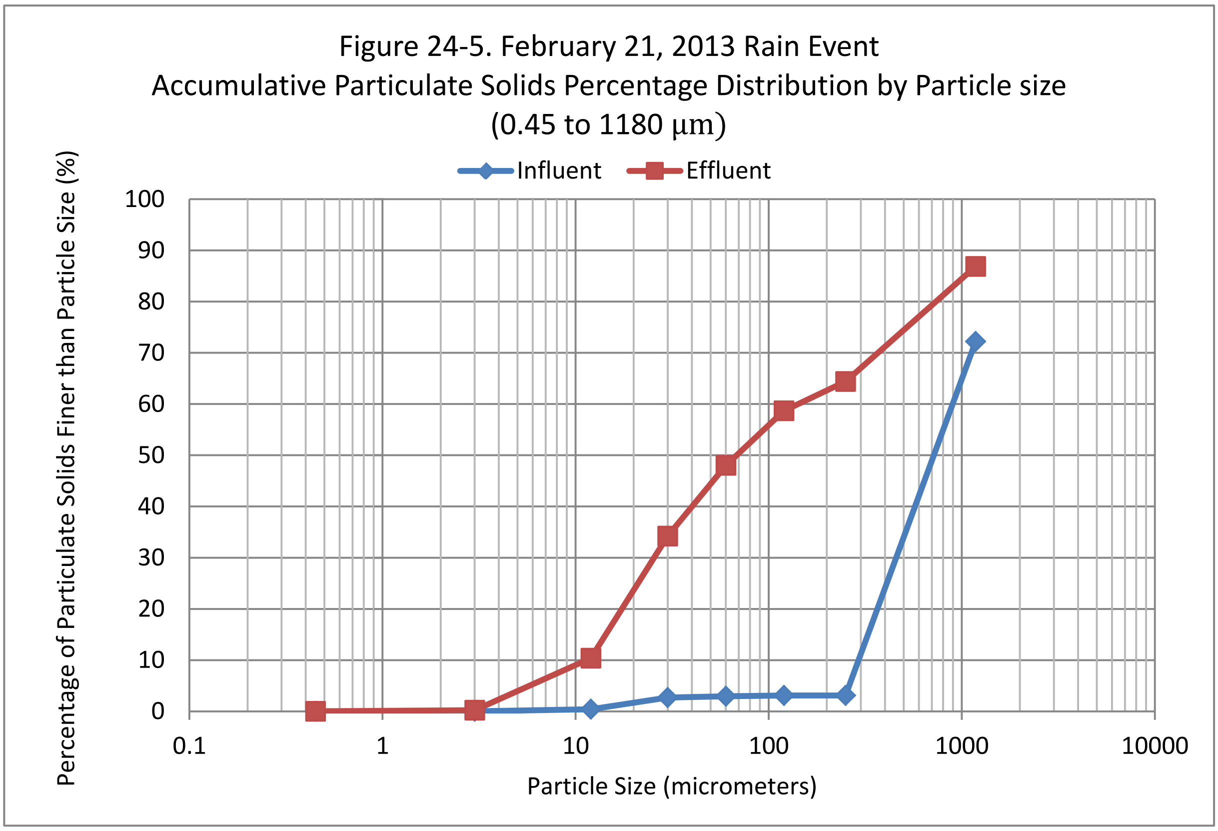
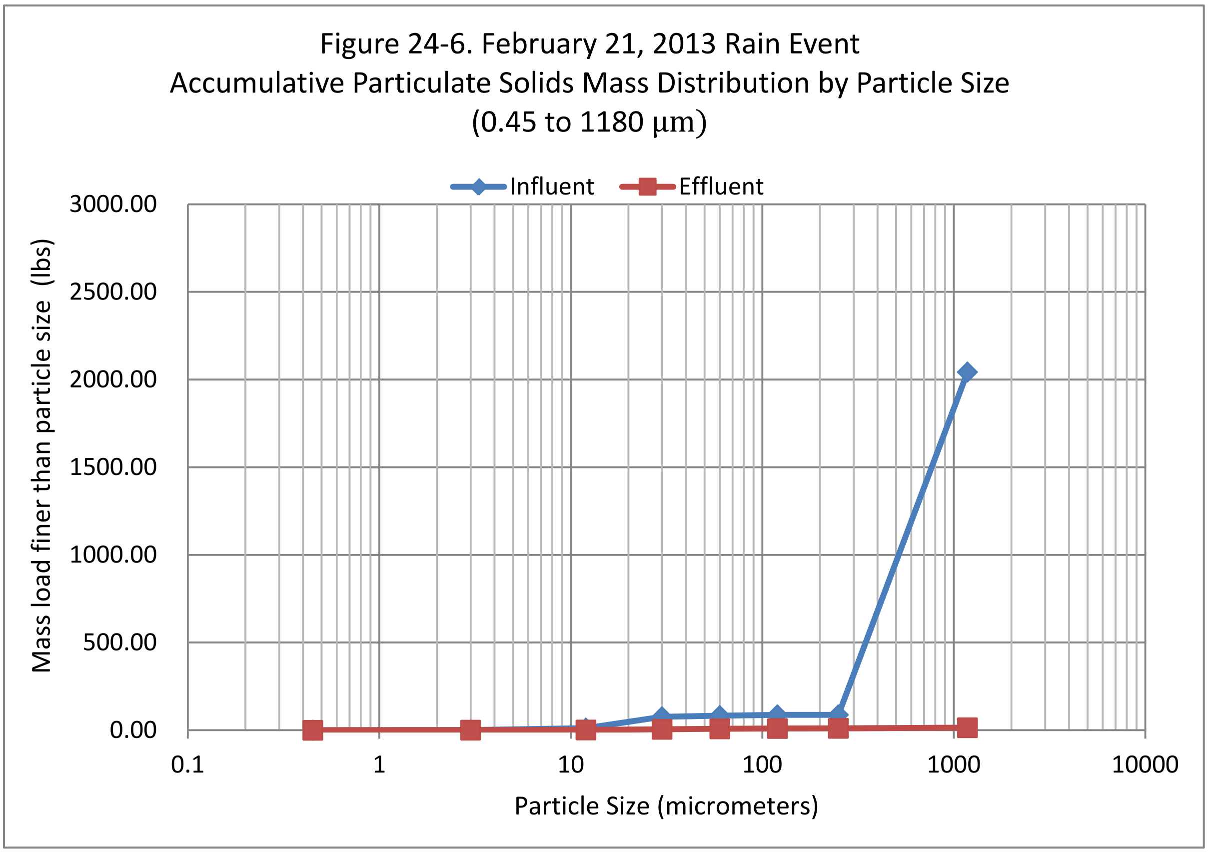


Figure 24-4. February 21, 2013 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 785.34 lbs larger than 1180 µm and the effluent had 2.10 lbs larger than 1180 µm (27.77% and 13.12% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 24-10. February 21, 2013 Rain Event Particle Size Distribution Information									
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.07	0.07	0.00	0.24	0.03	0.04	0.00	-13.37
3 to 12	26.01	3.19	0.41	10.16	11.65	1.63	10.03	86.04
12 to 30	143.55	7.48	2.28	23.83	64.33	3.82	60.51	94.07
30 to 60	15.59	4.34	0.25	13.81	6.99	2.21	4.78	68.36
60 to 120	10.11	3.35	0.16	10.66	4.53	1.71	2.82	62.33
120 to 250	0.00	1.79	0.00	5.70	0.00	0.91	-0.91	#DIV/0!
250 to 1180	4361.91	7.06	69.13	22.49	1954.66	3.60	1951.06	99.82
>1180	1752.52	4.12	27.77	13.12	785.34	2.10	783.24	99.73
Total	6310	31	100.00	100.00	2827.54	16.01	2811.52	99.43

Table 24-11. February 21, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.00	0.24	0.03	0.04
<12	0.41	10.39	11.69	1.66
<30	2.69	34.22	76.02	5.48
<60	2.94	48.03	83.00	7.69
<120	3.10	58.69	87.54	9.40
<250	3.10	64.39	87.54	10.31
<1180	72.23	86.88	2042.20	13.91
>1180	100.00	100.00	2827.54	16.01

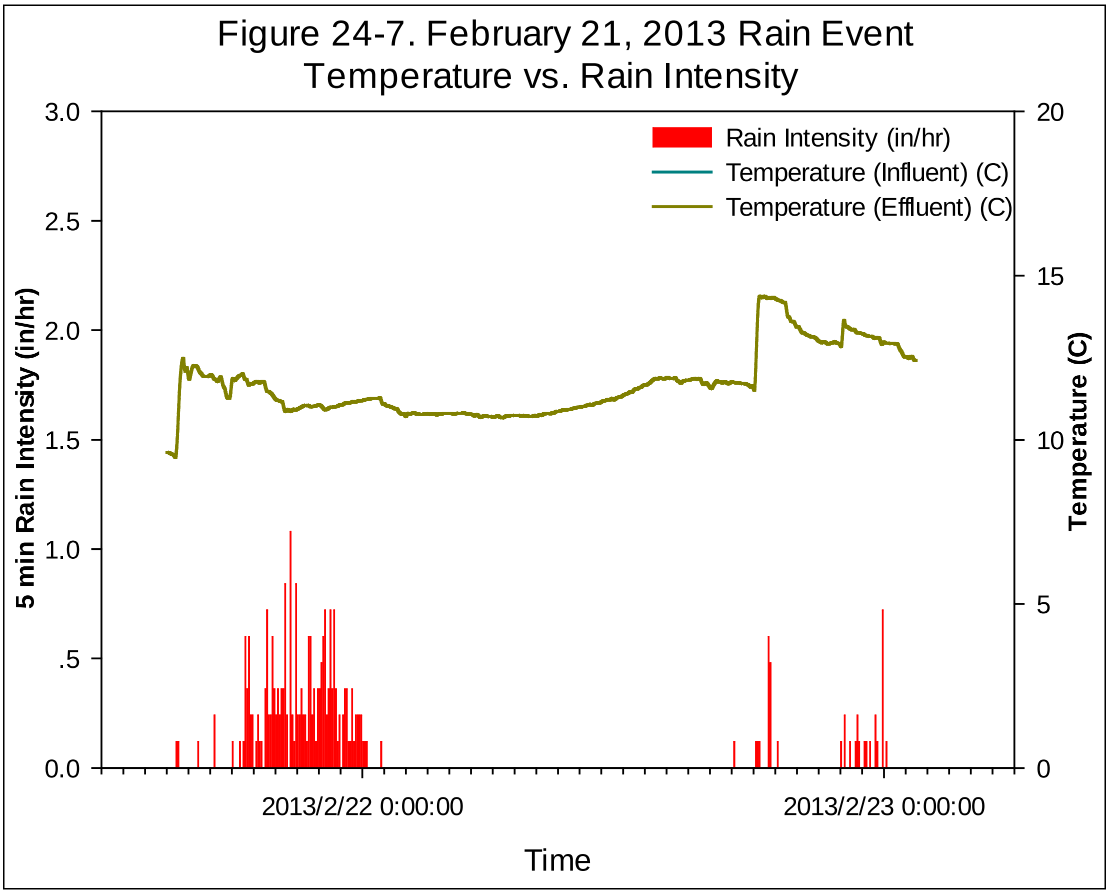


Figure 24-7. February 21, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
2013/2/22 0:00:00
2013/2/23 0:00:00
Time

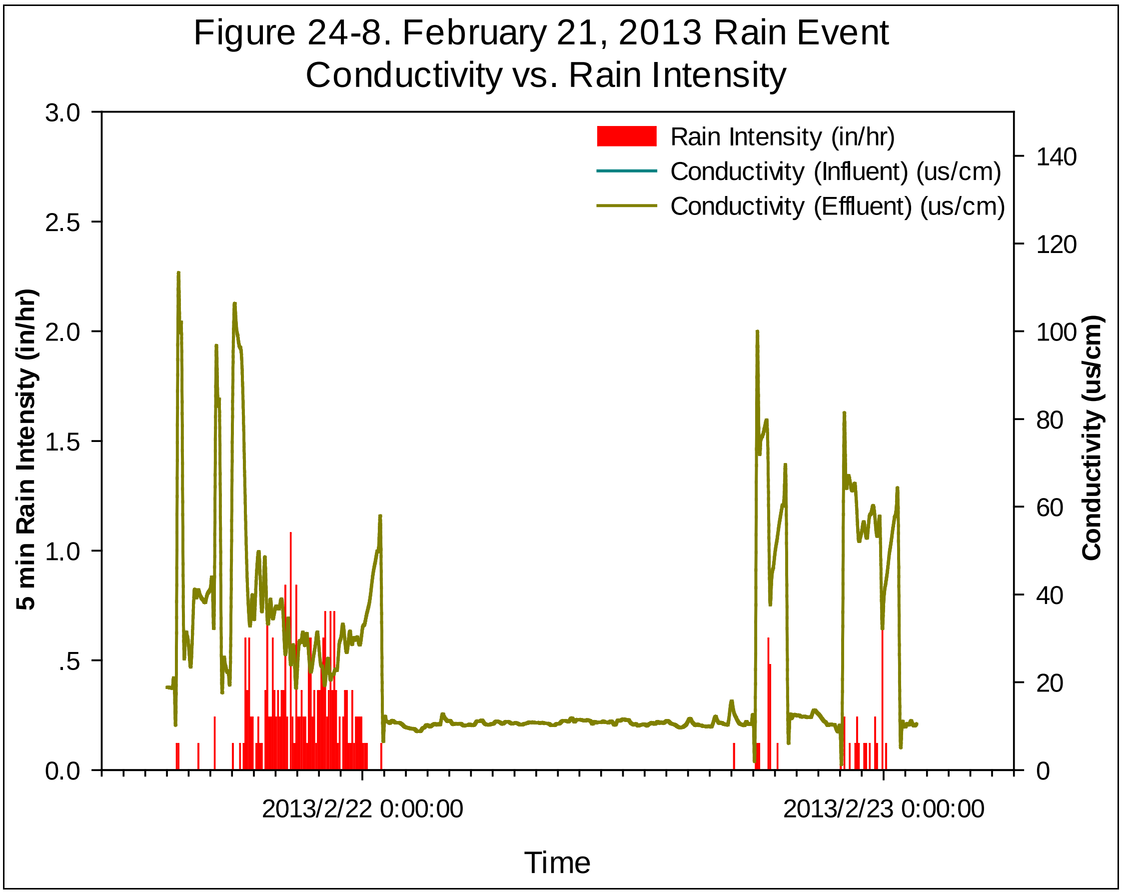


Figure 24-8. February 21, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
140
120
100
80
60
40
20
0
2013/2/22 0:00:00
2013/2/23 0:00:00
Time

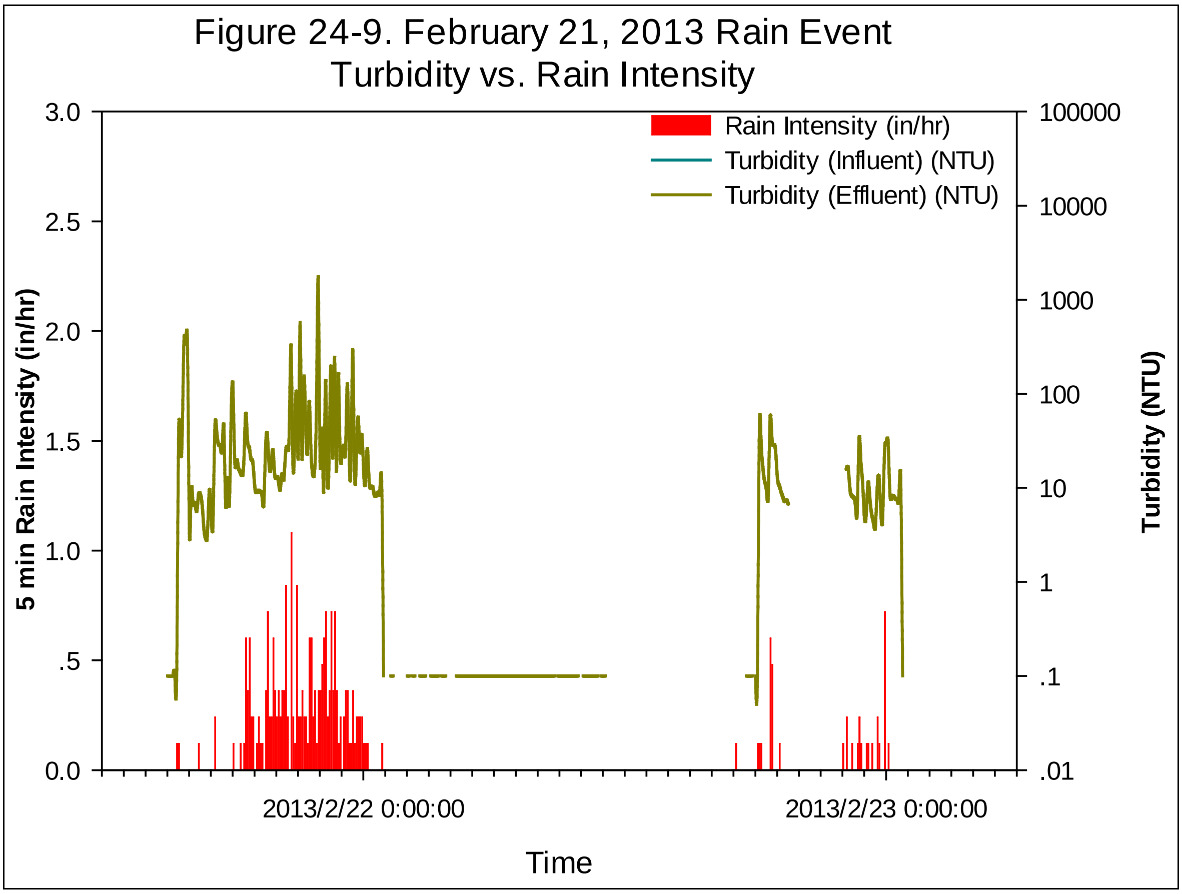
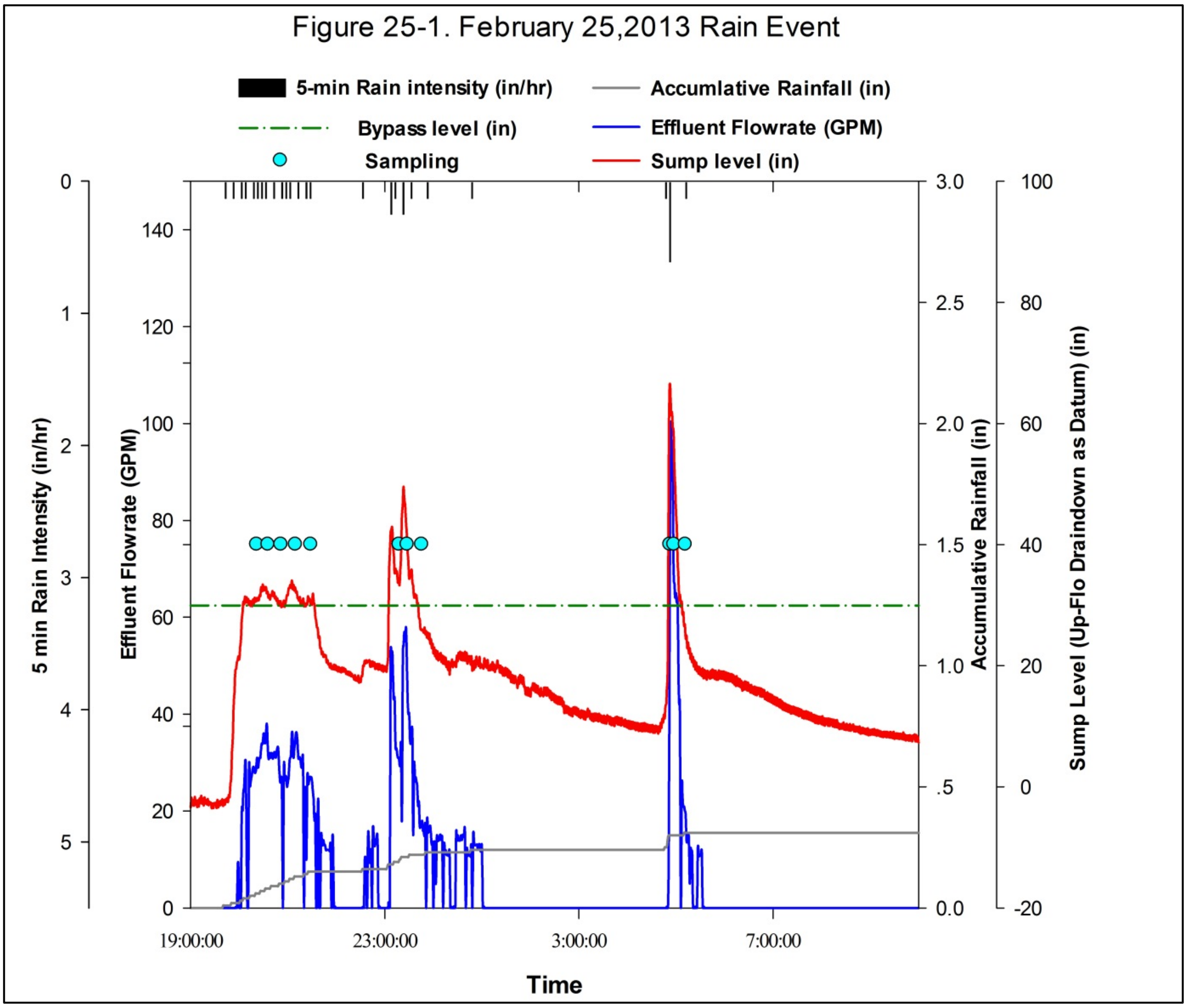


Figure 24-9. February 21, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
2013/2/22 0:00:00
2013/2/23 0:00:00
Time

Appendix F.25: February 25, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 15.81 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 25-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.41
Volumetric Runoff Coefficient (Rv)	0.85

Table 25-2. February 25, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/2/25 19:40
Rain Event End Date/Time:			2013/2/26 5:10
Total Precipitation (inch):	≥ 0.1	0.31	
Total Runoff Depth (inch):	NA	0.26	
Total Outflow (gallon):	NA	6432	
Rain Duration (hours):	≥ 1	9.50	
Flow Start Date/Time:			2013/2/25 19:58
Flow End Date/Time:			2013/2/26 5:33
Flow Duration (hours):	NA	9.58	
Average Rain Intensity (in/hr):	NA	0.03	
Average Runoff Rate (gallons/min):	NA	11	
Peak 5-min Rain Intensity (in/hr):	NA	0.60	
Peak Runoff Rate (gallons/min):	NA	98	
Peak to Average Runoff Ratio:	NA	8.76	
Bypassed flow volume (gallon):	NA	1341	
Percentage of Bypassed Flow (%):	NA	20.86	
Inter-Event Time since prior rain (hours)	≥ 6.0	64.43	

Table 25-3. February 25, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	11	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	2.8	The actual volumes of both samples were visually consistent with the programmed one
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	90.44	

Table 25-4. February 25, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	35	15	57.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	210	4	98.1	SM 2540D	1 mg/L	UA Lab
SSC	307	11	96.4	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	524	8	98.4	ASTM D3977-97B	1 mg/L	UA Lab
TDS	80	57	28.8	EPA 160.2	1 mg/L	UA Lab
VSS	33	2	93.9	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.4	0.4	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.11	0.14	-27.3	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.64	0.49	23.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.46	0.31	32.6	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.023	0.014	39.1	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.005	BDL	>0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	22560	3476	84.6	IDEXX Method	<1	UA Lab
E. Coli	BDL	BDL	NA	IDEXX Method	<1	UA Lab
Enterococci	125	20	84.0	IDEXX Method	<1	UA Lab
pH	6.79	6.82	-0.4	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	6.21	3.61	41.9	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	59.3	49.4	16.7	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	9.0	8.3	7.8	SM 212/ EPA 170.1	5 °C	UA Lab

Table 25-5. February 25, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	307	NA*	NA*	11	NA*	NA*	96.4	NA*	NA*
UA Lab	354	169	524	7	2	8	98.1	98.9	98.4

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 25-6. February 25, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	13967	8164	74	4	5.3	0.5

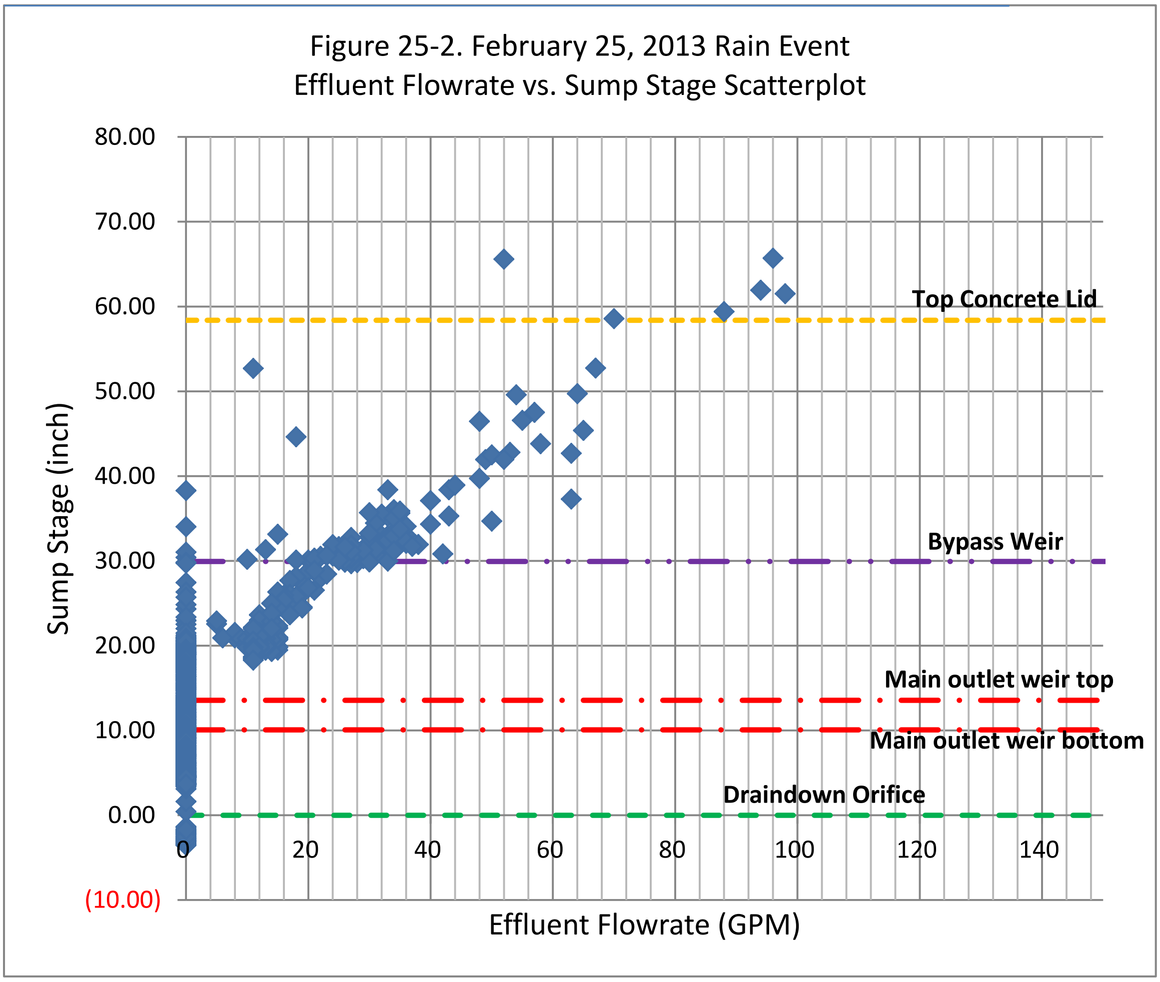
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 25-7. February 25, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	192	228	210	2	6	4
Millipore Membrane Filter, 0.45µm	106	116	111	BDL	BDL	BDL

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 25-8. February 25, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	24196	20924	22,560	4286	2666	3,476
E. Coli	BDL	BDL	BDL	BDL	BDL	BDL
Enterococci	104	146	125	20	BDL	20

Table 25-9. February 25, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	34	32	33	2	2	2



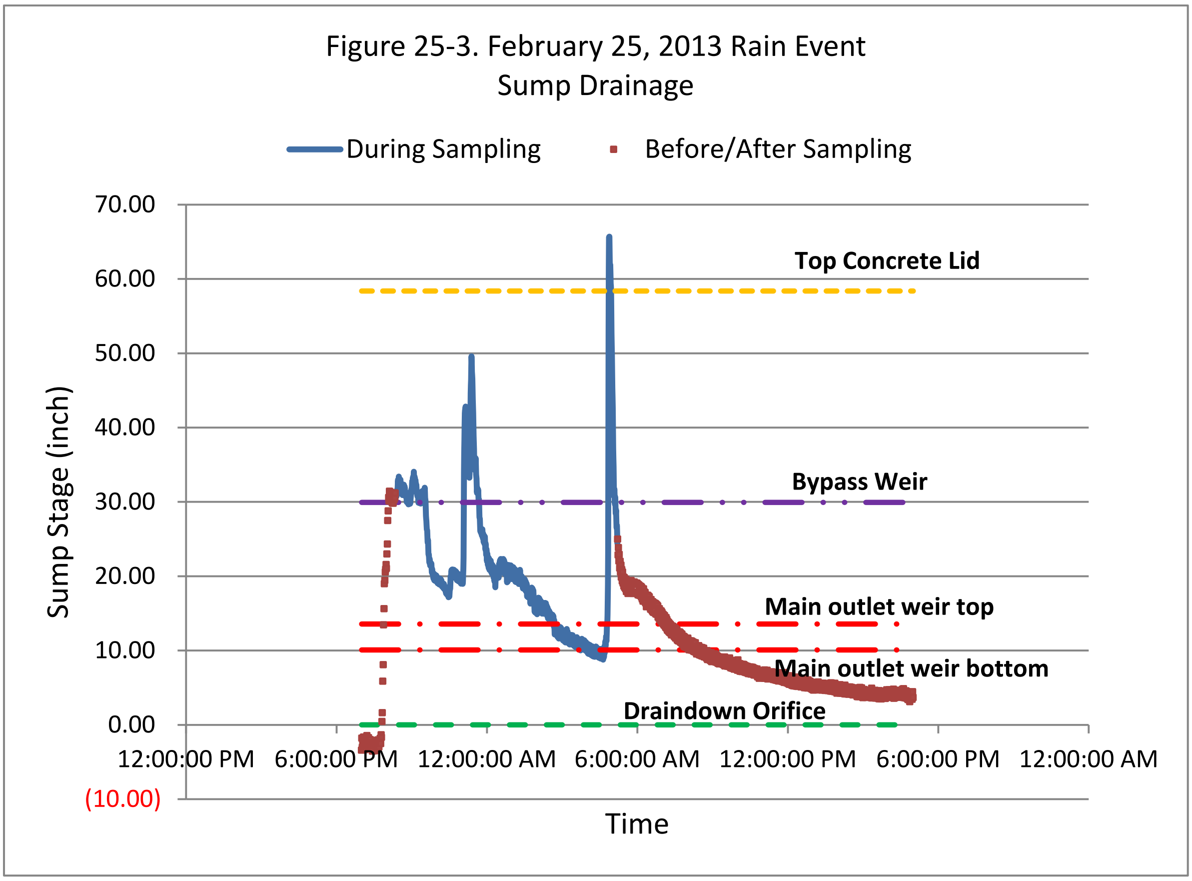


Figure 25-3. February 25, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
Sump Stage (inch)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(10.00)
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
12:00:00 AM
Time

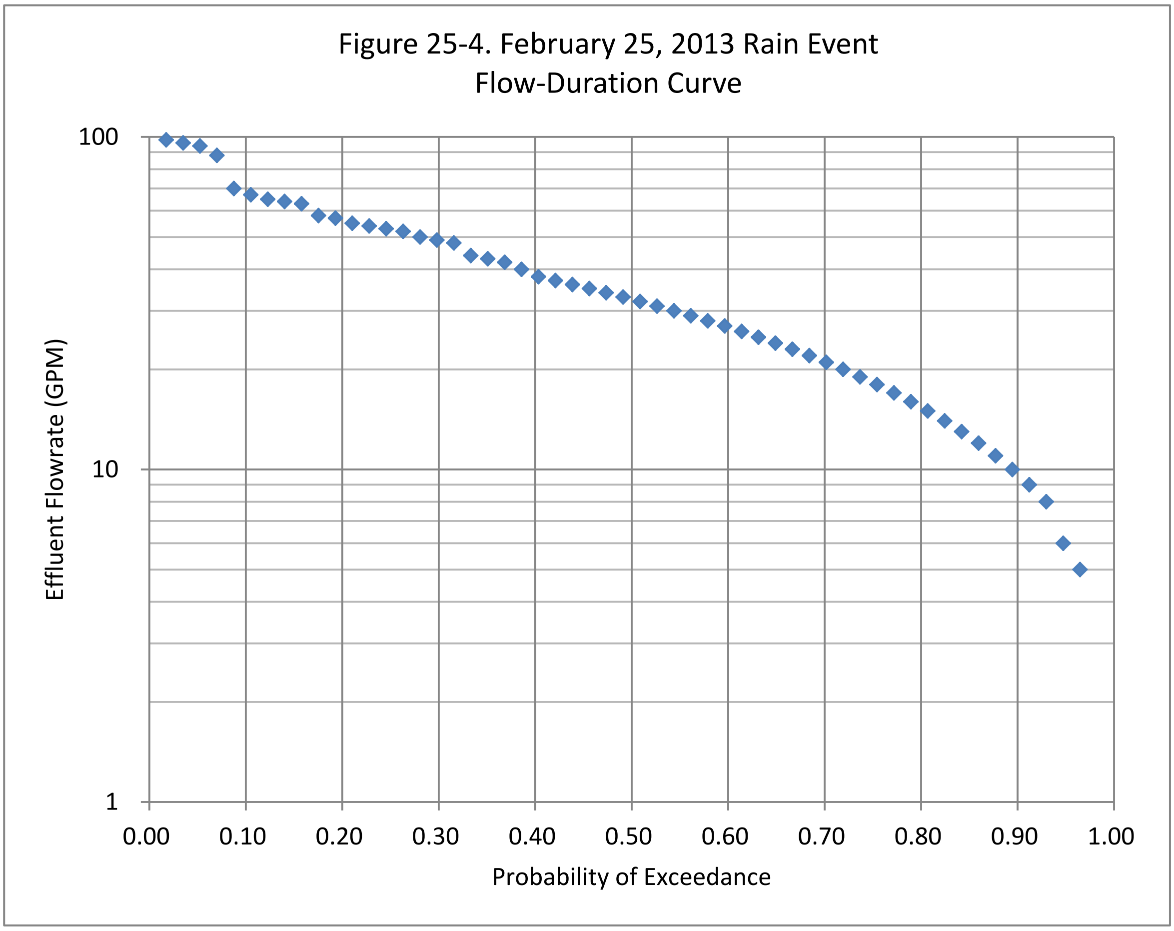
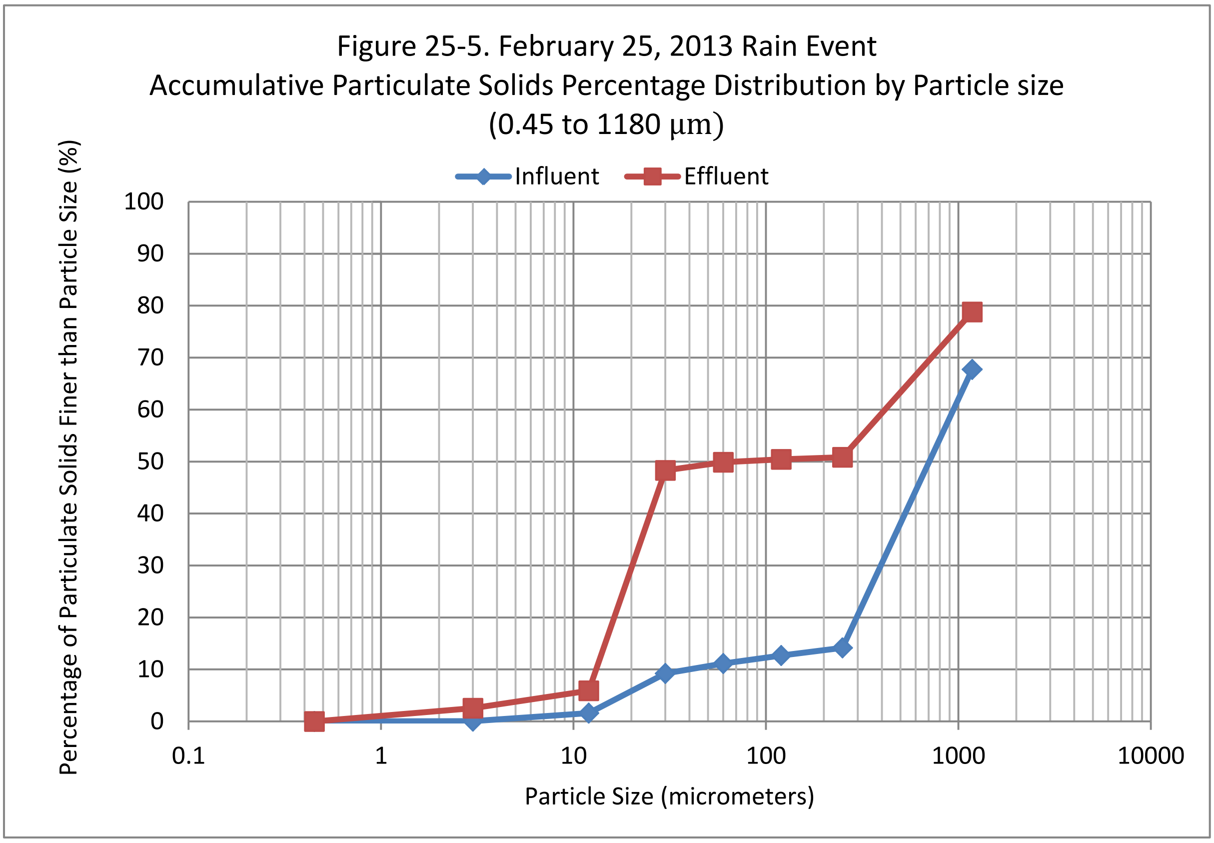
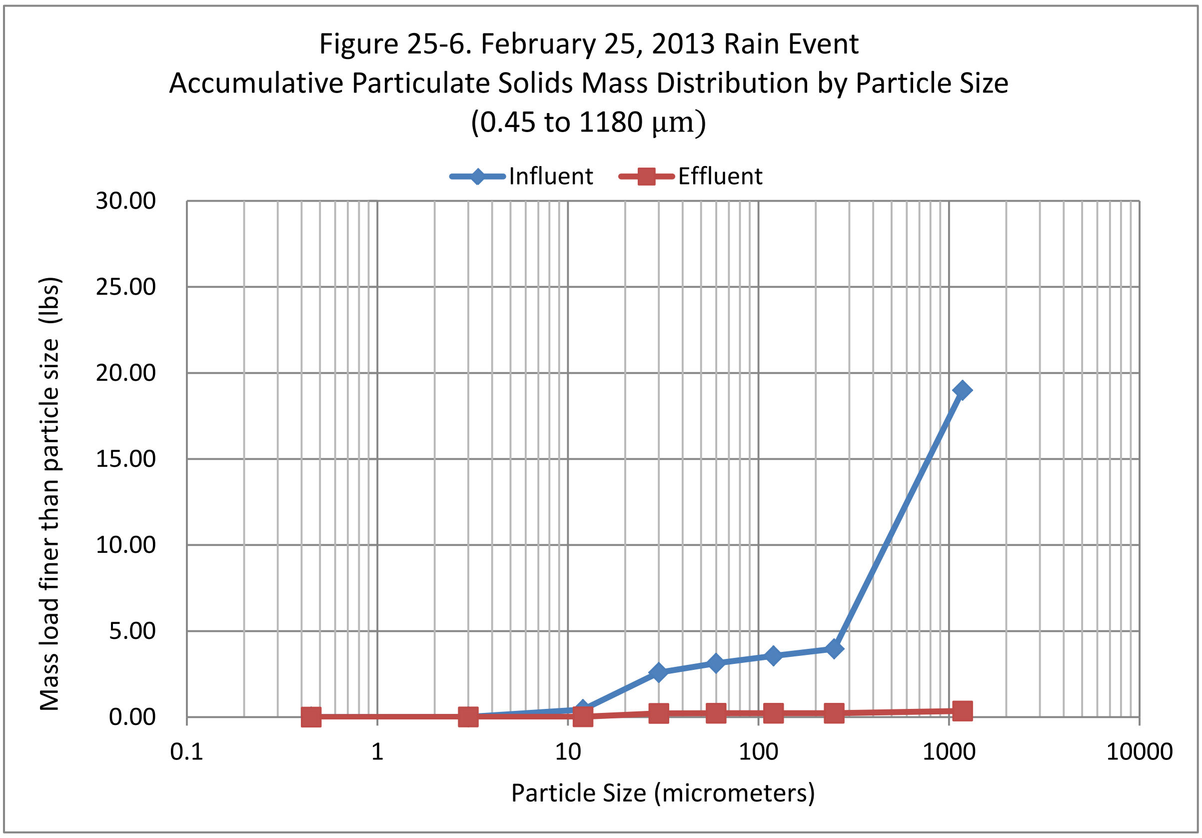


Figure 25-4. February 25, 2013 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 9.05 lbs larger than 1180 μm and the effluent had 0.10 lbs larger than 1180 μm (32.27% and 21.20% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 25-10. February 25, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.26	0.22	0.05	2.54	0.01	0.01	0.00	19.17
3 to 12	8.06	0.29	1.54	3.36	0.43	0.02	0.42	96.49
12 to 30	40.03	3.66	7.64	42.40	2.14	0.19	1.95	91.09
30 to 60	10.06	0.14	1.92	1.58	0.54	0.01	0.53	98.68
60 to 120	7.98	0.05	1.52	0.55	0.43	0.00	0.42	99.42
120 to 250	7.68	0.03	1.47	0.40	0.41	0.00	0.41	99.56
250 to 1180	280.69	2.41	53.59	27.96	15.03	0.13	14.90	99.16
>1180	169.01	1.83	32.27	21.20	9.05	0.10	8.95	98.94
Total	524	9	100.00	100.00	28.04	0.45	27.59	98.39

Table 25-11. February 25, 2013 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.05	2.54	0.01	0.01
<12	1.59	5.91	0.45	0.03
<30	9.23	48.31	2.59	0.22
<60	11.15	49.89	3.13	0.22
<120	12.68	50.44	3.55	0.23
<250	14.14	50.84	3.97	0.23
<1180	67.73	78.80	18.99	0.35
>1180	100.00	100.00	28.04	0.45

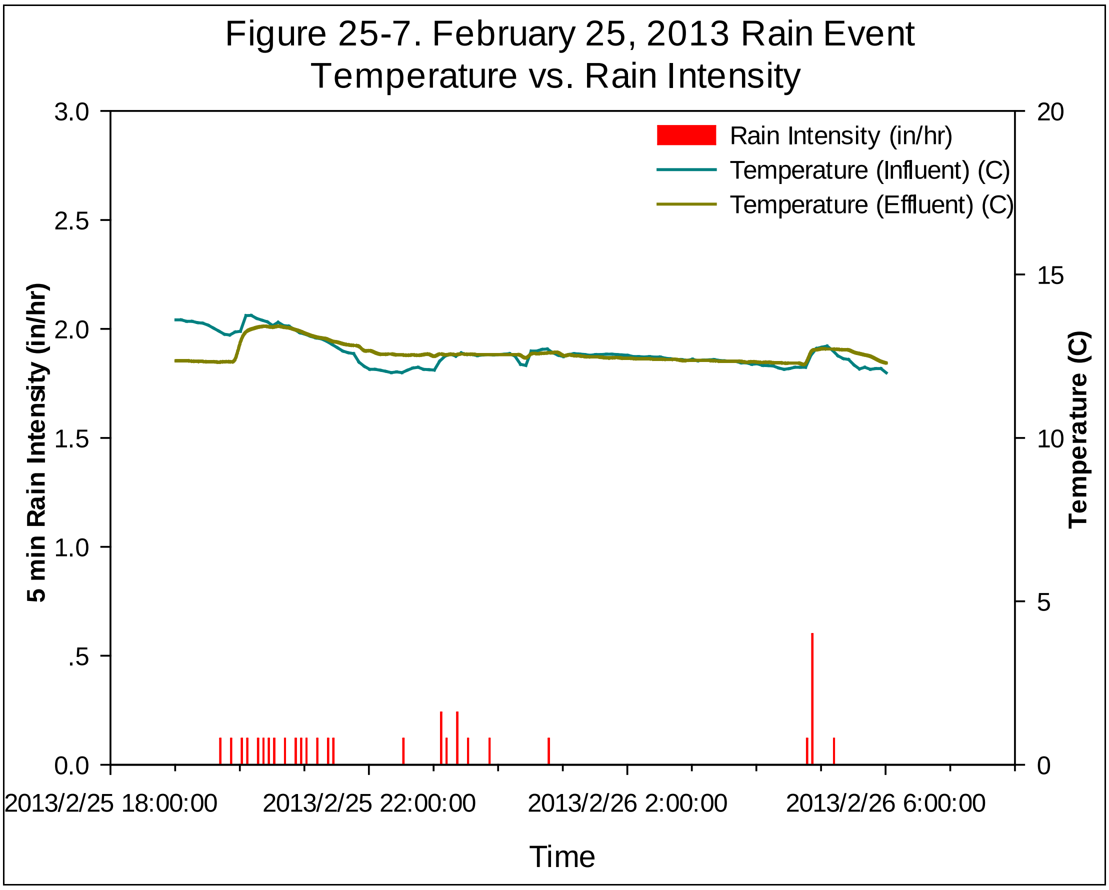


Figure 25-7. February 25, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
2013/2/25 18:00:00
2013/2/25 22:00:00
2013/2/26 2:00:00
2013/2/26 6:00:00
Time

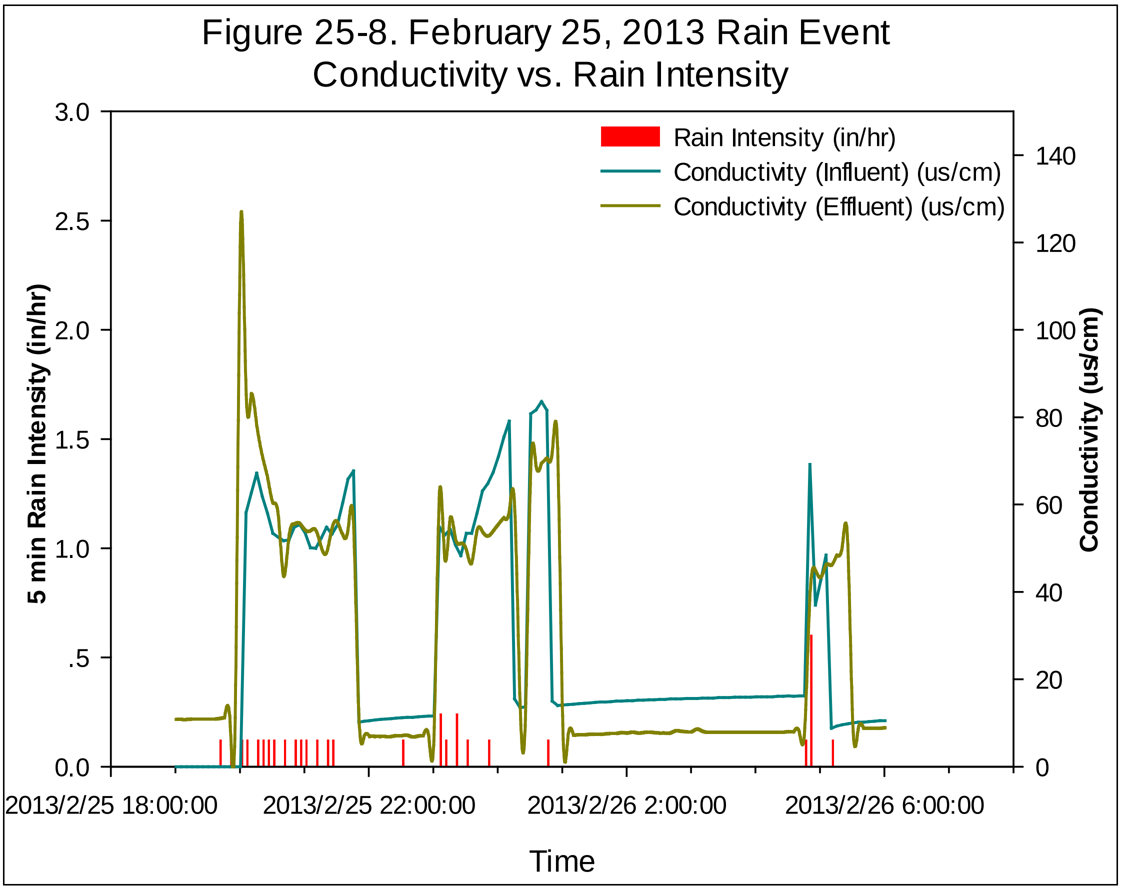


Figure 25-8. February 25, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
140
120
100
80
60
40
20
0
2013/2/25 18:00:00
2013/2/25 22:00:00
2013/2/26 2:00:00
2013/2/26 6:00:00
Time

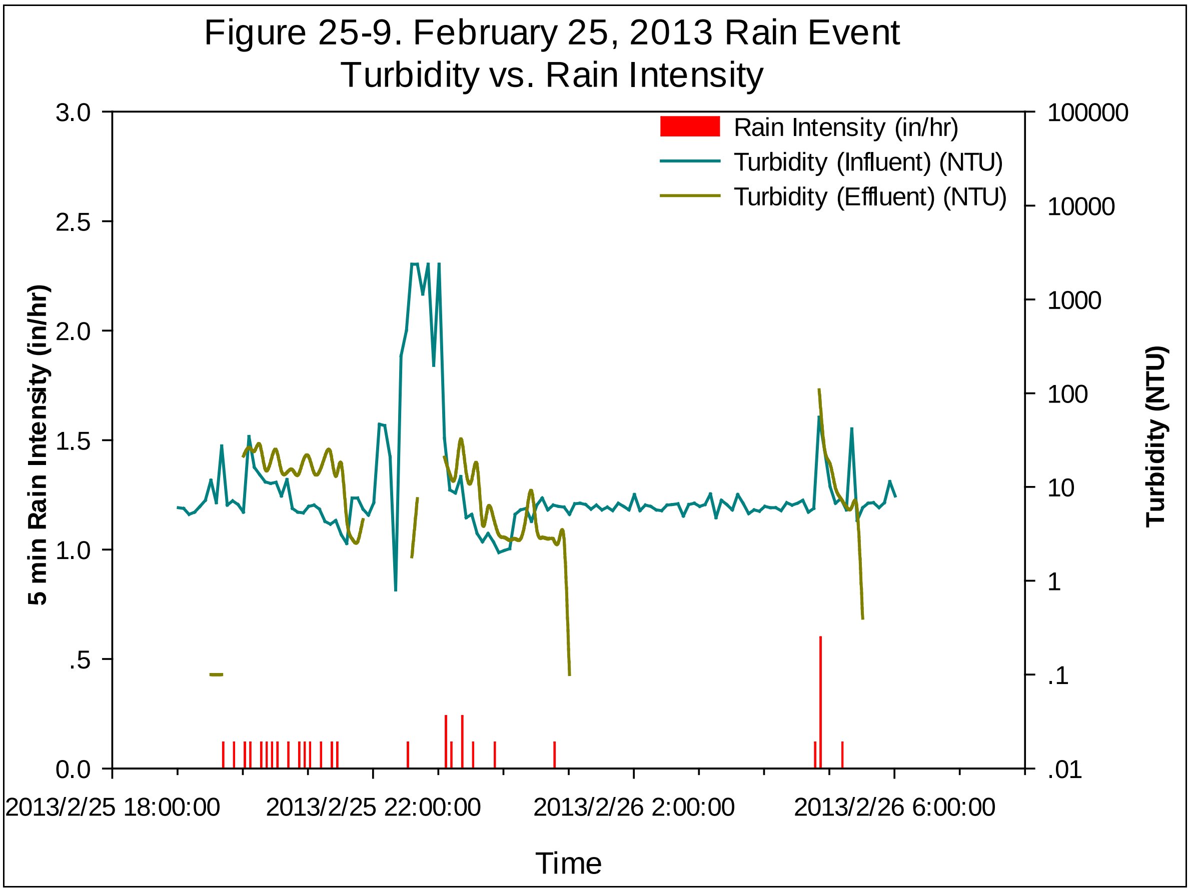
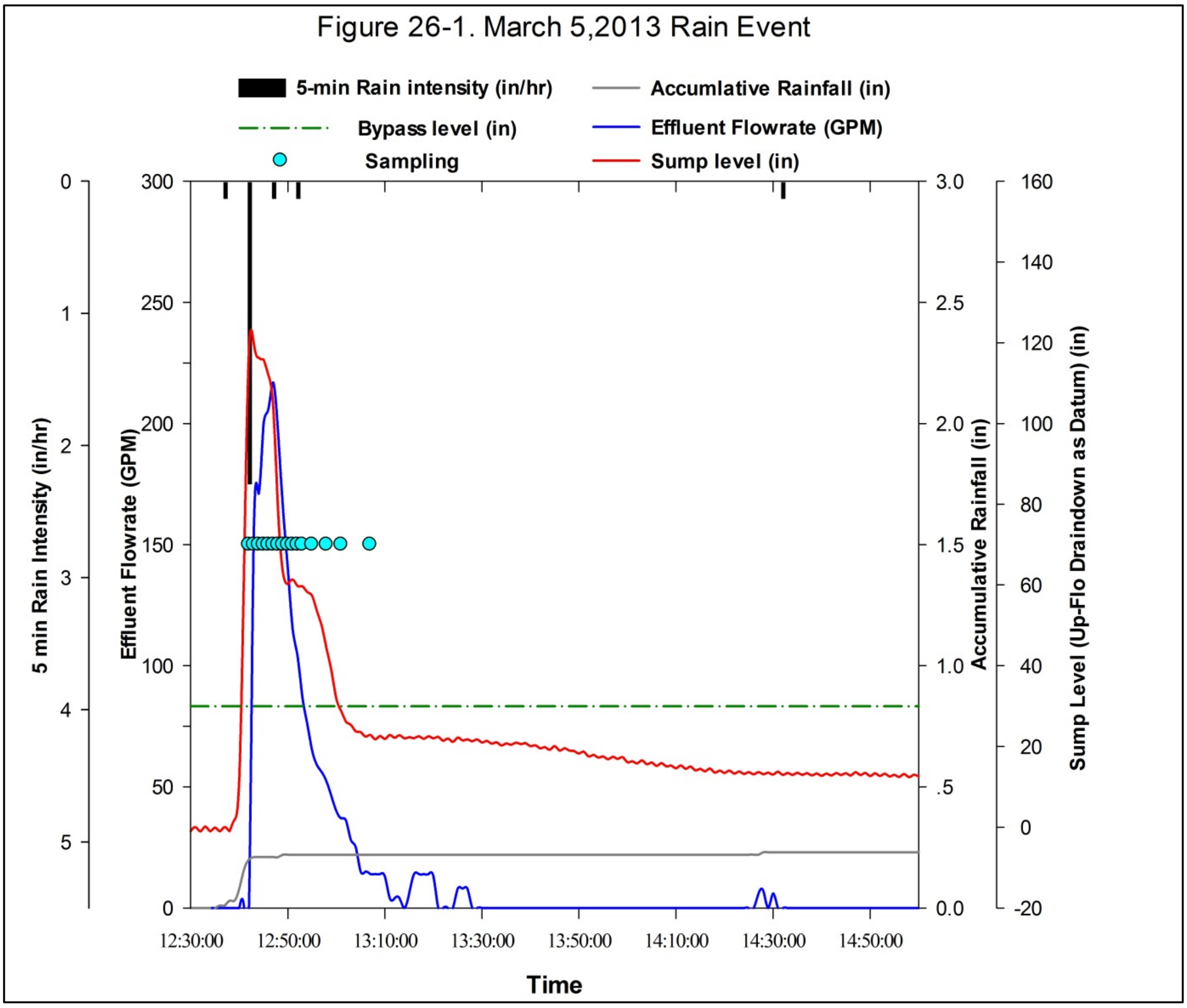


Figure 25-9. February 25, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
2013/2/25 18:00:00
2013/2/25 22:00:00
2013/2/26 2:00:00
2013/2/26 6:00:00
Time

Appendix F.26: March 5, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 11.47 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 26-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.24
Volumetric Runoff Coefficient (Rv)	0.47

Table 26-2. March 5, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/3/5 12:36
Rain Event End Date/Time:			2013/3/5 14:28
Total Precipitation (inch):	≥ 0.1	0.23	
Total Runoff Depth (inch):	NA	0.11	
Total Outflow (gallon):	NA	2492	
Rain Duration (hours):	≥ 1	1.87	
Flow Start Date/Time:			2013/3/5 12:43
Flow End Date/Time:			2013/3/5 14:31
Flow Duration (hours):	NA	1.80	
Average Rain Intensity (in/hr):	NA	0.12	
Average Runoff Rate (gallons/min):	NA	23	
Peak 5-min Rain Intensity (in/hr):	NA	2.28	
Peak Runoff Rate (gallons/min):	NA	217	
Peak to Average Runoff Ratio:	NA	9.40	
Bypassed flow volume (gallon):	NA	1485	
Percentage of Bypassed Flow (%):	NA	59.59	
Inter-Event Time since prior rain (hours)	≥ 6.0	175.43	

Table 26-3. March 5, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	19	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	4.8	The actual volumes of both samples were visually consistent with the programmed one
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	93.14	

Table 26-4. March 5, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	35	22	37.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	197	56	71.6	SM 2540D	1 mg/L	UA Lab
SSC	43	25	41.9	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	495	68	86.3	ASTM D3977-97B	1 mg/L	UA Lab
TDS	76	71	6.6	EPA 160.2	1 mg/L	UA Lab
VSS	57	22	61.4	SM 2540E	1 mg/L	UA Lab
Total N as N	0.9	0.9	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.6	0.7	-16.7	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.24	0.28	-16.7	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.55	0.43	21.8	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.43	0.25	41.9	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.025	BDL	>80.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.008	BDL	>37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.008	BDL	>37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.042	0.035	16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.006	0.008	-33.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	>48392	NA	IDEXX Method	<1	UA Lab
E. Coli	31	113	-270.5	IDEXX Method	<1	UA Lab
Enterococci	96	148	-54.5	IDEXX Method	<1	UA Lab
pH	6.77	6.75	0.3	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	77.30	33.15	57.1	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	63.6	45.8	28.0	SM 2510B/ EPA 120.6	0 µS	UA Lab

Temperature	10.0	9.2	8.0	SM 212/ EPA 170.1	5 °C	UA Lab

Table 26-5. March 5, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	43	NA*	NA*	25	NA*	NA*	41.9	NA*	NA*
UA Lab	276	219	495	50	18	68	81.9	91.9	86.3

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 26-6. March 5, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	32279	23140	74	42	2.3	1.8

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 26-7. February 25, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	204	190	197	50	62	56
Millipore Membrane Filter, 0.45µm	172	174	173	62	56	59

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 26-8. March 5, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	>48392	>48392
E. Coli	41	20	31	144	82	113
Enterococci	109	82	96	145	150	148

Table 26-9. March 5, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5μm	62	52	57	20	24	22

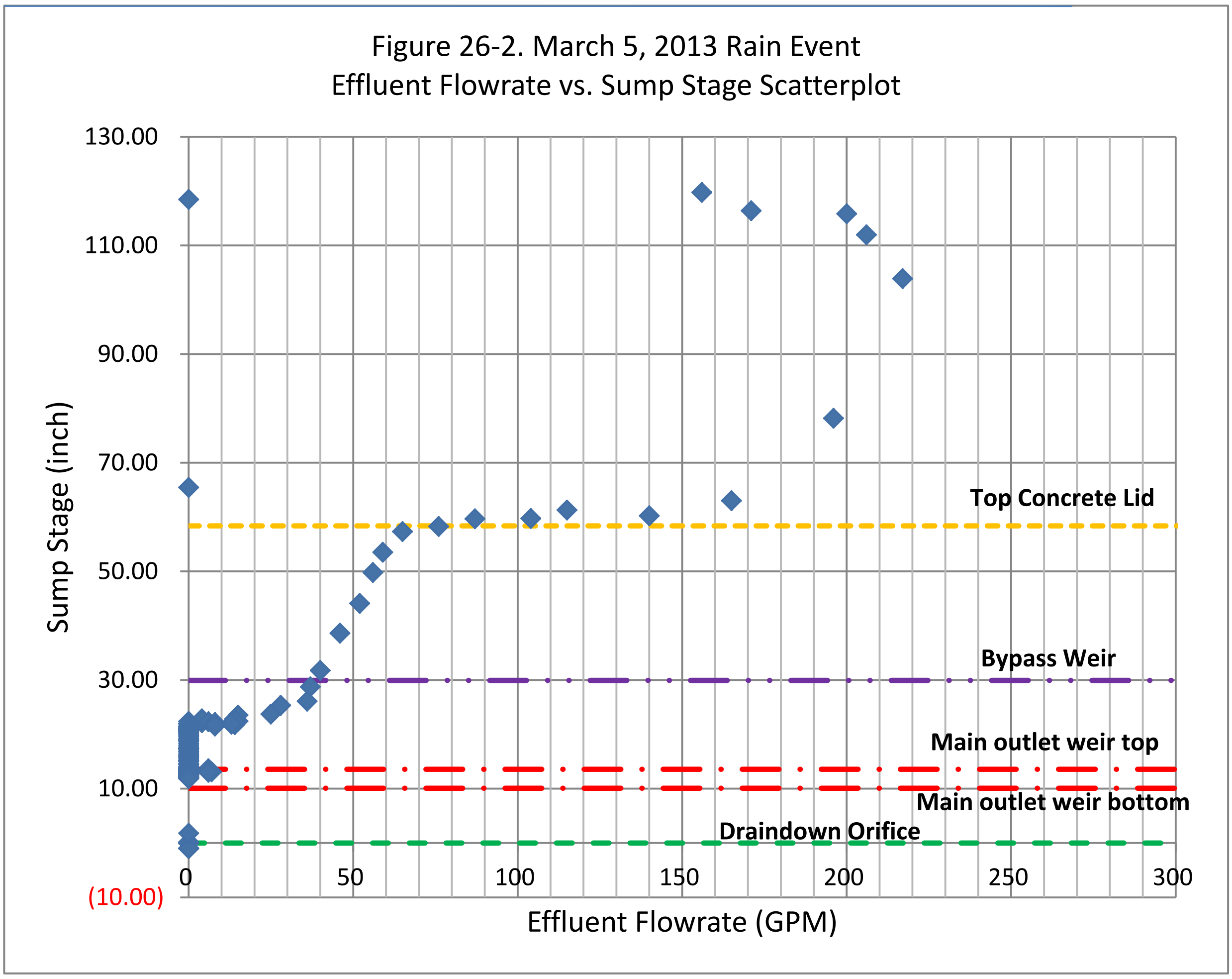


Figure 26-2. March 5, 2013 Rain Event
Effluent Flowrate vs. Sump Stage Scatterplot
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Sump Stage (inch)
0
50
100
150
200
250
300
Effluent Flowrate (GPM)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice

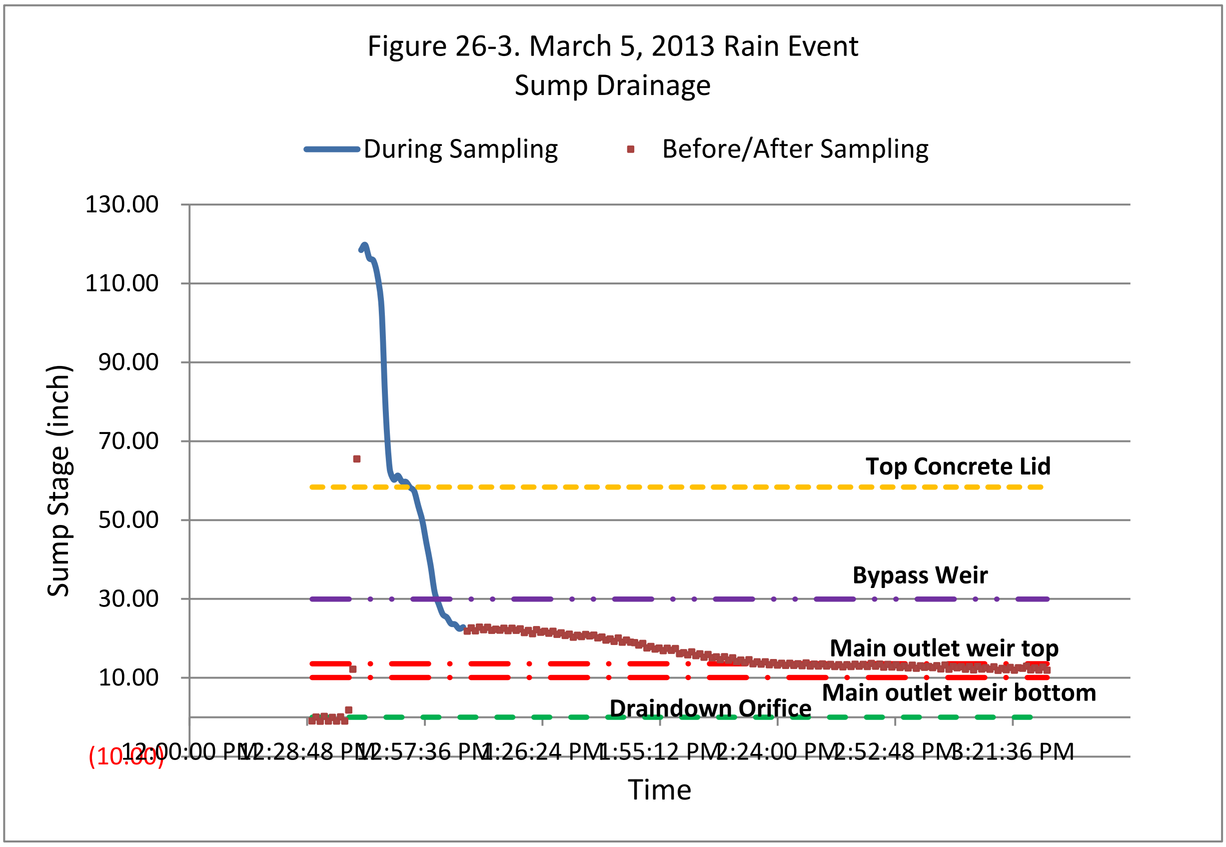


Figure 26-3. March 5, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
12:28:48 PM
12:57:36 PM
1:26:24 PM
1:55:12 PM
2:24:00 PM
2:52:48 PM
3:21:36 PM
Time

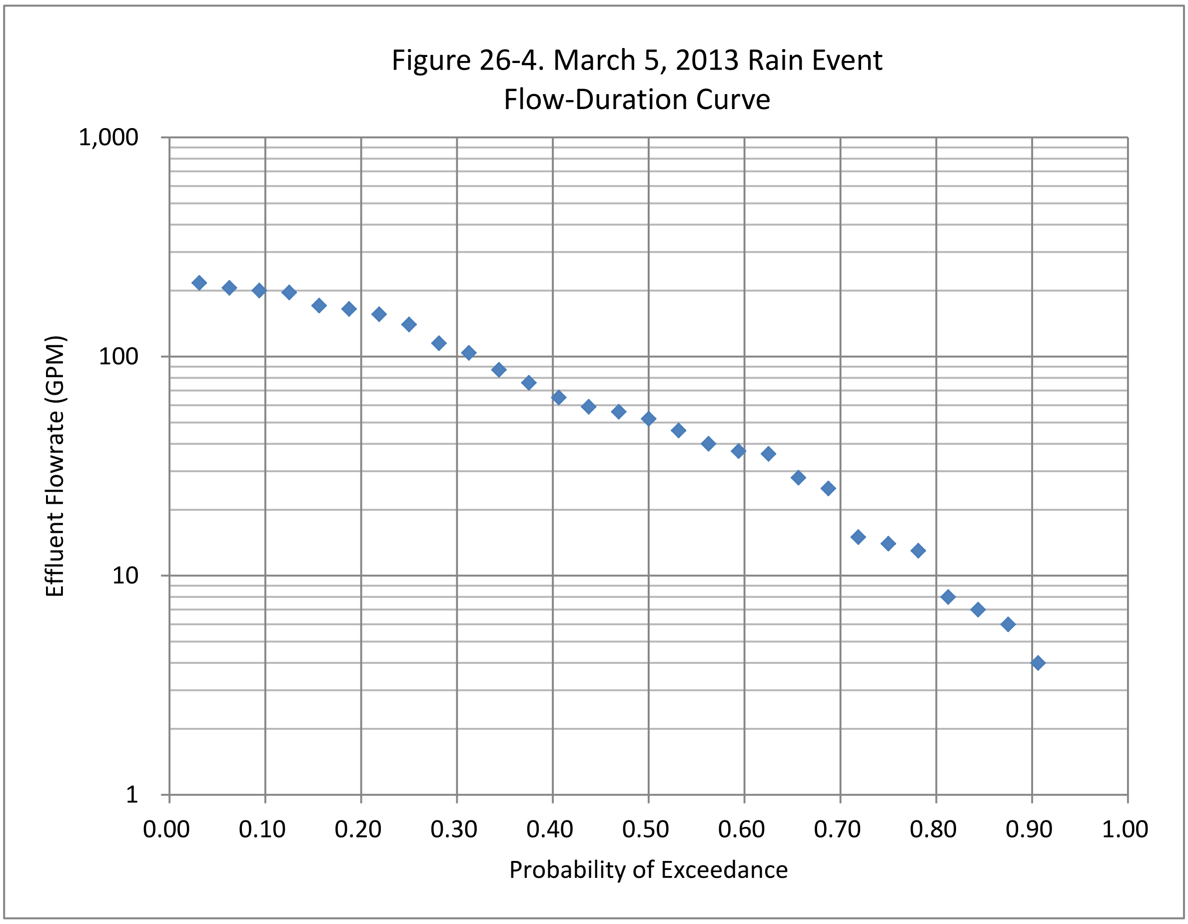
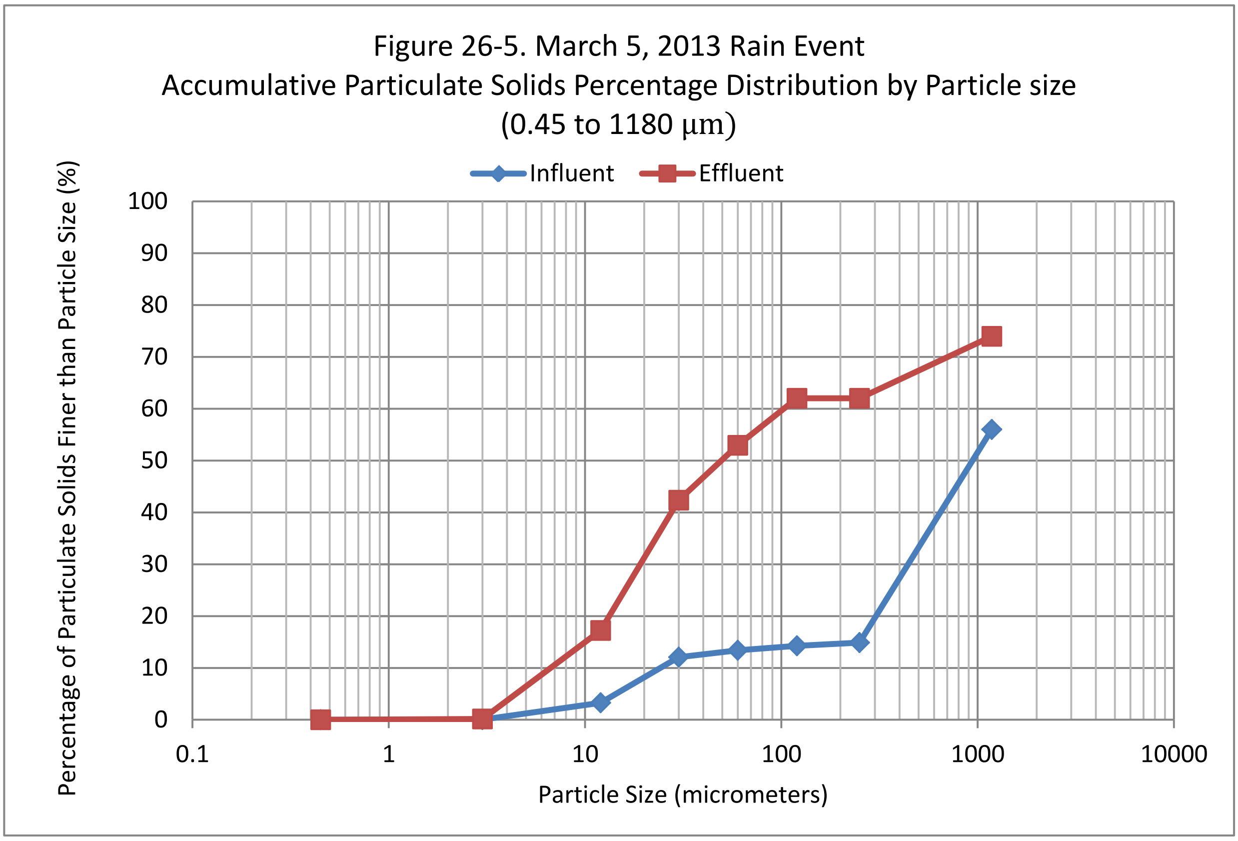
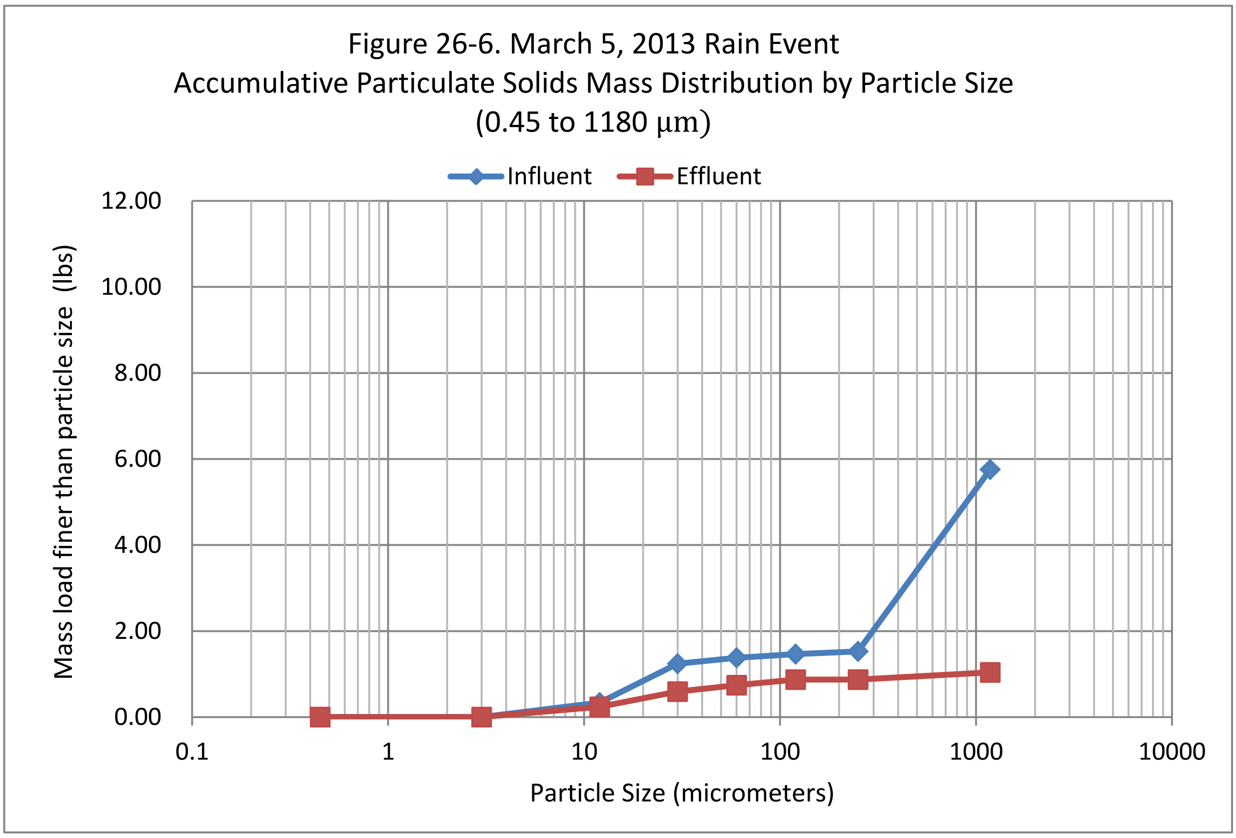


Figure 26-4. March 5, 2013 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 4.52 lbs larger than 1180 µm and the effluent had 0.37 lbs larger than 1180 µm (43.99 % and 26.03% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 26-10. March 5, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.16	0.11	0.03	0.16	0.00	0.00	0.00	31.04
3 to 12	16.09	11.63	3.23	17.05	0.33	0.24	0.09	27.92
12 to 30	43.82	17.15	8.81	25.15	0.91	0.35	0.55	60.98
30 to 60	6.62	7.21	1.33	10.57	0.14	0.15	-0.01	-8.61
60 to 120	4.24	6.19	0.85	9.08	0.09	0.13	-0.04	-45.50
120 to 250	3.11	0.00	0.63	0.00	0.06	0.00	0.06	100.00
250 to 1180	204.62	8.15	41.13	11.95	4.23	0.17	4.06	96.03
>1180	218.88	17.75	43.99	26.03	4.52	0.37	4.16	91.91
Total	498	68	100.00	100.00	10.28	1.40	8.87	86.33

Table 26-11. March 5, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.03	0.16	0.00	0.00
<12	3.27	17.21	0.34	0.24
<30	12.07	42.36	1.24	0.59
<60	13.40	52.94	1.38	0.74
<120	14.26	62.02	1.46	0.87
<250	14.88	62.02	1.53	0.87
<1180	56.01	73.97	5.76	1.04
>1180	100.00	100.00	10.28	1.40

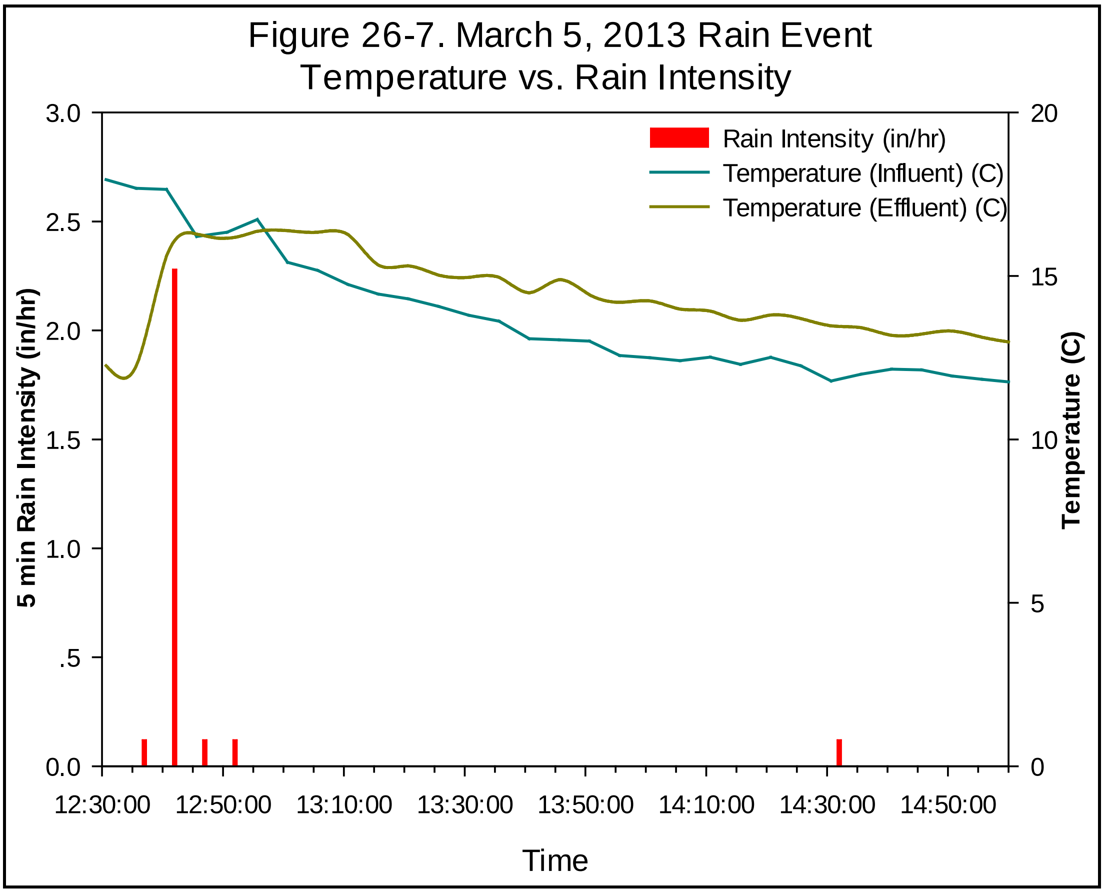


Figure 26-7. March 5, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
12:30:00
12:50:00
13:10:00
13:30:00
13:50:00
14:10:00
14:30:00
14:50:00
Time

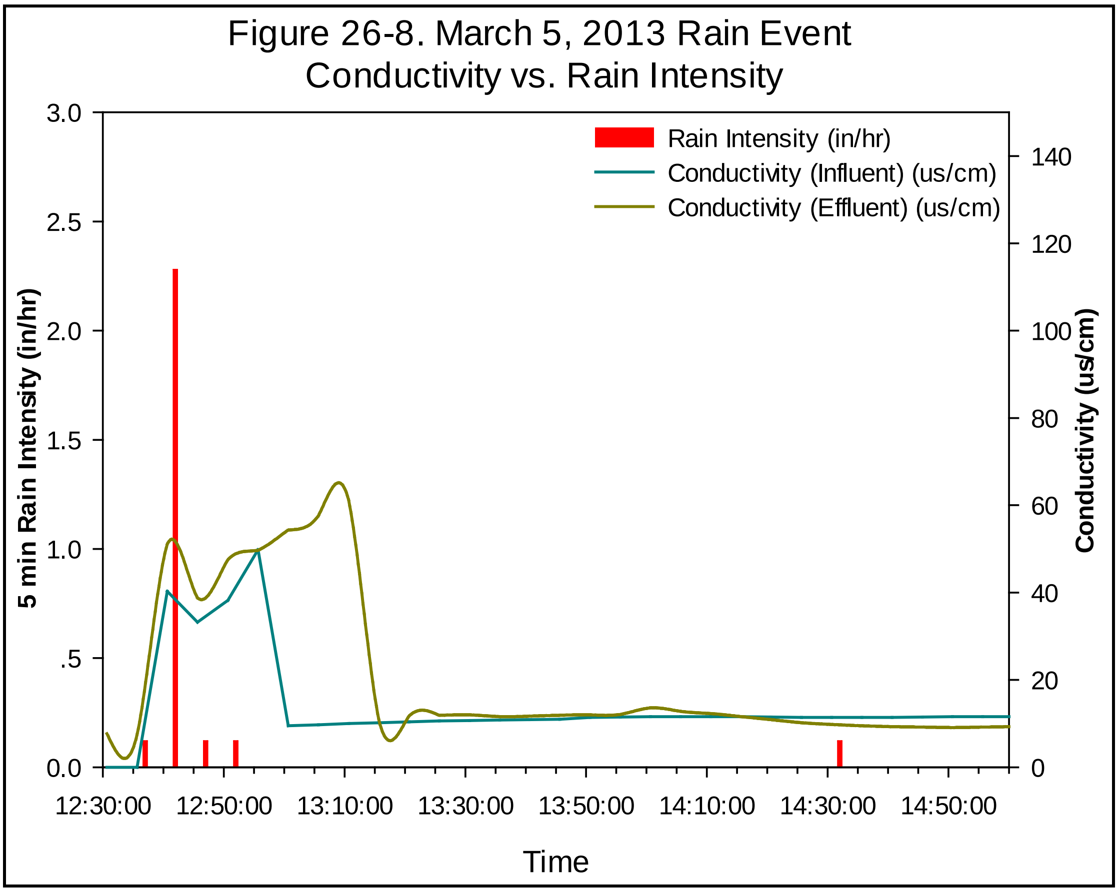


Figure 26-8. March 5, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
140
120
100
80
60
40
20
0
12:30:00
12:50:00
13:10:00
13:30:00
13:50:00
14:10:00
14:30:00
14:50:00
Time

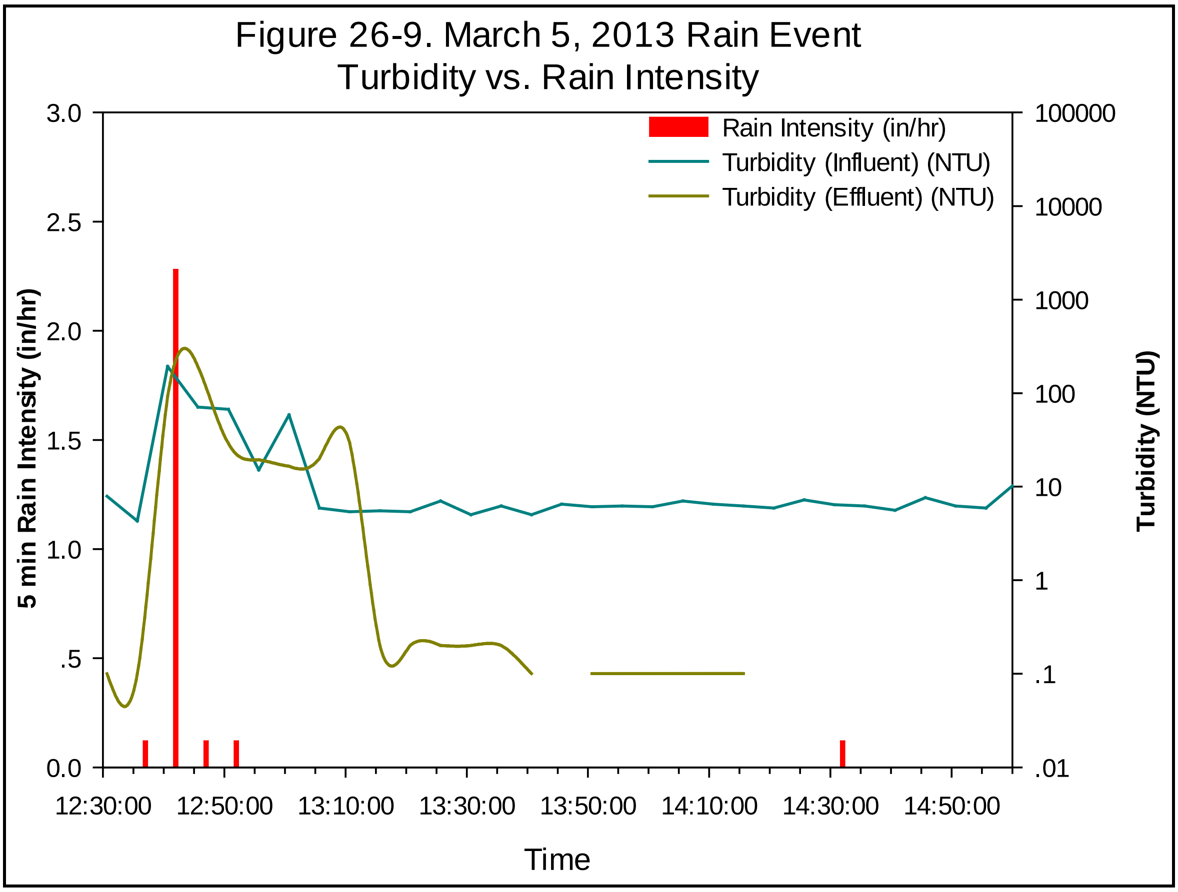
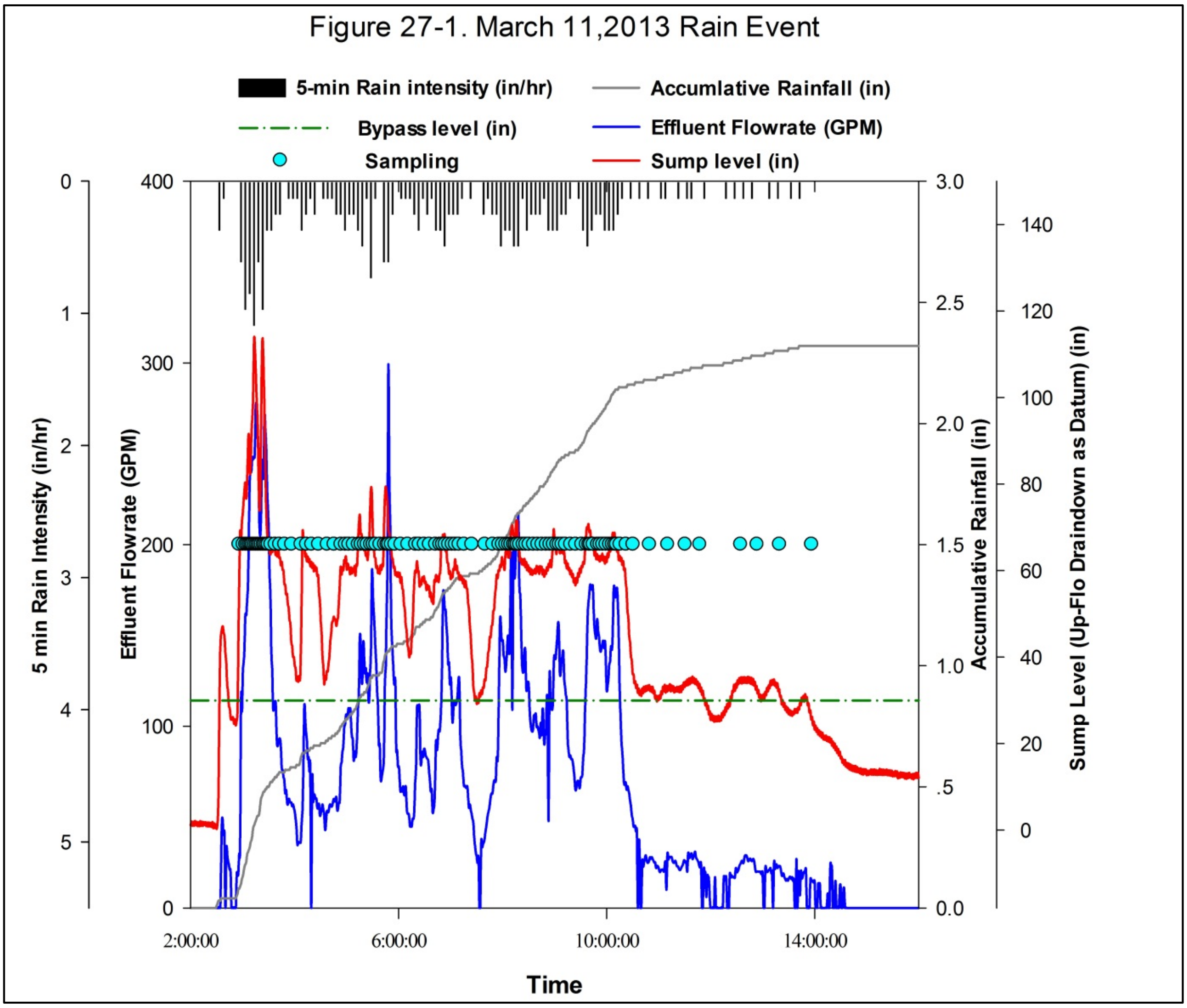


Figure 26-9. March 5, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
12:30:00
12:50:00
13:10:00
13:30:00
13:50:00
14:10:00
14:30:00
14:50:00

Appendix F.27: March 11, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 11.47 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 27-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.69
Volumetric Runoff Coefficient (Rv)	0.90

Table 27-2. March 11, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/3/11 2:30
Rain Event End Date/Time:			2013/3/11 13:42
Total Precipitation (inch):	≥ 0.1	2.32	
Total Runoff Depth (inch):	NA	2.08	
Total Outflow (gallon):	NA	53629	
Rain Duration (hours):	≥ 1	11.20	
Flow Start Date/Time:			2013/3/11 2:35
Flow End Date/Time:			2013/3/11 14:35
Flow Duration (hours):	NA	12.00	
Average Rain Intensity (in/hr):	NA	0.21	
Average Runoff Rate (gallons/min):	NA	74	
Peak 5-min Rain Intensity (in/hr):	NA	1.08	
Peak Runoff Rate (gallons/min):	NA	299	
Peak to Average Runoff Ratio:	NA	4.01	
Bypassed flow volume (gallon):	NA	33803	
Percentage of Bypassed Flow (%):	NA	63.03	
Inter-Event Time since prior rain (hours)	≥ 6.0	132.03	

Table 27-3. March 11, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	110	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	27.5	The actual volumes of both samples were visually only about 16 liter
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	98.80	

Table 27-4. March 11, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	58	23	60.3	SM 2540D	1 mg/L	Stillbrook Lab
TSS	245	28	88.6	SM 2540D	1 mg/L	UA Lab
SSC	62	20	67.7	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	2386	30	98.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	46	35	23.1	EPA 160.2	1 mg/L	UA Lab
VSS	36	9	75.3	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.7	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.5	0.5	0.0	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.09	0.09	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.49	0.40	18.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.34	0.31	8.8	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.033	BDL	>84.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.009	BDL	>44.4	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.008	BDL	>37.5	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.071	0.020	71.8	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	0.005	<0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	28272	9211	67.4	IDEXX Method	<1	UA Lab
E. Coli	56	41	27.7	IDEXX Method	<1	UA Lab
Enterococci	232	89	61.6	IDEXX Method	<1	UA Lab
pH	6.69	6.73	-0.6	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	22.15	10.20	54.0	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	35.3	31.9	9.6	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	11.0	10.5	4.5	SM 212/ EPA 170.1	5 °C	UA Lab

Table 27-5. March 11, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	62	NA*	NA*	20	NA*	NA*	67.7	NA*	NA*
UA Lab	1191	1195	2386	25	5	30	97.9	99.6	98.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 27-6. March 11, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	43648	14048	84	22	1.9	1.5

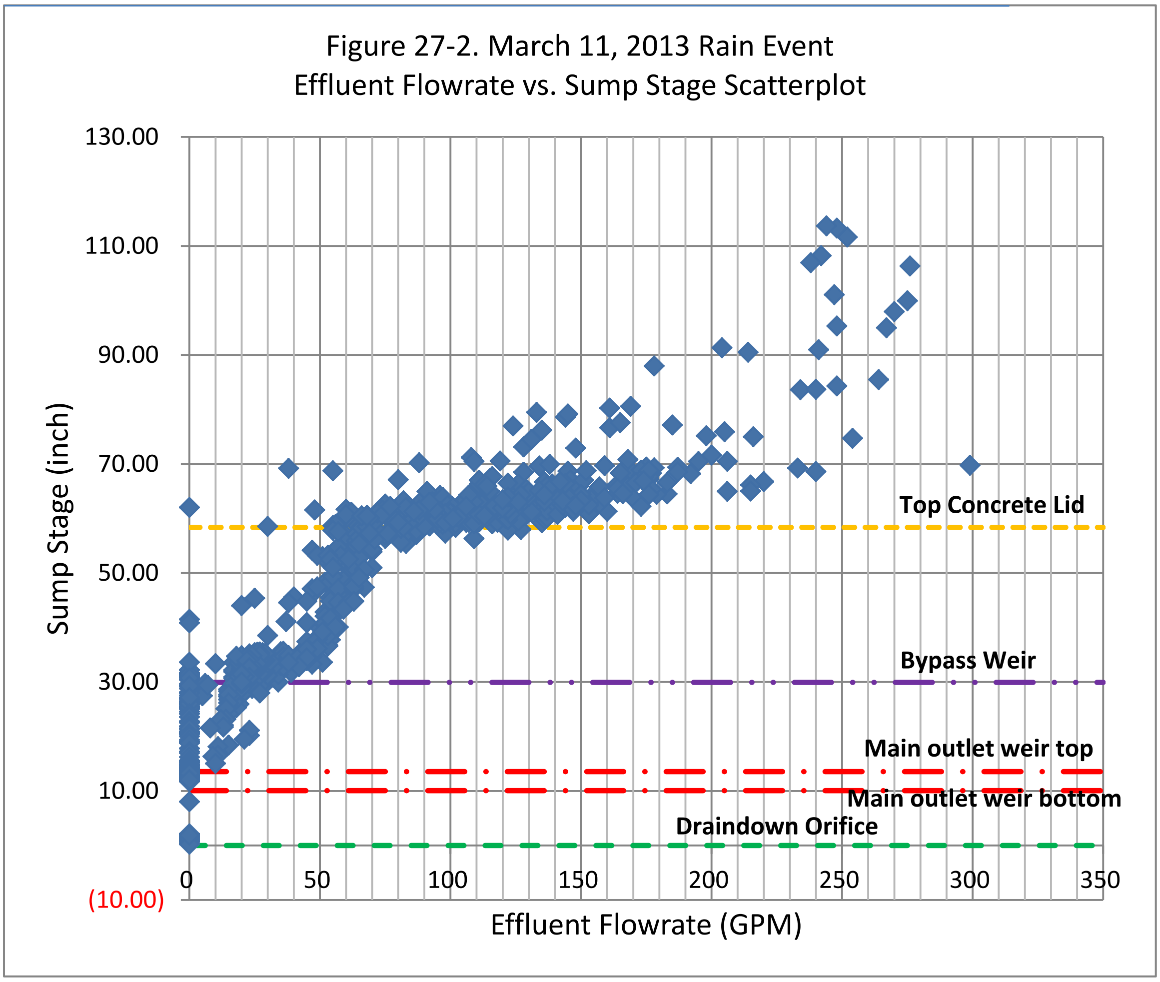
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 27-7. March 11, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	202	288	245	32	24	28
Millipore Membrane Filter, 0.45µm	154	177	166	21	26	23

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 27-8. March 11, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	28272	28,272	14136	4286	9,211
E. Coli	52	60	56	41	40	41
Enterococci	269	194	232	96	82	89

Table 27-9. March 11, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	34	39	36	10	8	9



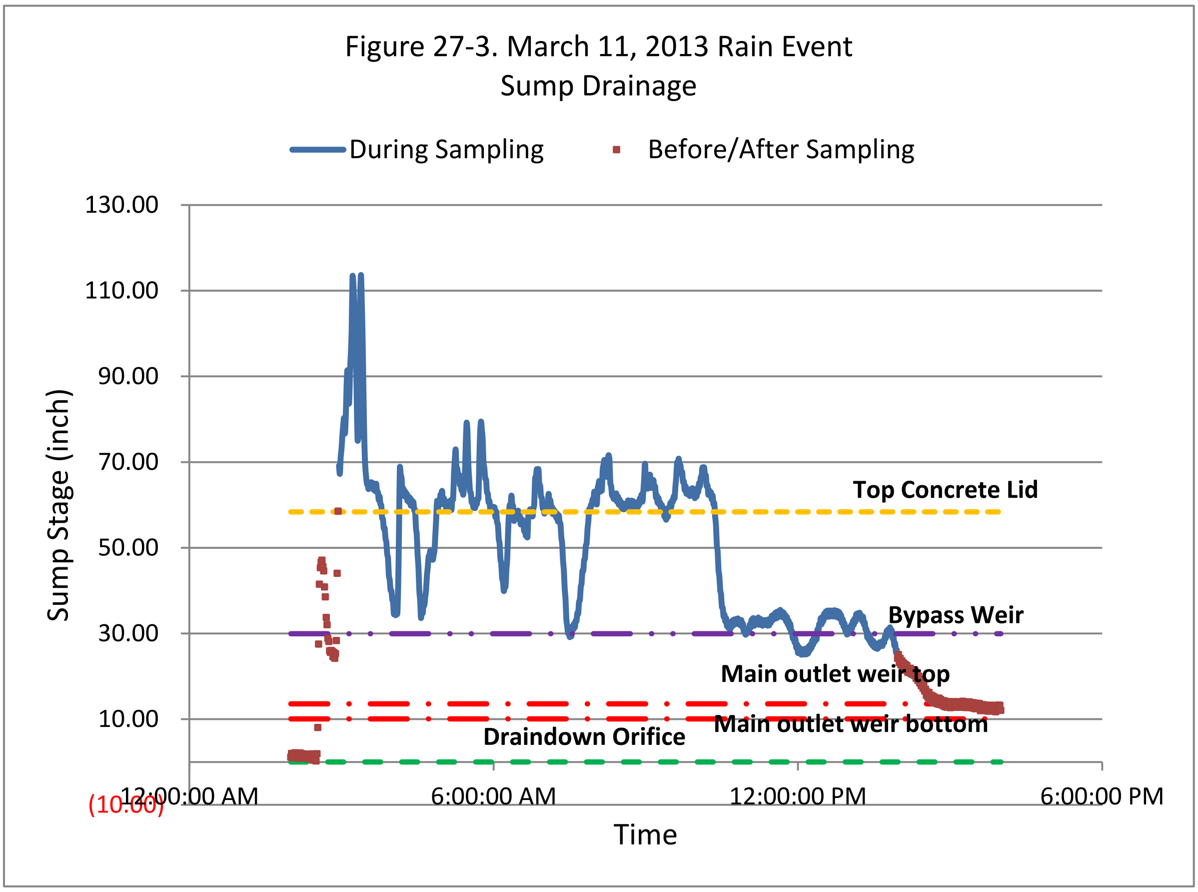


Figure 27-3. March 11, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
Time

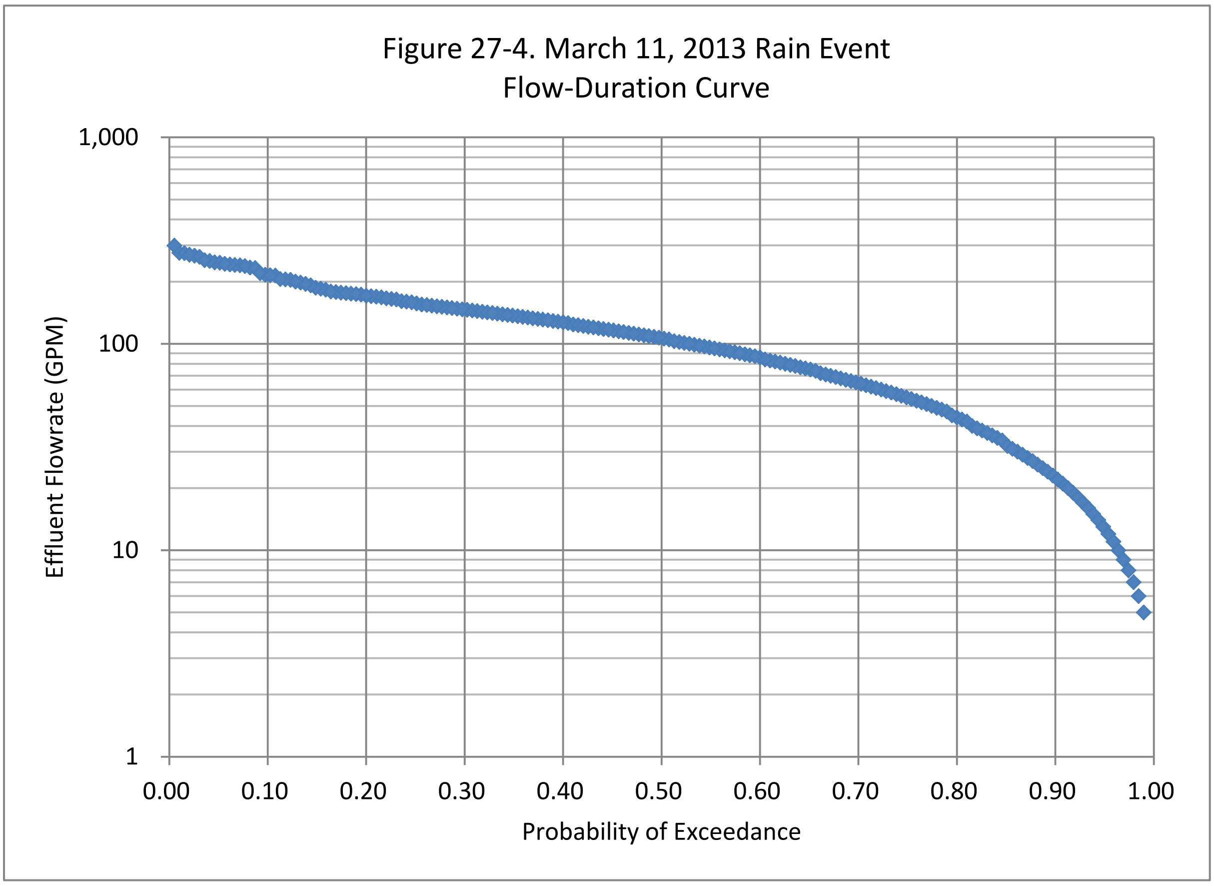
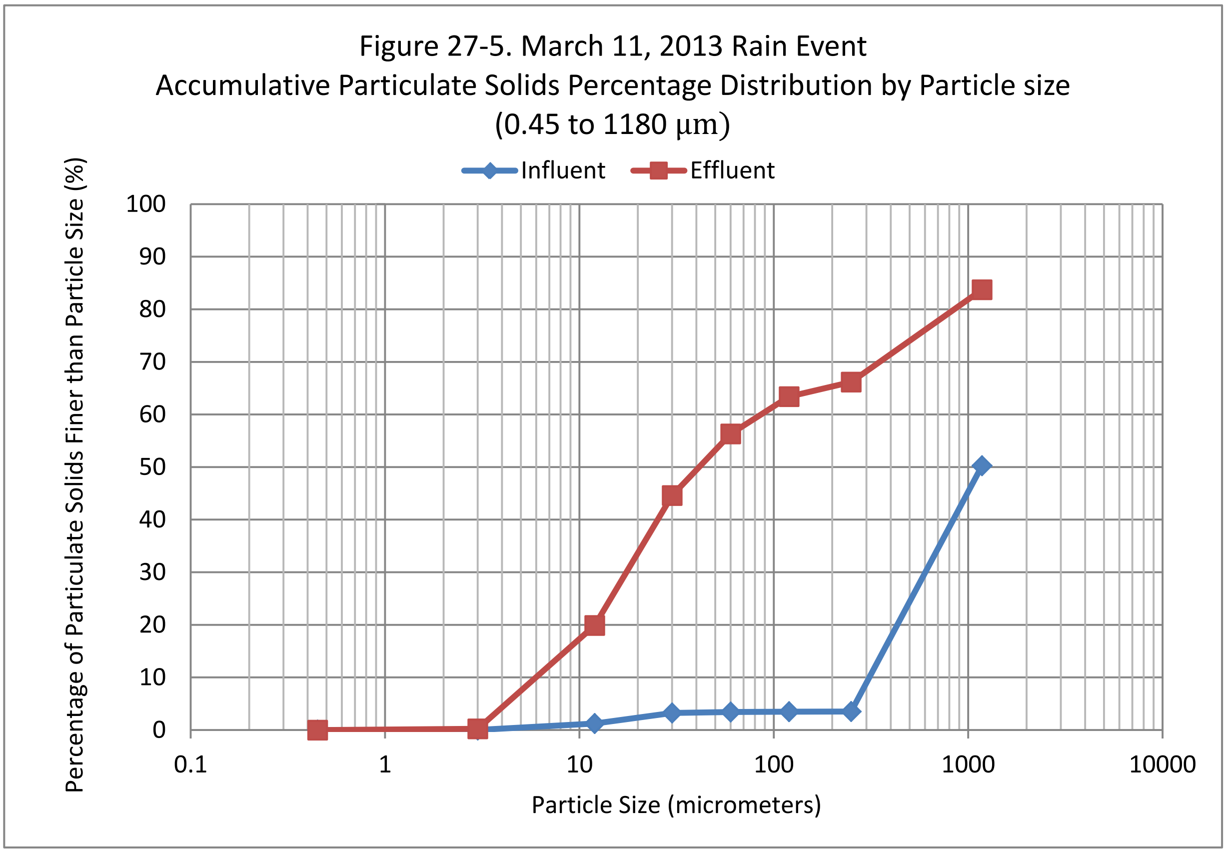
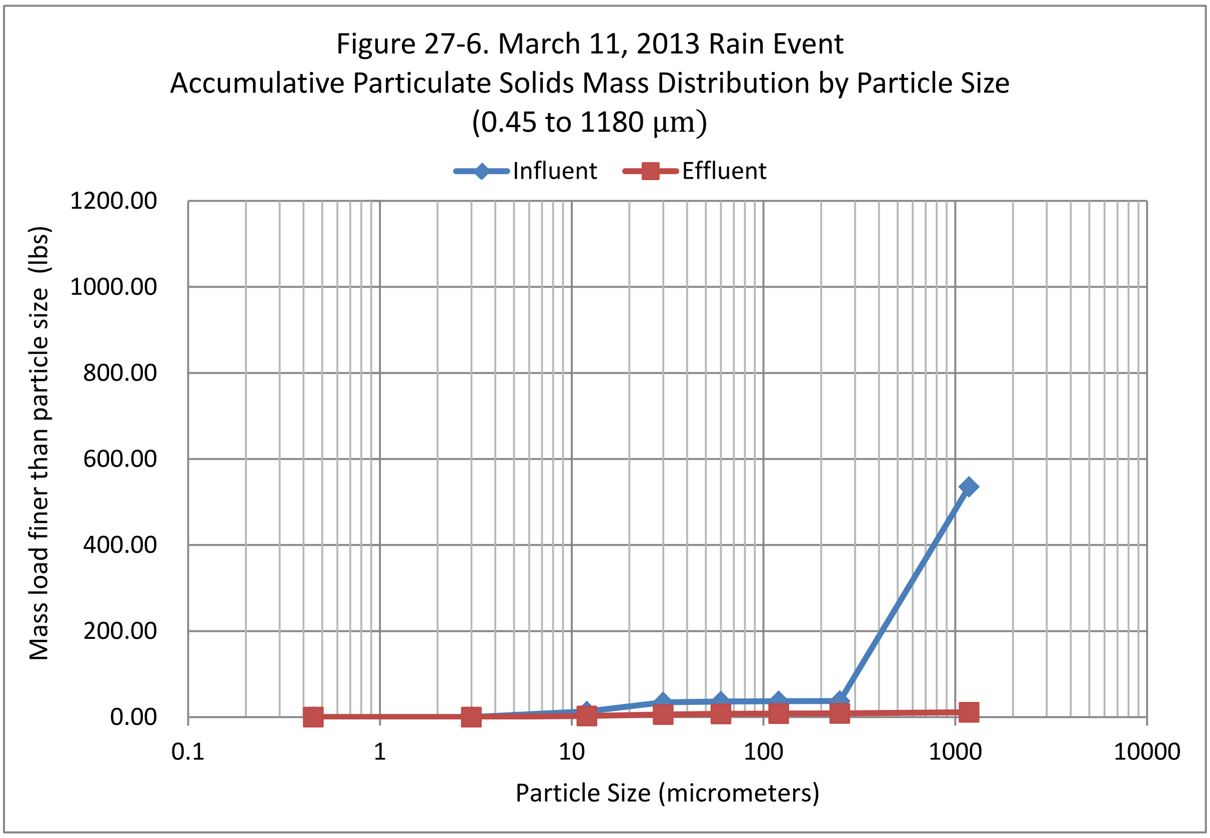


Figure 27-4. March 11, 2013 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 530.13 lbs larger than 1180 µm and the effluent had 2.17 lbs larger than 1180 µm (49.75% and 16.27% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 27-10. March 11, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.07	0.08	0.00	0.23	0.03	0.03	0.00	6.56
3 to 12	29.87	6.41	1.24	19.64	13.25	2.62	10.63	80.24
12 to 30	47.81	8.06	1.99	24.72	21.21	3.30	17.91	84.46
30 to 60	4.34	3.82	0.18	11.72	1.92	1.56	0.36	18.80
60 to 120	1.67	2.32	0.07	7.10	0.74	0.95	-0.21	-27.79
120 to 250	0.52	0.90	0.02	2.77	0.23	0.37	-0.14	-60.07
250 to 1180	1123.22	5.73	46.75	17.55	498.18	2.34	495.84	99.53
>1180	1195.26	5.31	49.75	16.27	530.13	2.17	527.96	99.59
Total	2403	33	100.00	100.00	1065.69	13.33	1052.36	98.75

Table 27-11. March 11, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.00	0.23	0.03	0.03
<12	1.25	19.87	13.28	2.65
<30	3.24	44.59	34.49	5.94
<60	3.42	56.31	36.41	7.51
<120	3.49	63.40	37.15	8.45
<250	3.51	66.17	37.38	8.82
<1180	50.25	83.73	535.56	11.16
>1180	100.00	100.00	1065.69	13.33

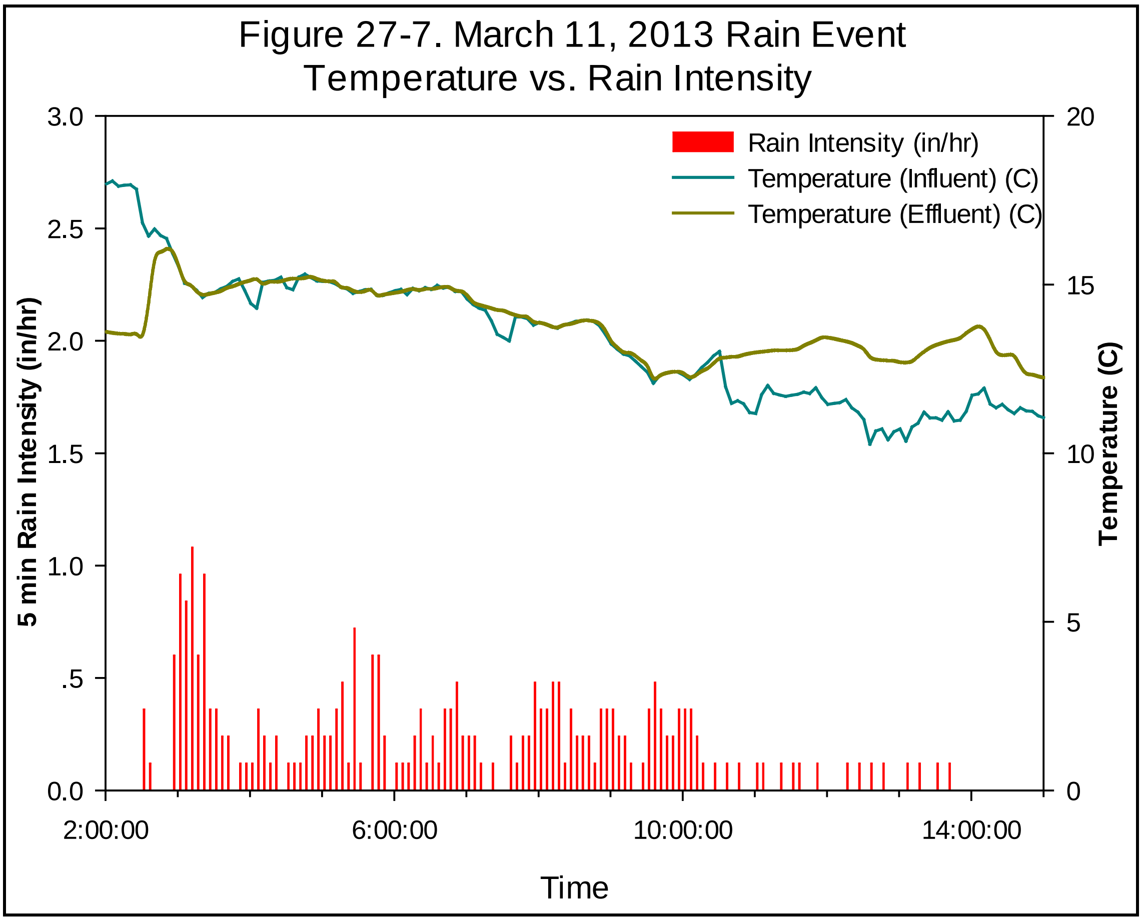


Figure 27-7. March 11, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
2:00:00
6:00:00
10:00:00
14:00:00

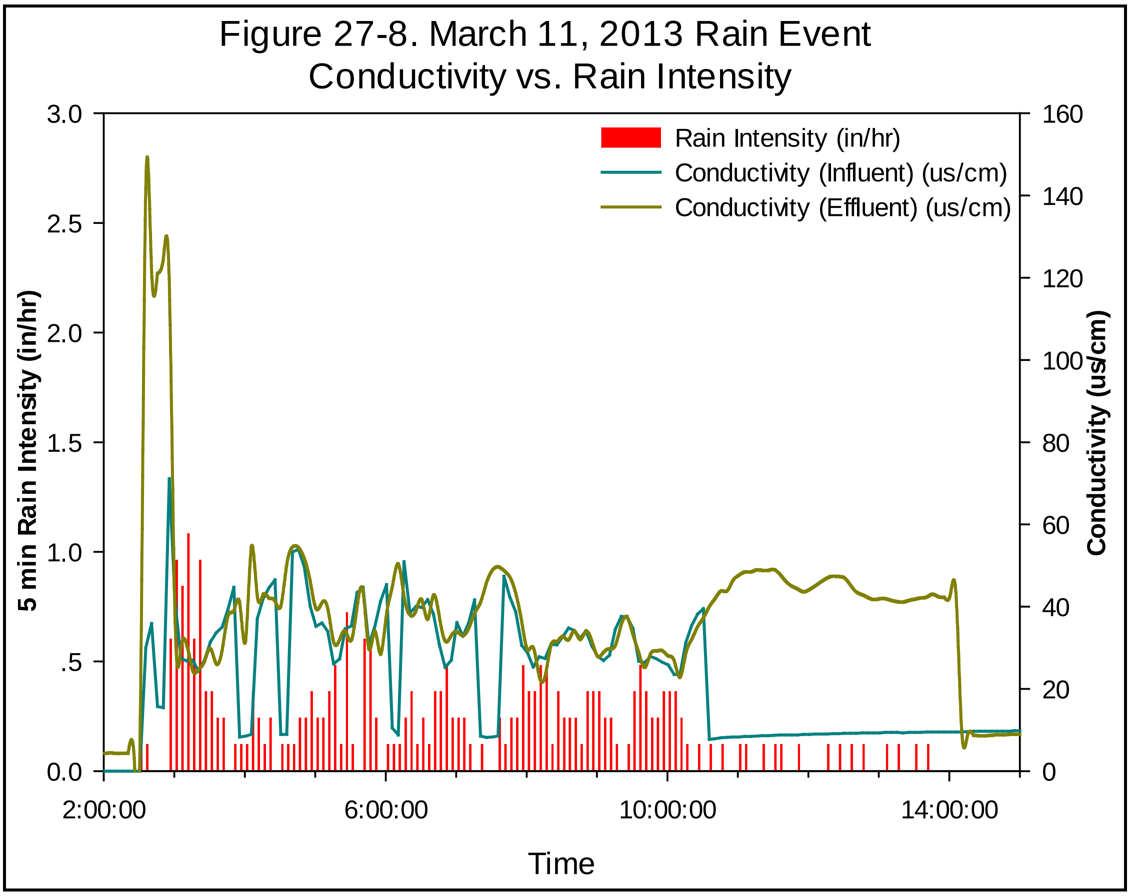


Figure 27-8. March 11, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
160
140
120
100
80
60
40
20
0
2:00:00
6:00:00
10:00:00
14:00:00

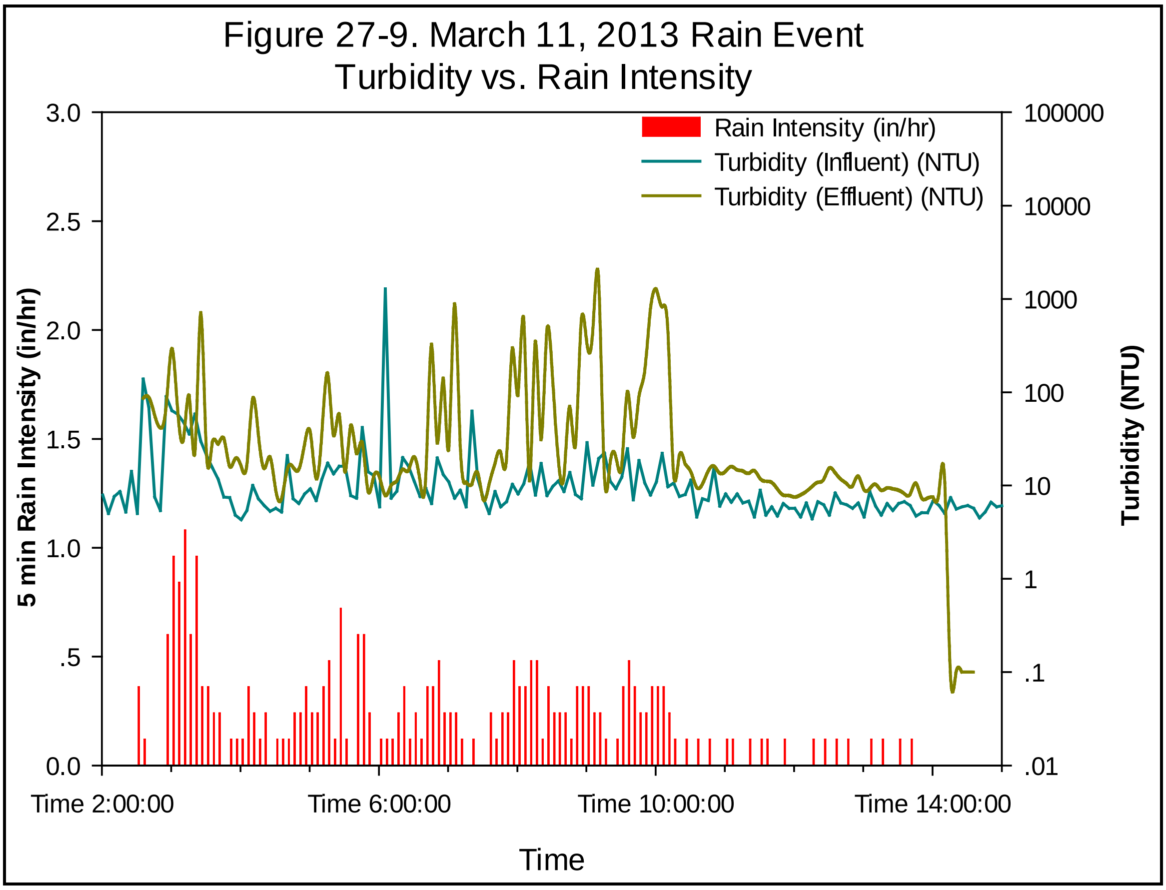
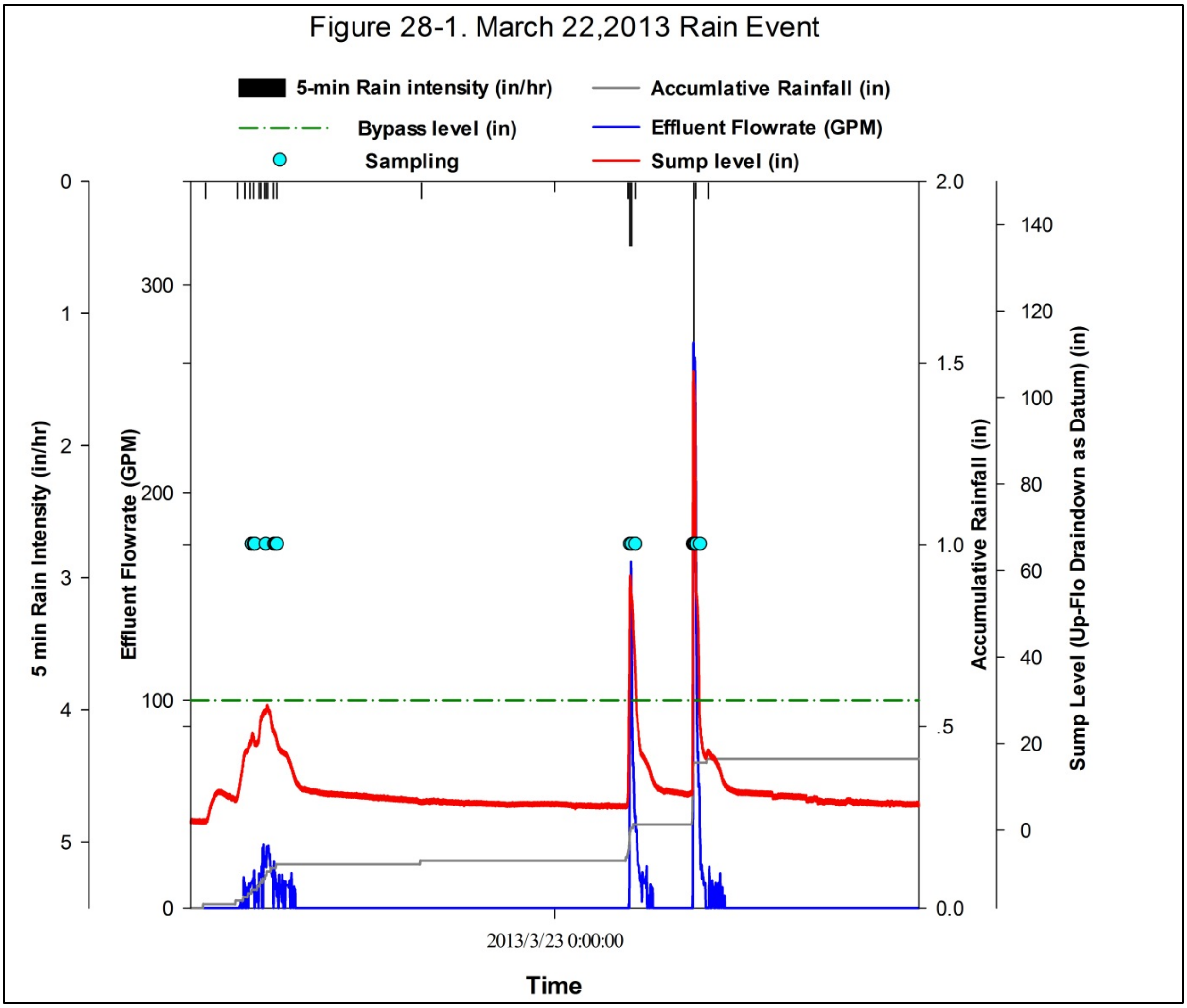


Figure 27-9. March 11, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
Time 2:00:00
Time 6:00:00
Time 10:00:00
Time 14:00:00
Time

Appendix F.28: March 22, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 12.47 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 28-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.35
Volumetric Runoff Coefficient (Rv)	0.75

Table 28-2. March 22, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/3/22 7:35
Rain Event End Date/Time:			2013/3/23 7:06
Total Precipitation (inch):	≥ 0.1	0.41	
Total Runoff Depth (inch):	NA	0.31	
Total Outflow (gallon):	NA	7129	
Rain Duration (hours):	≥ 1	23.52	
Flow Start Date/Time:			2013/3/22 9:17
Flow End Date/Time:			2013/3/23 7:57
Flow Duration (hours):	NA	22.67	
Average Rain Intensity (in/hr):	NA	0.02	
Average Runoff Rate (gallons/min):	NA	5	
Peak 5-min Rain Intensity (in/hr):	NA	1.92	
Peak Runoff Rate (gallons/min):	NA	265	
Peak to Average Runoff Ratio:	NA	50.55	
Bypassed flow volume (gallon):	NA	2627	
Percentage of Bypassed Flow (%):	NA	36.85	
Inter-Event Time since prior rain (hours)	≥ 6.0	87.25	

Table 28-3. March 22, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	21	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	5.3	The actual volumes of both samples were visually consistent with programmed one
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	120	
Samples Coverage of total storm flow (%)	75.00	91.26	

Table 28-4. March 22, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	66	29	56.1	SM 2540D	1 mg/L	Stillbrook Lab
TSS	197	43	78.4	SM 2540D	1 mg/L	UA Lab
SSC	108	30	72.2	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	302	42	86.1	ASTM D3977-97B	1 mg/L	UA Lab
TDS	51	57	-12.9	EPA 160.2	1 mg/L	UA Lab
VSS	50	22	55.6	SM 2540E	1 mg/L	UA Lab
Total N as N	0.8	0.9	-12.5	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.8	0.9	-12.5	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.18	0.30	-66.7	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.73	0.55	24.7	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.22	0.34	-54.5	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.007	BDL	>28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.007	0.005	28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	0.007	BDL	>28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.006	BDL	>16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.053	0.032	39.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.015	0.010	33.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	39726	>17.9	IDEXX Method	<1	UA Lab
E. Coli	236	190	19.5	IDEXX Method	<1	UA Lab
Enterococci	716	402	43.9	IDEXX Method	<1	UA Lab
pH	6.81	6.83	-0.3	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	86.75	32.85	62.1	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	62.5	65.9	-5.4	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	14.0	13.7	2.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 28-5. March 22, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	108	NA*	NA*	30	NA*	NA*	72.2	NA*	NA*
UA Lab	216	86	302	36	6	42	83.4	93.1	86.1

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 28-6. March 22, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	43038	35605	87	32	2.0	0.9

* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 28-7. March 22, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	181	212	197	45	40	43
Millipore Membrane Filter, 0.45µm	158	188	173	37	38	38

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 28-8. March 22, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	39726	39,726
E. Coli	211	260	236	185	194	190
Enterococci	616	816	716	426	378	402

Table 28-9. March 22, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH[TM] Glass Microfiber Filters, 1.5µm	50	49	50	23	21	22

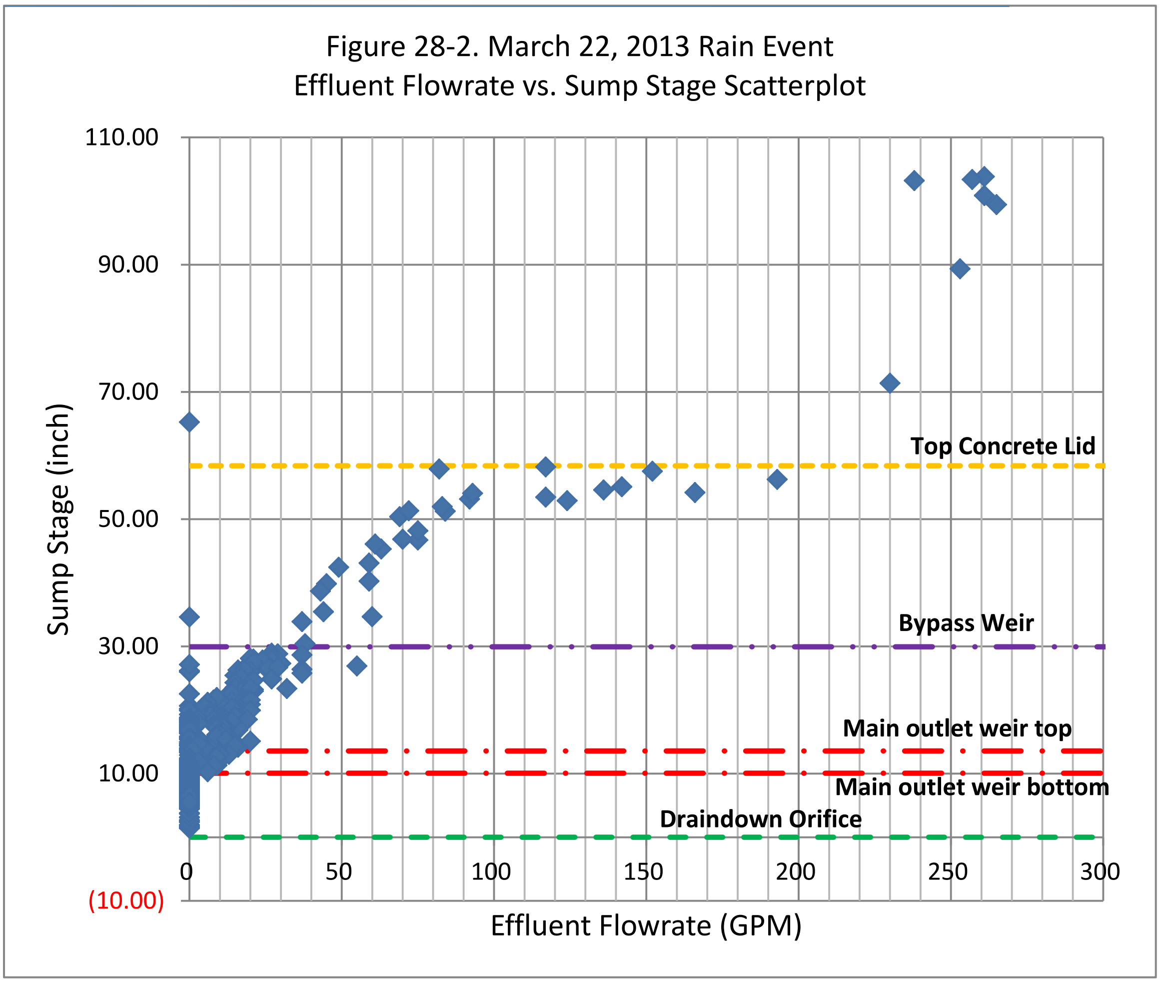


Figure 28-3. March 22, 2013 Rain Event
Sump Drainage

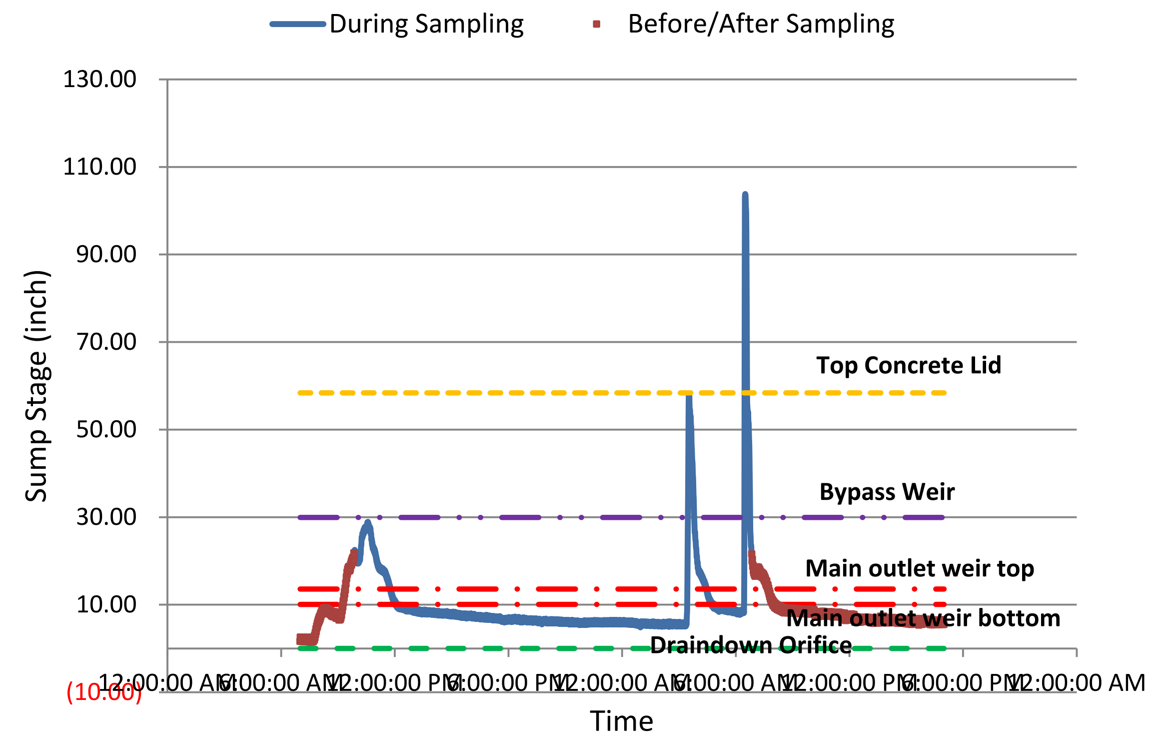
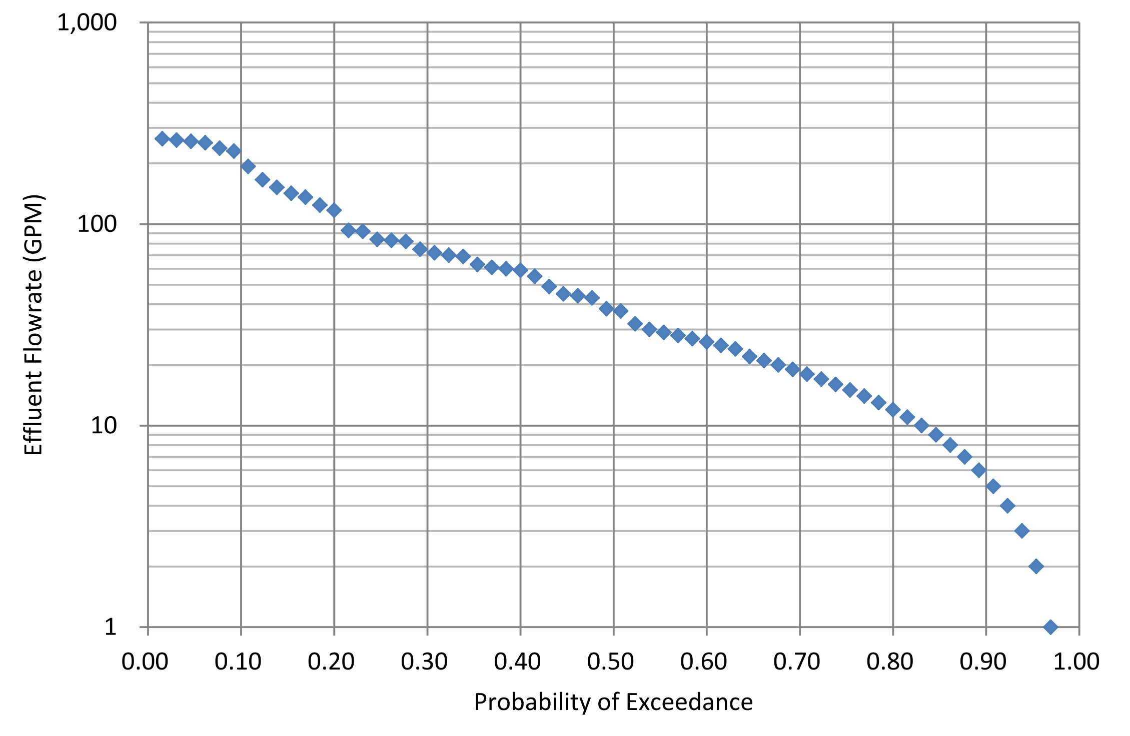
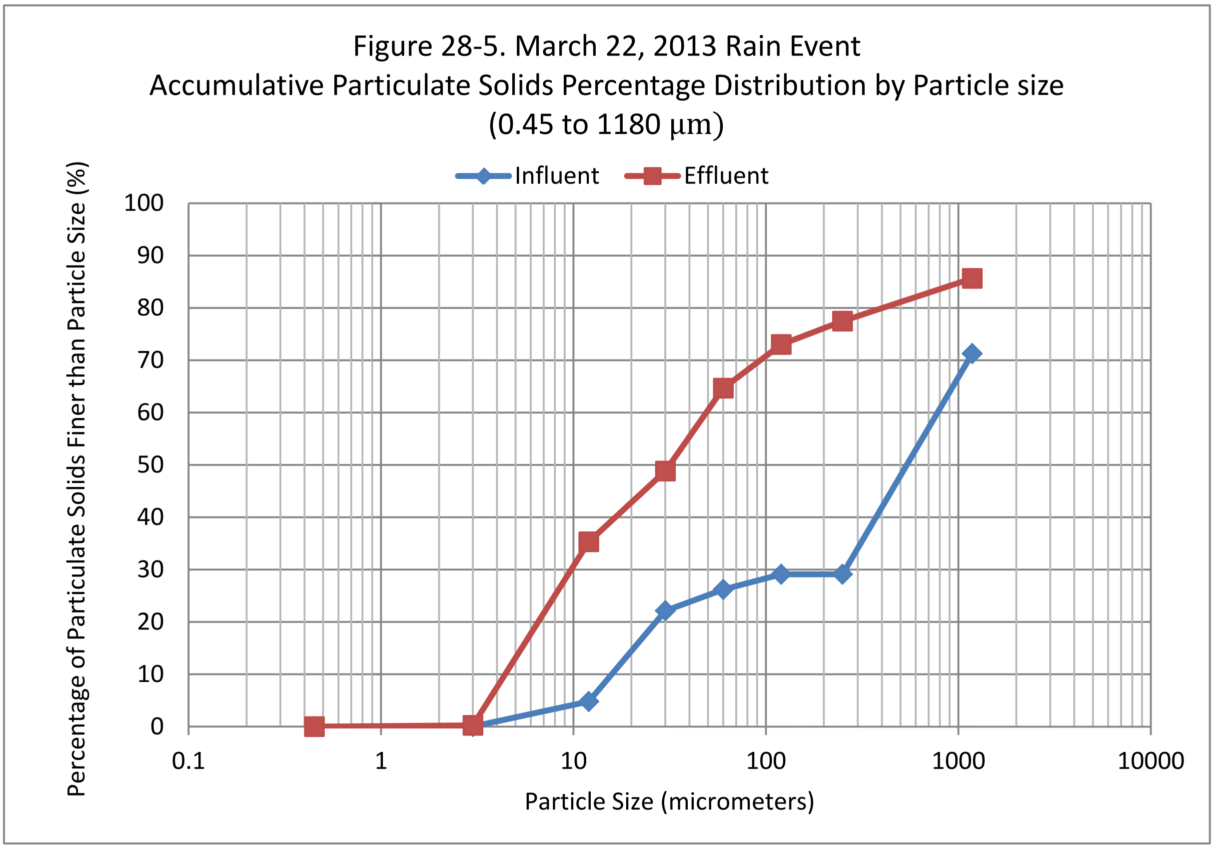
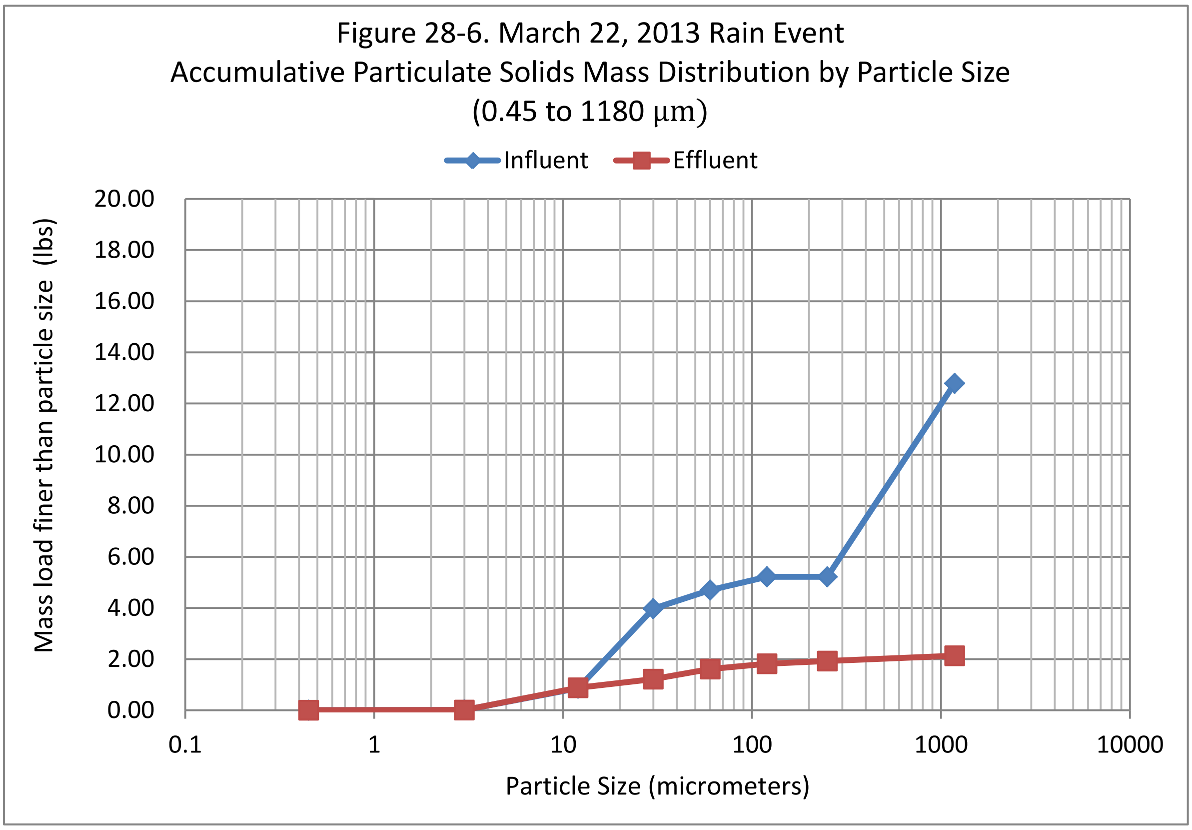


Figure 28-4. March 22, 2013 Rain Event
Flow-Duration Curve







Not shown: The influent sample had 5.15 lbs larger than 1180 µm and the effluent had 0.36 lbs larger than 1180 µm (28.73% and 14.35% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 28-10. March 22, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.13	0.10	0.04	0.24	0.01	0.01	0.00	25.19
3 to 12	14.24	14.56	4.77	35.06	0.86	0.87	-0.02	-2.07
12 to 30	51.76	5.61	17.33	13.52	3.11	0.34	2.77	89.17
30 to 60	12.18	6.58	4.08	15.85	0.73	0.39	0.34	46.06
60 to 120	8.62	3.46	2.88	8.34	0.52	0.21	0.31	59.89
120 to 250	0.00	1.86	0.00	4.47	0.00	0.11	-0.11	#DIV/0!
250 to 1180	126.00	3.40	42.17	8.18	7.57	0.20	7.36	97.31
>1180	85.83	5.96	28.73	14.35	5.15	0.36	4.80	93.07
Total	299	42	100.00	100.00	17.94	2.49	15.45	86.12

Table 28-11. March 22, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.04	0.24	0.01	0.01
<12	4.81	35.30	0.86	0.88
<30	22.14	48.81	3.97	1.22
<60	26.21	64.66	4.70	1.61
<120	29.10	73.00	5.22	1.82
<250	29.10	77.47	5.22	1.93
<1180	71.27	85.65	12.79	2.13
>1180	100.00	100.00	17.94	2.49

Figure 28-7. March 22, 2013 Rain Event
Temperature vs. Rain Intensity

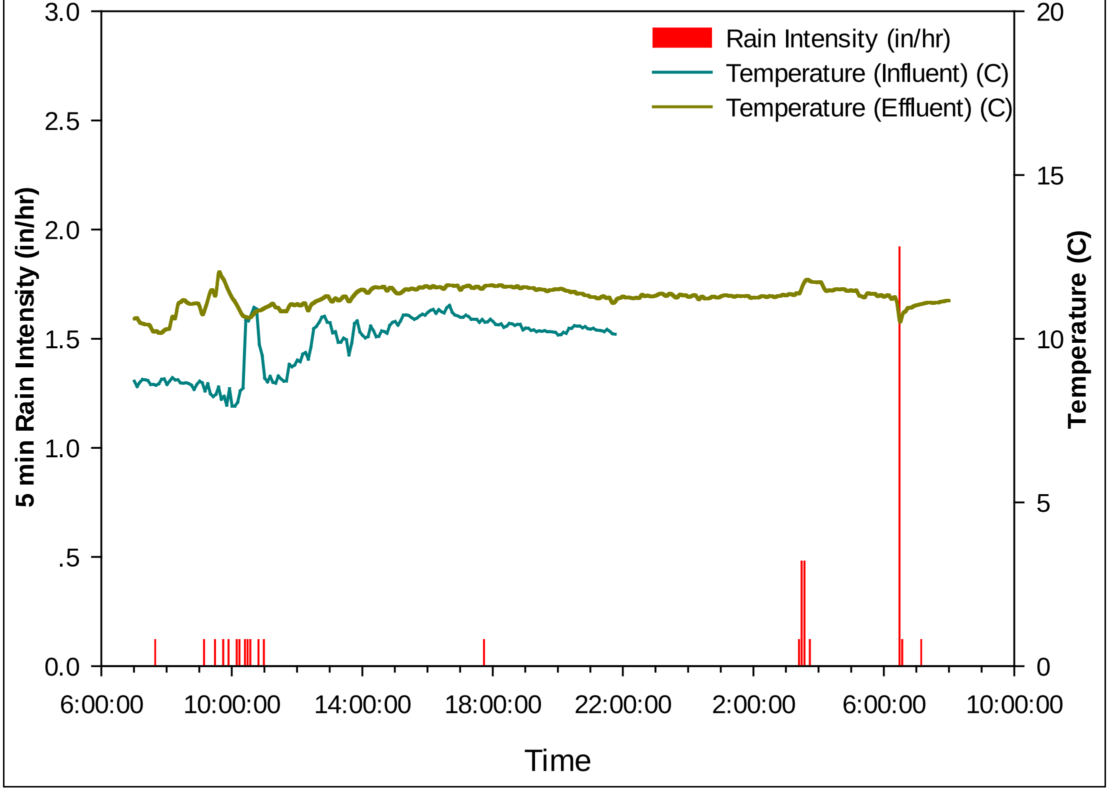
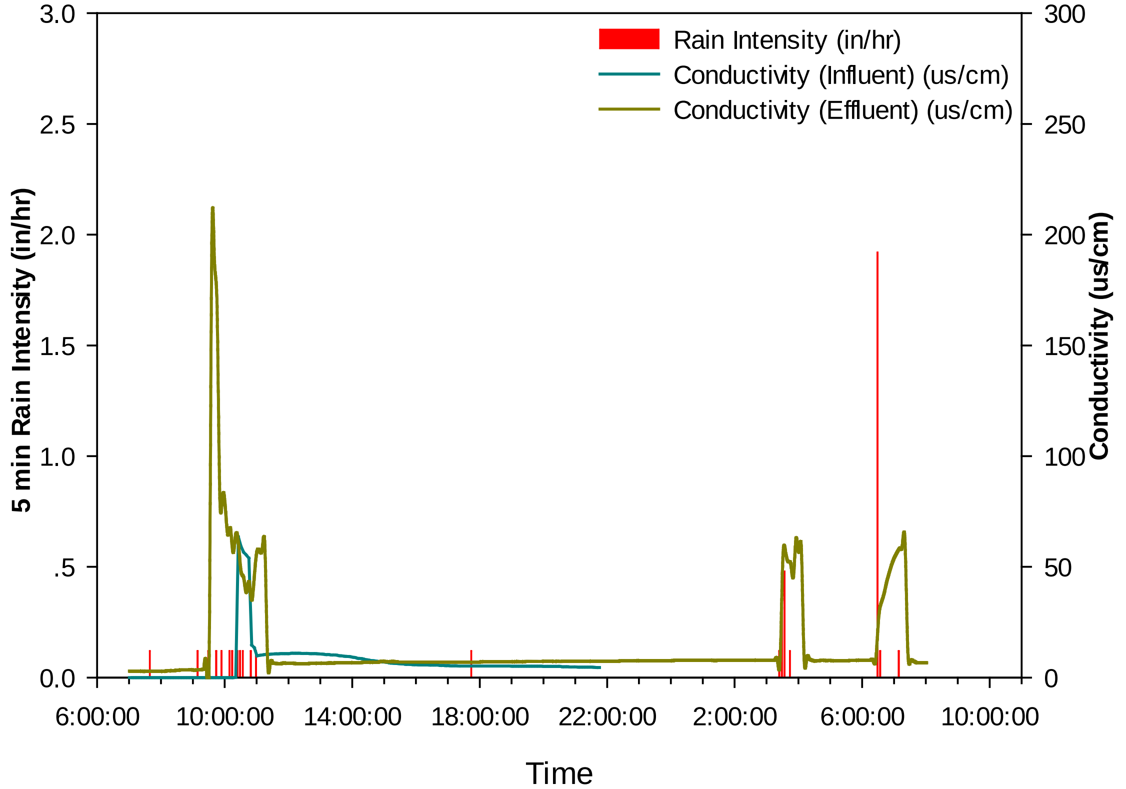


Figure 28-8. March 22, 2013 Rain Event
Conductivity vs. Rain Intensity



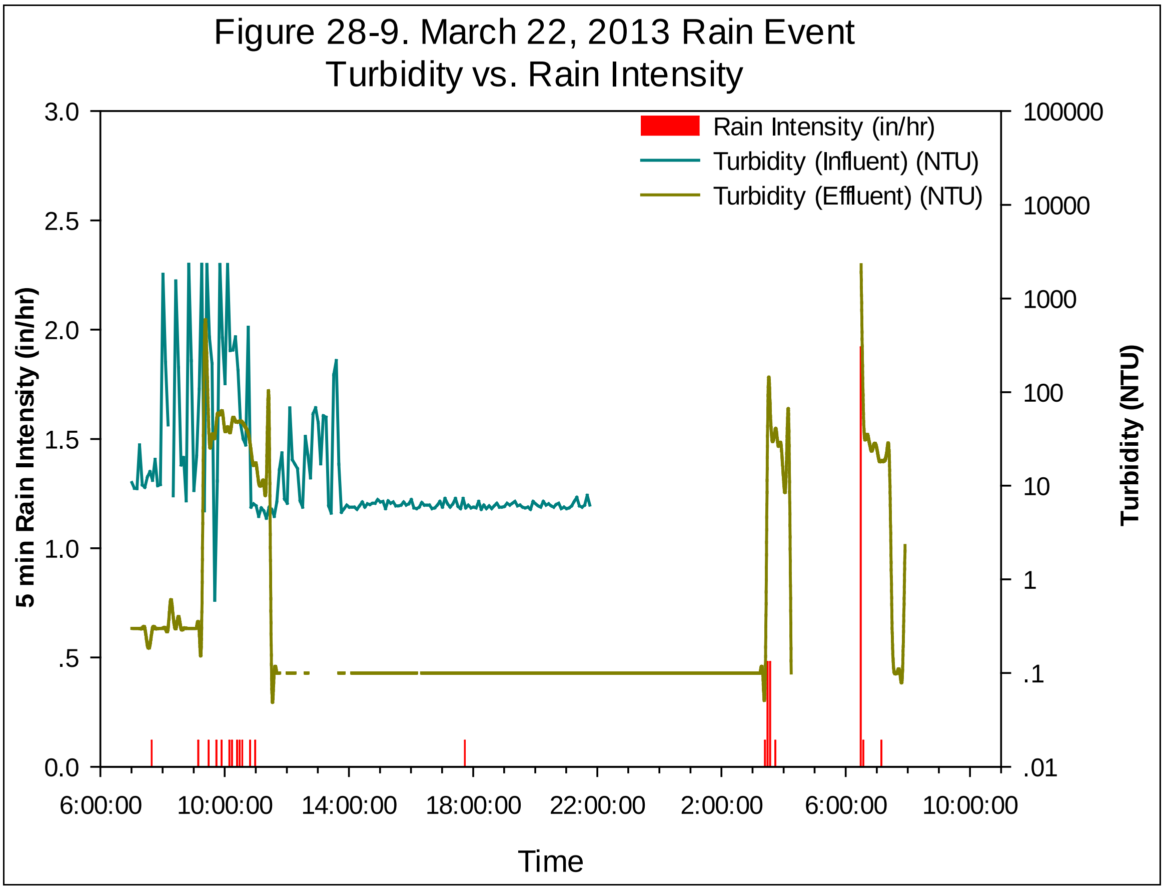
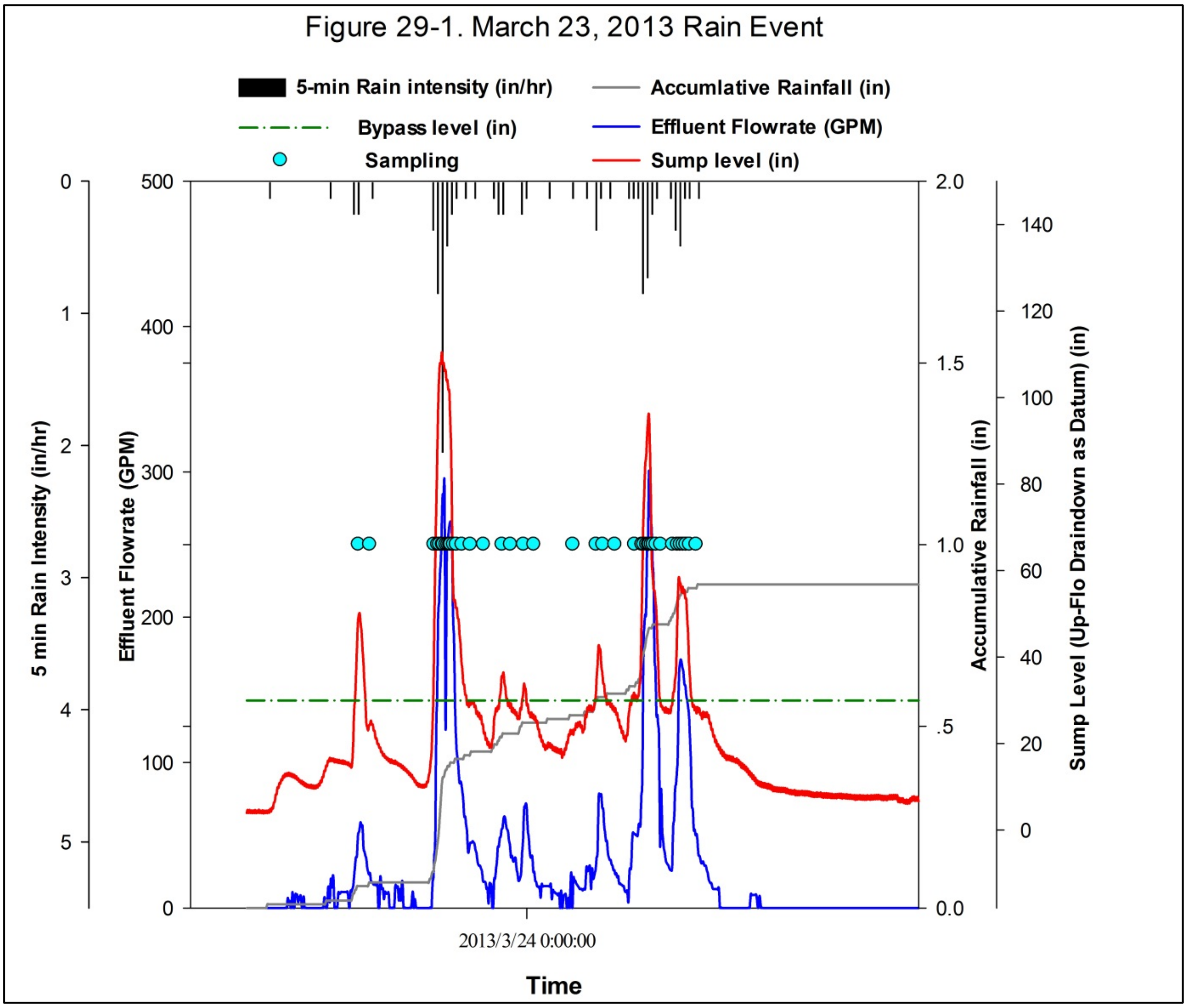


Figure 28-9. March 22, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
Time
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
6:00:00
10:00:00
14:00:00
18:00:00
22:00:00
2:00:00
6:00:00
10:00:00

Appendix F.29: March 23, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 13.35 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 29-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.37
Volumetric Runoff Coefficient (Rv)	0.87

Table 29-2. March 23, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/3/23 19:22
Rain Event End Date/Time:			2013/3/24 3:03
Total Precipitation (inch):	≥ 0.1	0.89	
Total Runoff Depth (inch):	NA	0.78	
Total Outflow (gallon):	NA	20583	
Rain Duration (hours):	≥ 1	7.68	
Flow Start Date/Time:			2013/3/23 19:44
Flow End Date/Time:			2013/3/24 4:11
Flow Duration (hours):	NA	8.45	
Average Rain Intensity (in/hr):	NA	0.12	
Average Runoff Rate (gallons/min):	NA	41	
Peak 5-min Rain Intensity (in/hr):	NA	2.04	
Peak Runoff Rate (gallons/min):	NA	299	
Peak to Average Runoff Ratio:	NA	7.36	
Bypassed flow volume (gallon):	NA	9364	
Percentage of Bypassed Flow (%):	NA	45.49	
Inter-Event Time since prior rain (hours)	≥ 6.0	12.27	

Table 29-3. March 23, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	41	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	10.3	The actual volumes of both samples were visually consistent with programmed one
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	94.22	

Table 29-4. March 23, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	40	21	47.5	SM 2540D	1 mg/L	Stillbrook Lab
TSS	369	26	92.8	SM 2540D	1 mg/L	UA Lab
SSC	53	30	43.4	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	3243	41	98.7	ASTM D3977-97B	1 mg/L	UA Lab
TDS	40	36	10.1	EPA 160.2	1 mg/L	UA Lab
VSS	30	10	66.7	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.12	0.12	0.0	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.68	0.25	63.2	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.14	0.04	71.4	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.019	0.020	-5.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.007	BDL	>28.6	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	>48392	NA	IDEXX Method	<1	UA Lab
E. Coli	124	129	-4.0	IDEXX Method	<1	UA Lab
Enterococci	4787	4656	2.7	IDEXX Method	<1	UA Lab
pH	6.85	6.84	0.1	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	71.00	17.70	75.1	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	47.2	33.5	29.0	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	14.0	13.7	2.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 29-5. March 23, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	53	NA*	NA*	30	NA*	NA*	43.4	NA*	NA*
UA Lab	1263	1980	3243	33	8	41	97.4	99.6	98.7

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 29-6. March 23, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	22592	11767	109	26	4.8	2.2

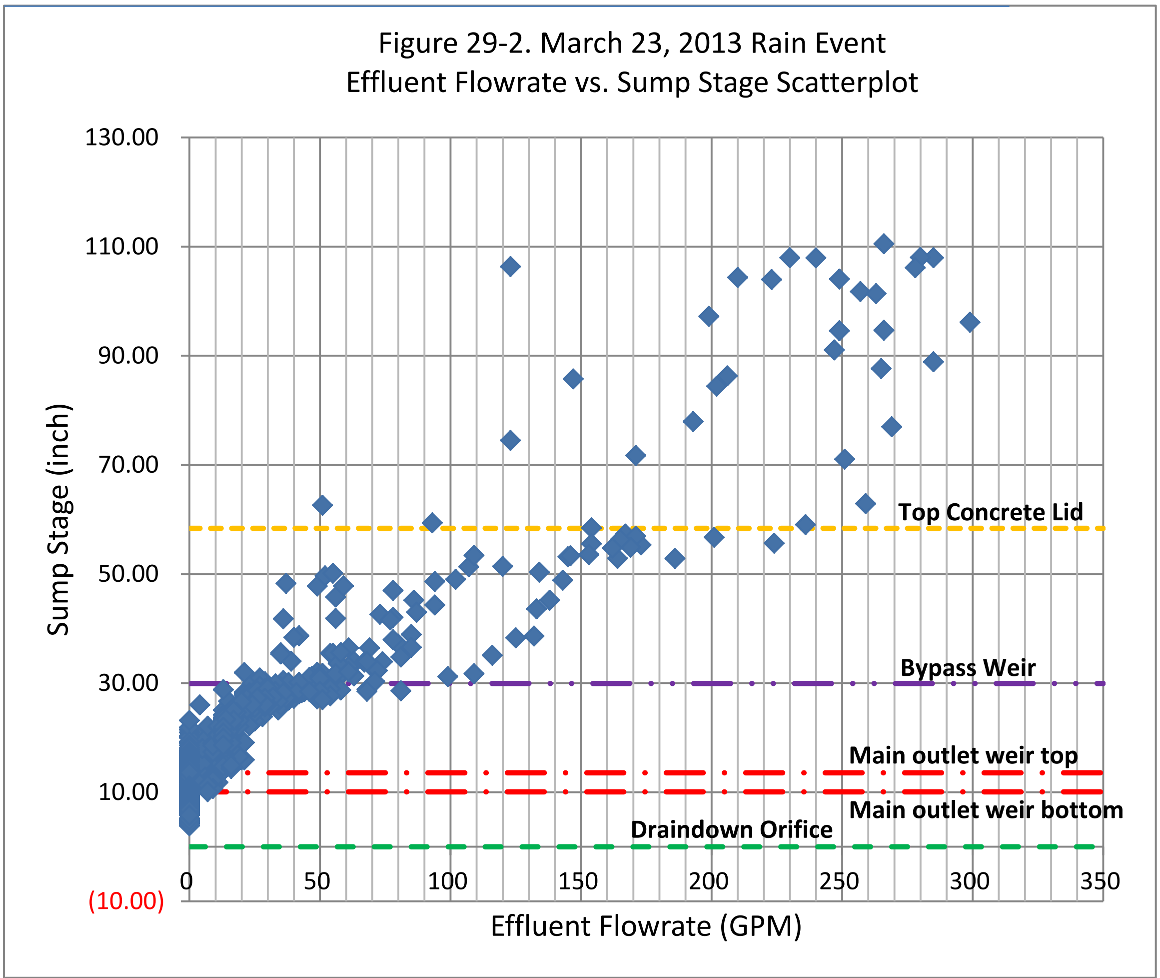
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 29-7. March 23, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	319	419	369	27	26	26
Millipore Membrane Filter, 0.45µm	188	209	199	23	22	22

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 29-8. March 23, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	>48392	>48392
E. Coli	187	60	124	175	82	129
Enterococci	4,611	4,962	4,787	4,106	5,206	4,656

Table 29-9. March 23, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	29	31	30	11	9	10



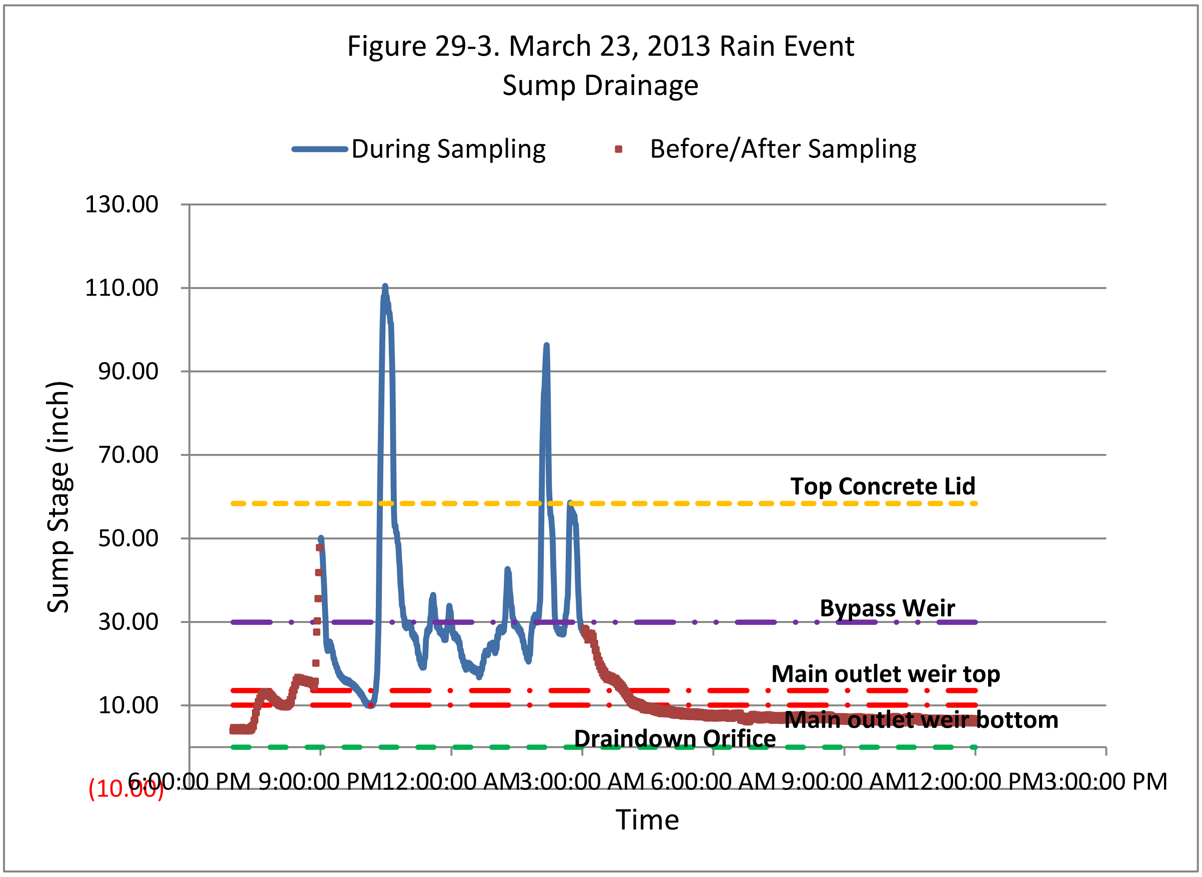


Figure 29-3. March 23, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
130.00
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Sump Stage (inch)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
6:00:00 PM
9:00:00 PM
12:00:00 AM
3:00:00 AM
6:00:00 AM
9:00:00 AM
12:00:00 PM
3:00:00 PM
Time

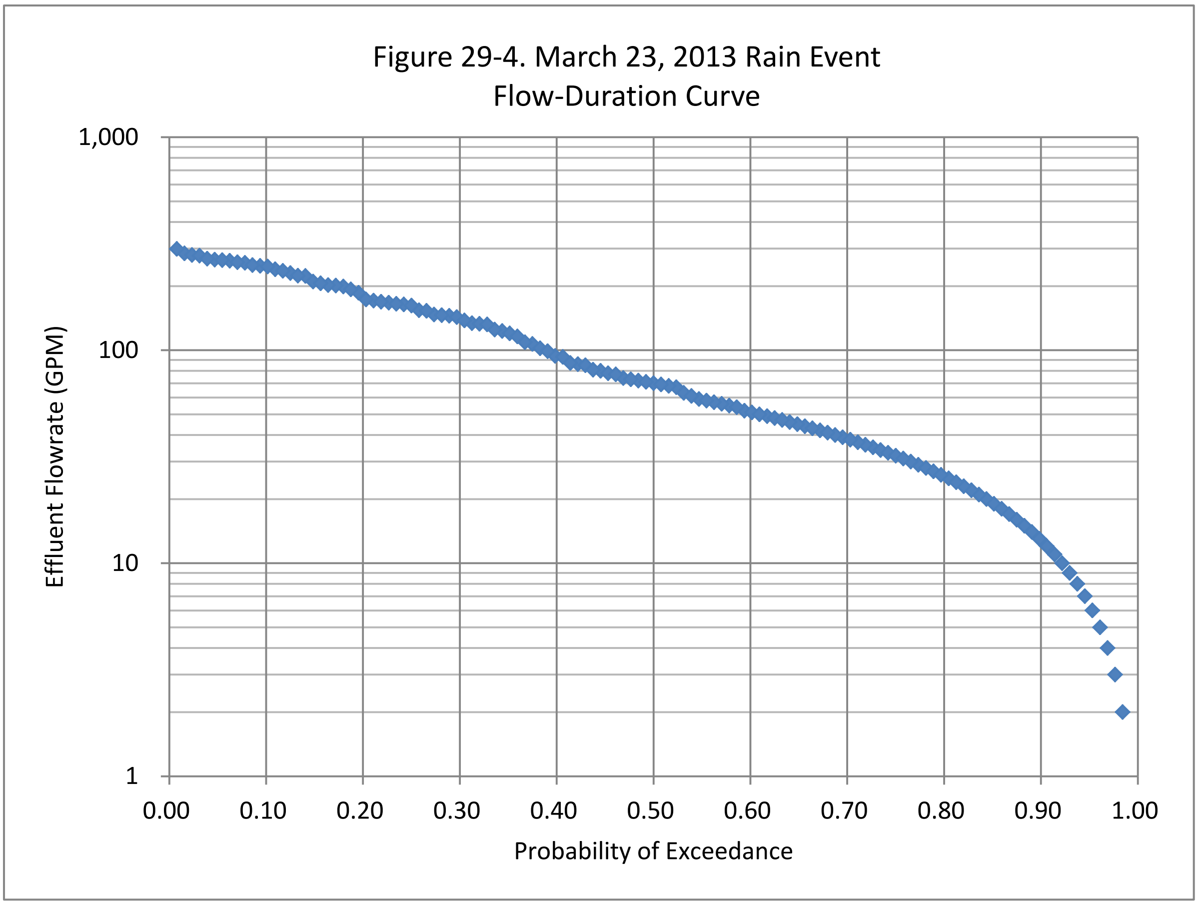
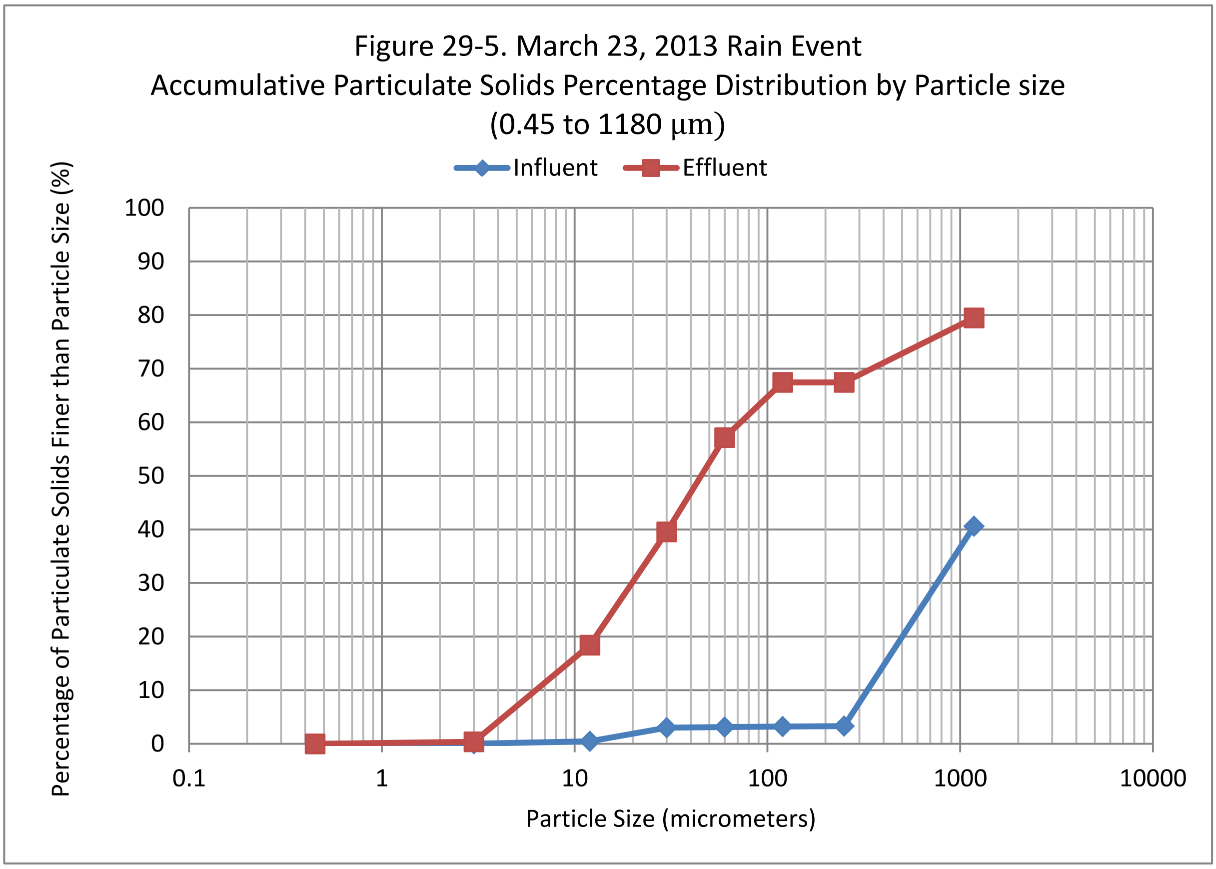
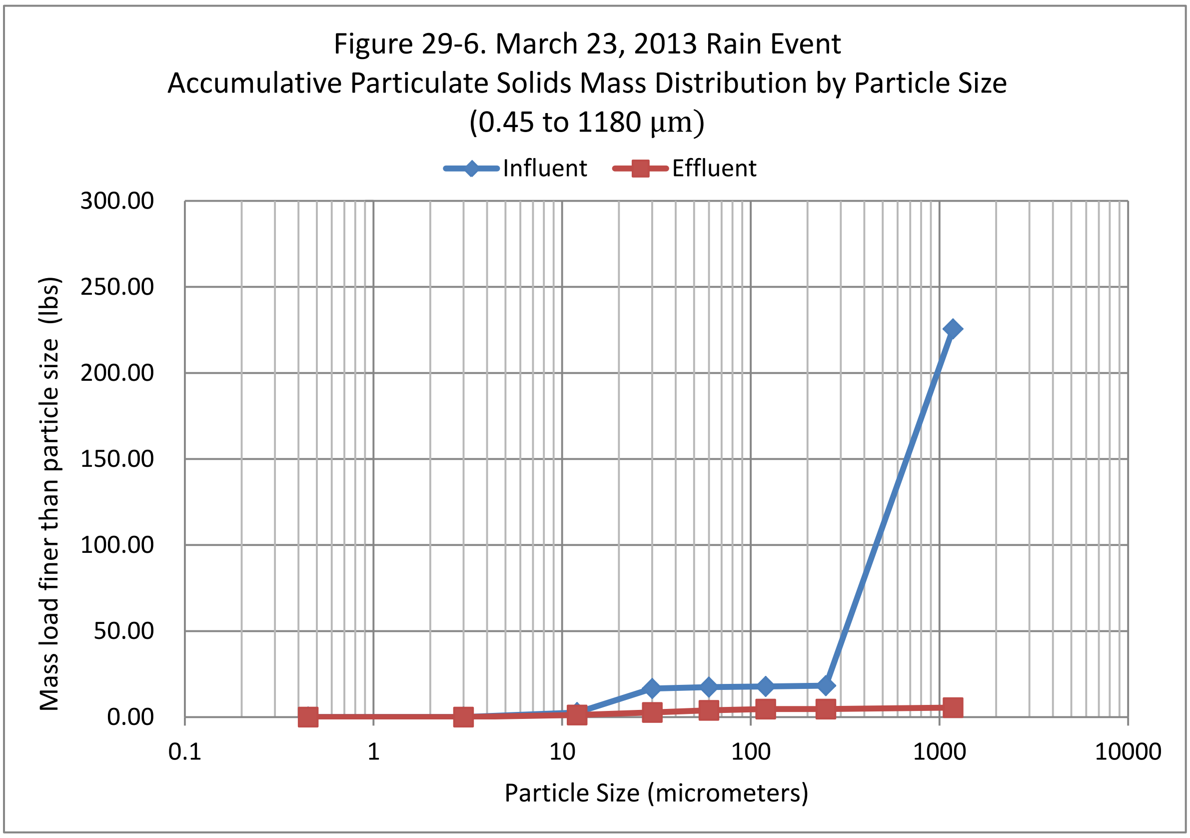


Figure 29-4. March 23, 2013 Rain Event
Flow-Duration Curve
1,000
100
10
1
Effluent Flowrate (GPM)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 330.31 lbs larger than 1180 µm and the effluent had 1.43 lbs larger than 1180 µm (59.42% and 20.53% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 29-10. March 23, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.18	0.15	0.01	0.39	0.03	0.03	0.00	9.38
3 to 12	15.67	6.85	0.47	18.01	2.61	1.26	1.36	51.86
12 to 30	83.94	8.04	2.52	21.14	14.00	1.48	12.52	89.45
30 to 60	4.74	6.69	0.14	17.60	0.79	1.23	-0.44	-55.56
60 to 120	2.53	3.92	0.08	10.32	0.42	0.72	-0.30	-70.73
120 to 250	2.55	0.00	0.08	0.00	0.43	0.00	0.43	100.00
250 to 1180	1243.07	4.57	37.30	12.02	207.34	0.84	206.50	99.59
>1180	1980.32	7.80	59.42	20.53	330.31	1.43	328.88	99.57
Total	3333	38	100.00	100.00	555.93	6.99	548.95	98.74

Table 29-11. March 23, 2013 Rain Event Particle Size Distribution Information				
Particles Size (µm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.01	0.39	0.03	0.03
<12	0.48	18.40	2.64	1.29
<30	2.99	39.54	16.65	2.76
<60	3.14	57.14	17.44	3.99
<120	3.21	67.46	17.86	4.71
<250	3.29	67.46	18.28	4.71
<1180	40.58	79.47	225.62	5.55
>1180	100.00	100.00	555.93	6.99

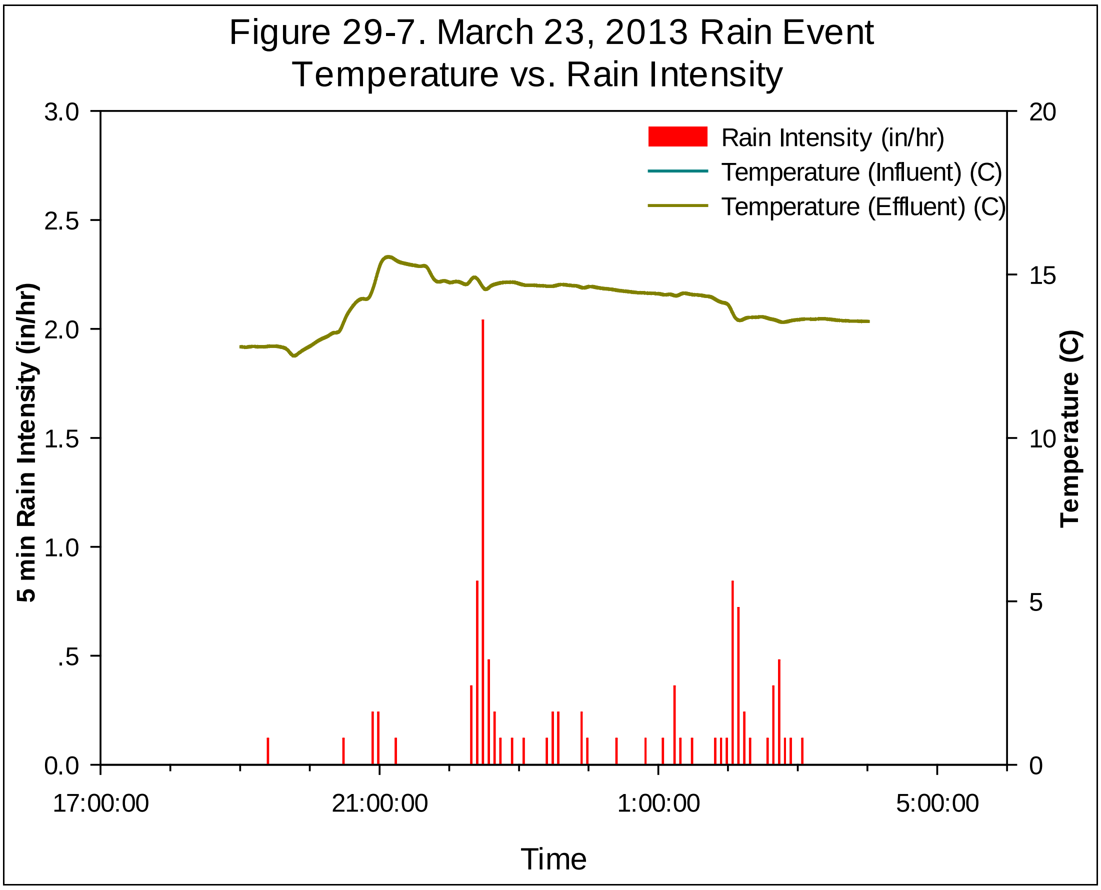


Figure 29-7. March 23, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
20
15
10
5
0
17:00:00
21:00:00
1:00:00
5:00:00
Time

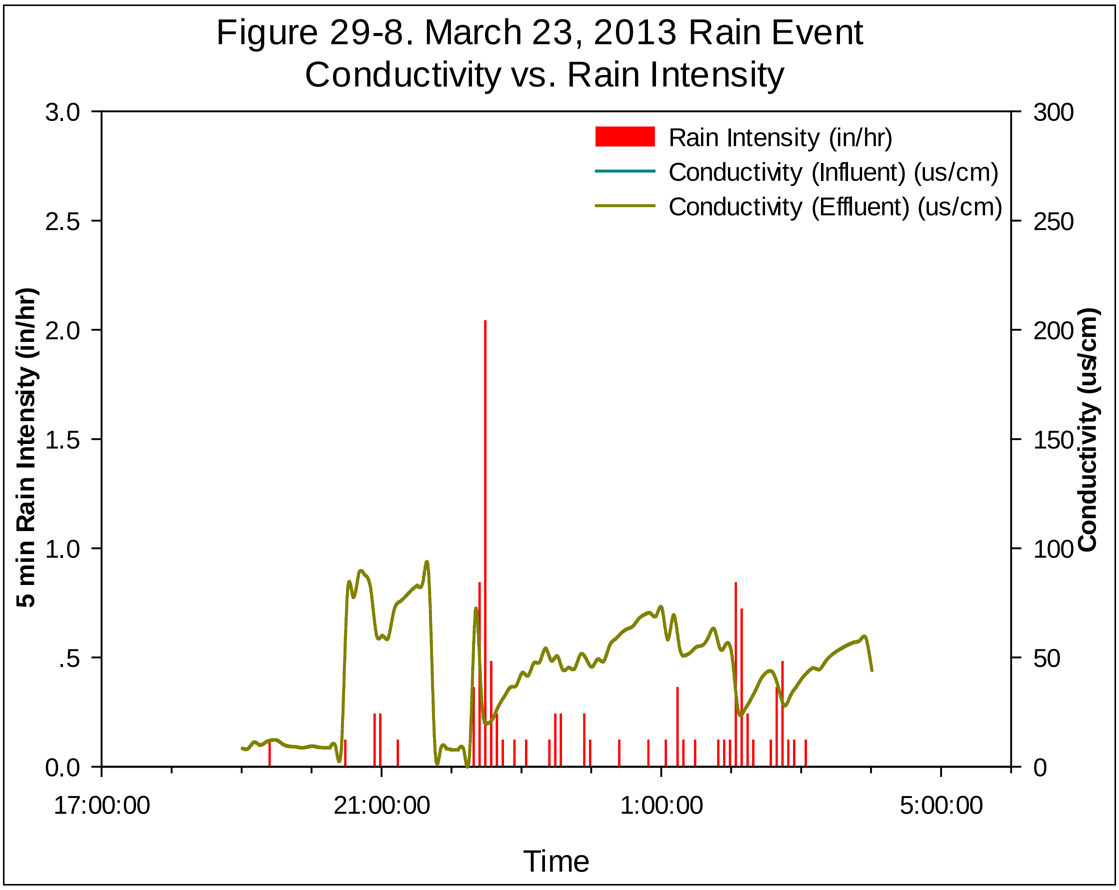


Figure 29-8. March 23, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
300
250
200
150
100
50
0
17:00:00
21:00:00
1:00:00
5:00:00
Time

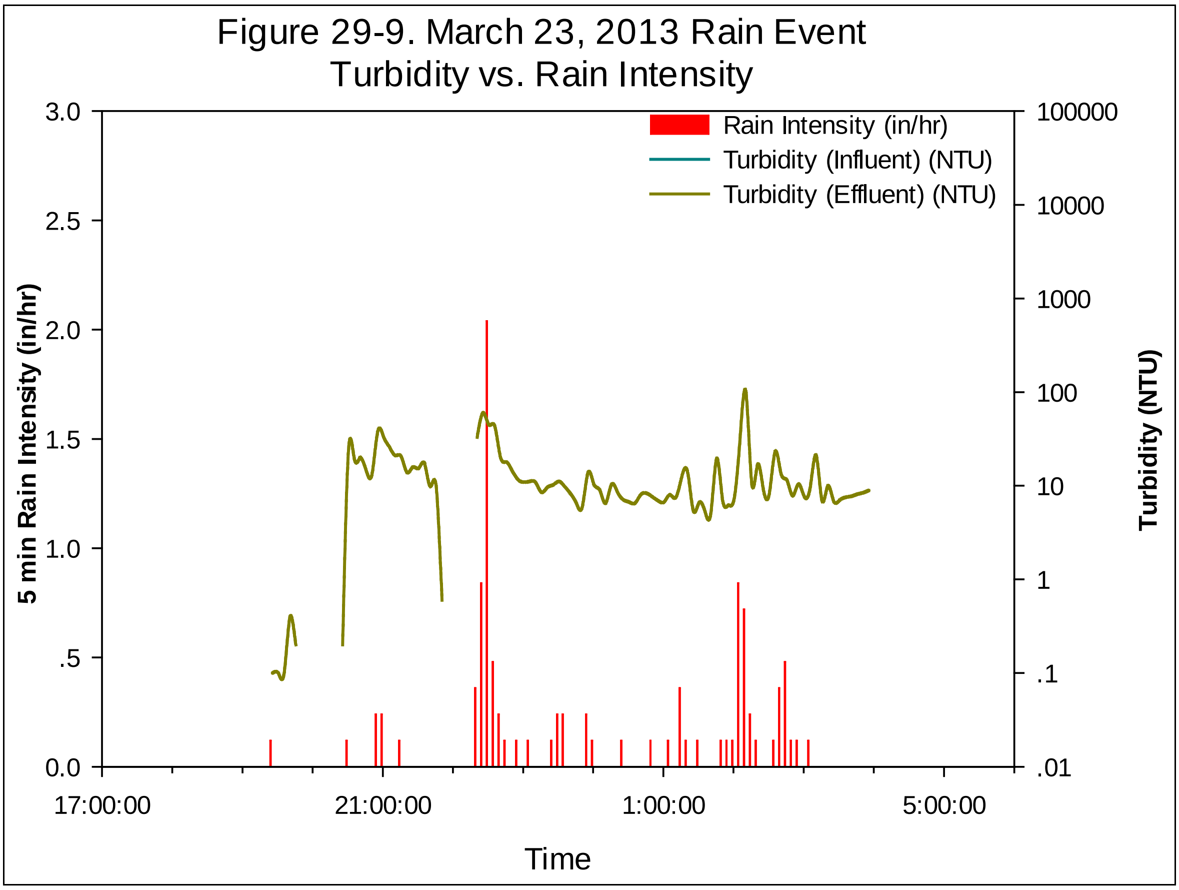
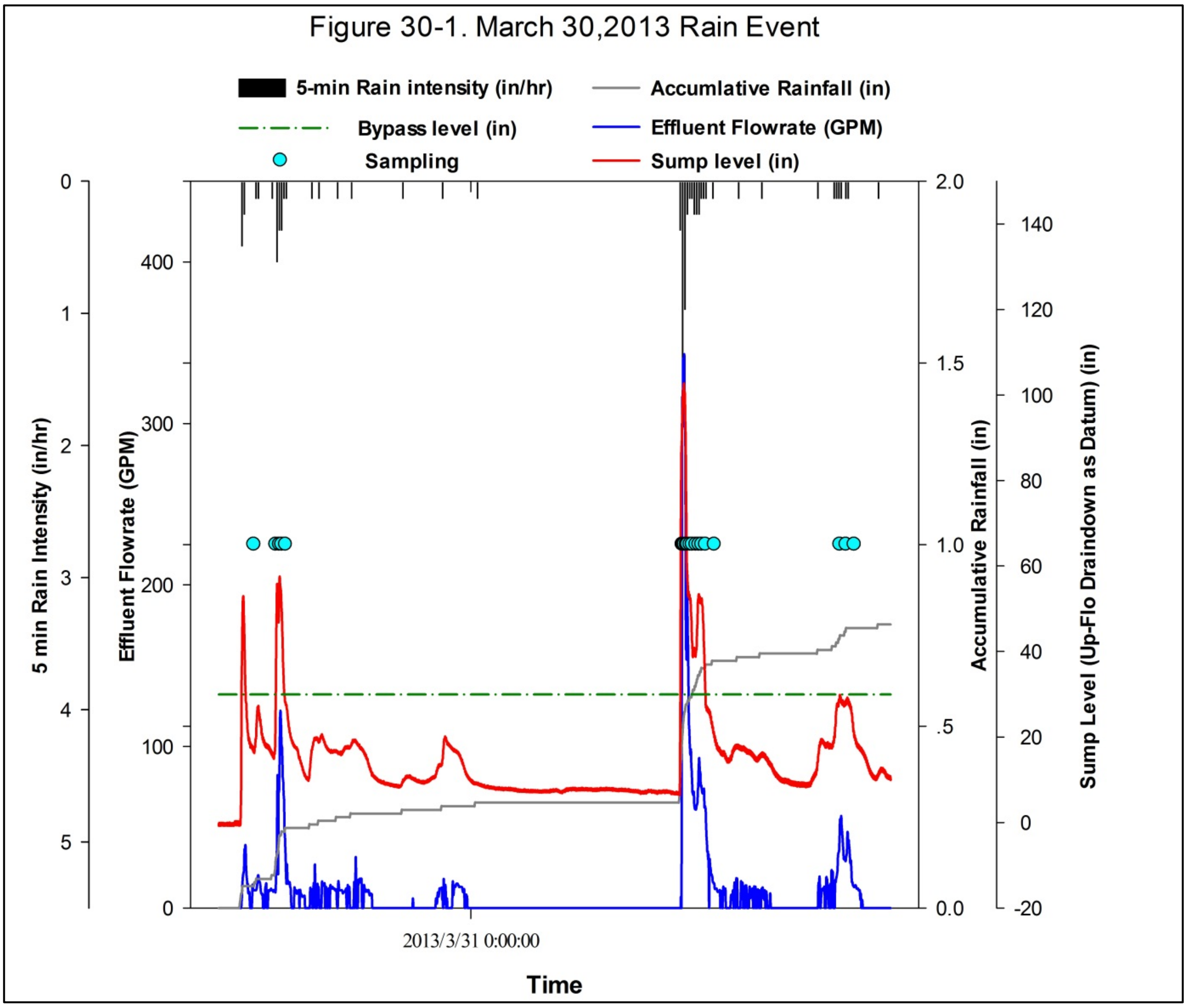


Figure 29-9. March 23, 2013 Rain Event
Turbidity vs. Rain Intensity
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
5 min Rain Intensity (in/hr)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
.5
0.0
100000
10000
1000
100
10
1
.1
.01
17:00:00
21:00:00
1:00:00
5:00:00
Time

Appendix F.30: March 30, 2013 Storm Event Summary



Note: The level of Up-Flo Draindown is set as the datum which is also the lowest water elevation. The depth sensor in the sump is approximately 13.32 inches below this datum. The depth to the depth sensor is inspected periodically during site maintenance.

Table 30-1. Site Information	
Site Name:	Bama Belle Parking Deck
Location:	N(33°12'50") W(87°34'17")
Drainage Area (acres):	0.89
Percentage of Impervious area (%):	68
Runoff Curve Number (CN):	84
Rational Equation C Coefficient:	0.51
Volumetric Runoff Coefficient (Rv)	0.76

Table 30-2. March 30, 2013 Rain Event Characteristics Information			
	Goal	Actual Value	Note
Rain Event Start Date/Time:			2013/3/30 15:45
Rain Event End Date/Time:			2013/3/31 14:32
Total Precipitation (inch):	≥ 0.1	0.78	
Total Runoff Depth (inch):	NA	0.60	
Total Outflow (gallon):	NA	13978	
Rain Duration (hours):	≥ 1	22.78	
Flow Start Date/Time:			2013/3/30 15:49
Flow End Date/Time:			2013/3/31 14:00
Flow Duration (hours):	NA	22.18	
Average Rain Intensity (in/hr):	NA	0.03	
Average Runoff Rate (gallons/min):	NA	11	
Peak 5-min Rain Intensity (in/hr):	NA	1.68	
Peak Runoff Rate (gallons/min):	NA	340	
Peak to Average Runoff Ratio:	NA	32.38	
Bypassed flow volume (gallon):	NA	4602	
Percentage of Bypassed Flow (%):	NA	32.92	
Inter-Event Time since prior rain (hours)	≥ 6.0	156.70	

Table 30-3. March 30, 2013 Rain Event Sampling Information			
	Goal	Actual Value	Note
Number of Subsamples in event:	≥ 10	22	
Volume per Subsample (mL):	250	250	
Total Volume for Event (L):	> 2.5	5.5	The actual volumes of both samples were visually consistent with programmed one
Programmed Passed Flow Volume per Subsample (gallon):	Small Event: 120 Moderate Event: 480 Large Event: 2000	480	
Samples Coverage of total storm flow (%)	75.00	96.09	

Table 30-4. March 30, 2013 Rain Event Water Quality Analysis Information						
All units are in mg/L except pH, Bacteria in MPN, Turbidity in NTU, Conductivity in µS and Temperature in °C						
Constituent	Influent	Effluent	Percentage reduction	Analytical Method	MDL	Laboratory
TSS	86	35	59.3	SM 2540D	1 mg/L	Stillbrook Lab
TSS	389	46	88.2	SM 2540D	1 mg/L	UA Lab
SSC	160	49	69.4	ASTM D3977-97B	1 mg/L	Stillbrook Lab
SSC	879	51	94.2	ASTM D3977-97B	1 mg/L	UA Lab
TDS	50	35	29.7	EPA 160.2	1 mg/L	UA Lab
VSS	77	21	73.4	SM 2540E	1 mg/L	UA Lab
Total N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Dissolved N as N	0.7	0.5	28.6	SM 4500-NH3 C / SM 4110B	0.1 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	NA	SM 4500-NH3 C	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.11	0.16	-45.5	SM 4110B	0.02 mg/L	Stillbrook Lab
Total P as P	0.10	0.42	-320.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Dissolved P as P	0.10	BDL	>80.0	SM 4500-P-E	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	NA	SM 4110B	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cr	0.006	BDL	>16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Cu	0.006	BDL	>16.7	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Pb	0.010	BDL	>50.0	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	NA	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Zn	0.044	0.021	52.3	EPA 200.8	0.005 mg/L	Stillbrook Lab
Dissolved Zn	0.007	0.010	-42.9	EPA 200.8	0.005 mg/L	Stillbrook Lab
Total Coliform	>48392	>48392	NA	IDEXX Method	<1	UA Lab
E. Coli	1100	136	87.6	IDEXX Method	<1	UA Lab
Enterococci	23297	10521	54.8	IDEXX Method	<1	UA Lab
pH	6.71	6.70	0.1	SM 4500-H+ B/ EPA 150	-2.00	UA Lab
Turbidity	117.50	33.05	71.9	SM 2130B/ EPA 180.1	0 NTU	UA Lab
Conductivity	57.3	40.1	30.0	SM 2510B/ EPA 120.6	0 µS	UA Lab
Temperature	16.0	15.5	3.1	SM 212/ EPA 170.1	5 °C	UA Lab

Table 30-5. March 30, 2013 Rain Event SSC Quality Control Table									
Laboratory	Influent (mg/L)			Effluent (mg/L)			Percentage reduction (%)		
	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total	1.5 to 1180 µm particles	> 1180 µm particles	Total
Stillbrook Lab	160	NA*	NA*	49	NA*	NA*	69.4	NA*	NA*
UA Lab	478	401	879	44	7	51	90.8	98.2	94.2

* This analysis does not include the mass of particle greater than 1180 µm since the sample was pre-sieved by the 1180 µm screen before the sample splitting to protect the cone splitter. This mass was analyzed separately by the UA lab.

Table 30-6. March 30, 2013 Rain Event Specific Gravity Quality Control Table						
Coulter Counter	Particle Volume (um^3/L sample)		Mass (mg/L sample)		Specific Gravity (3 to 250 um) (g/cc)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Particles from 3 to 250 um *	47757	22387	189	37	3.9	1.7

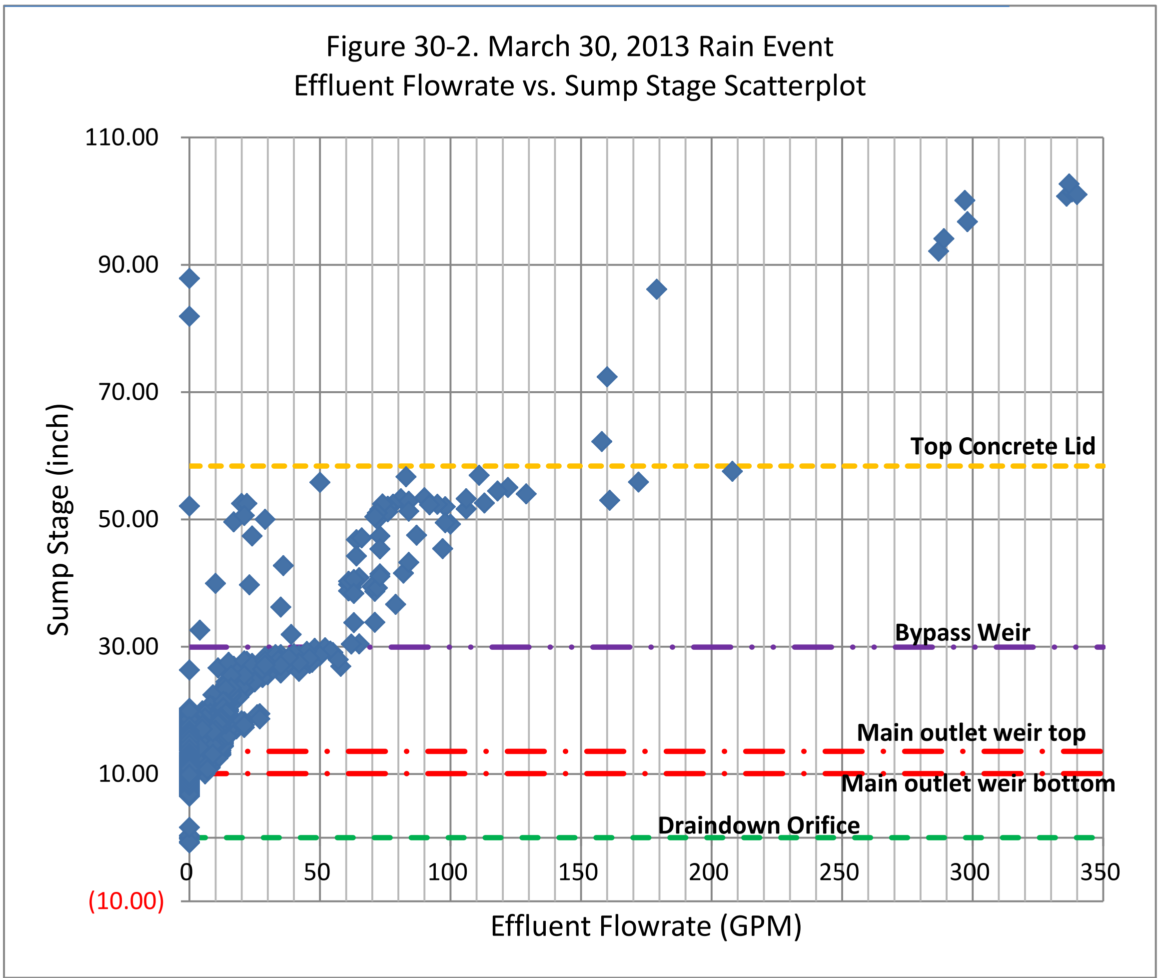
* This particle specific gravity was calculated using the Coulter Counter particle volume data for 3 to 250 um particles along with the measured mass concentration for the same particle size range.

Table 30-7. March 30, 2013 Rain Event TSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	347	432	389	44	48	46
Millipore Membrane Filter, 0.45µm	320	353	337	38	45	42

Note: The average TSS values from Whatman® 934-AH™ Glass Microfiber Filters are reported as the formal TSS results. The TSS values from the 0.45µm membrane filters are used for the particle size distribution calculations and secondarily to test the repeatability of the method and the significance of the different filters types for these small pore sizes.

Table 30-8. March 30, 2013 Rain Event Bacteria Quality Control Table						
	Influent (MPN/100 mL)			Effluent (MPN/100 mL)		
Constituents	Dilution 1 (10X)	Dilution 2 (20X)	Average	Dilution 1 (10X)	Dilution 2 (20X)	Average
Total Coliform	>24196	>48392	>48392	>24196	>48392	>48392
E. Coli	1,160	1,040	1,100	146	126	136
Enterococci	24,196	22,398	23,297	15,531	5,510	10,521

Table 30-9. March 30, 2013 Rain Event VSS Quality Control Table						
	Influent (mg/L)			Effluent (mg/L)		
Filter Type & Pore Size	1	2 (replicate)	Average	1	2 (replicate)	Average
Whatman® 934-AH™ Glass Microfiber Filters, 1.5µm	72	82	77	18	23	21



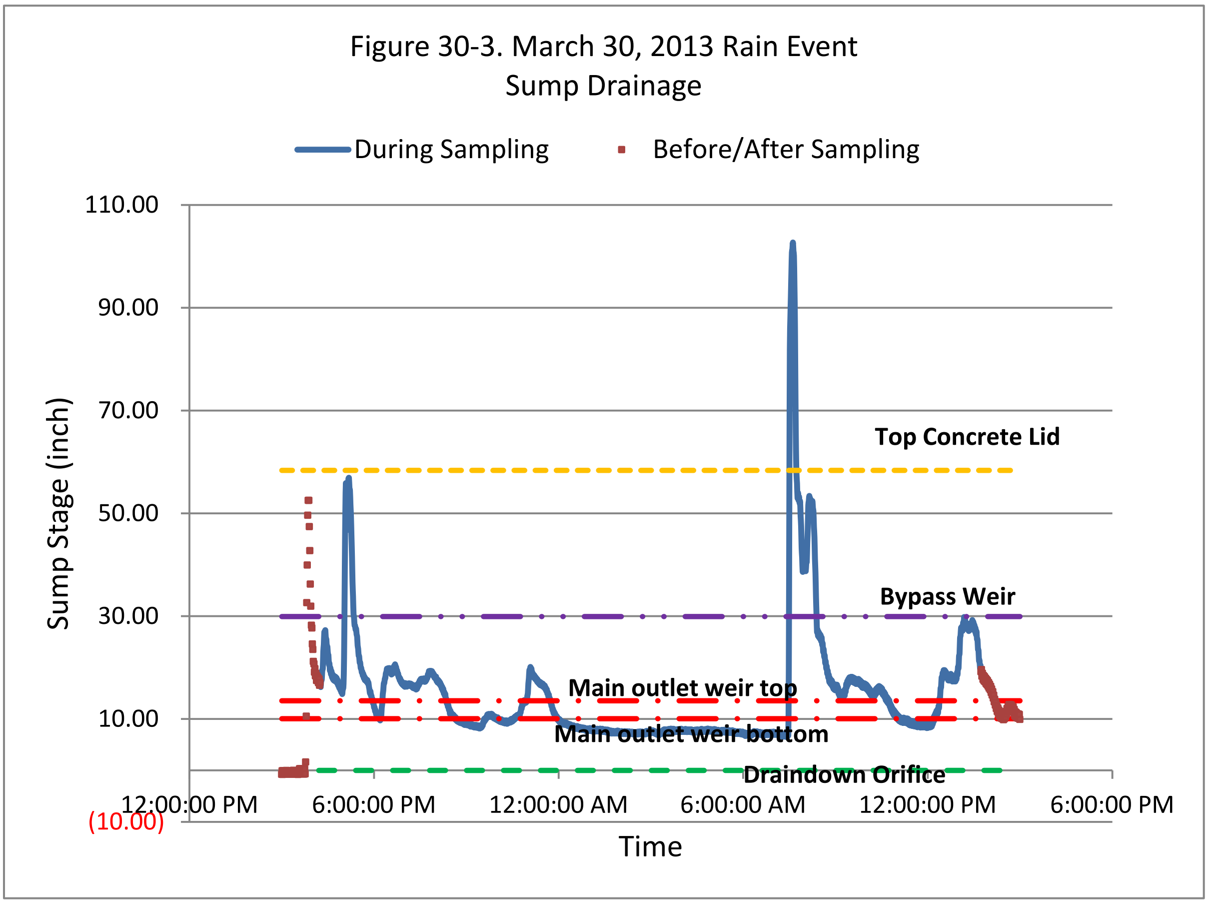


Figure 30-3. March 30, 2013 Rain Event
Sump Drainage
During Sampling
Before/After Sampling
Sump Stage (inch)
110.00
90.00
70.00
50.00
30.00
10.00
(10.00)
Top Concrete Lid
Bypass Weir
Main outlet weir top
Main outlet weir bottom
Draindown Orifice
12:00:00 PM
6:00:00 PM
12:00:00 AM
6:00:00 AM
12:00:00 PM
6:00:00 PM
Time

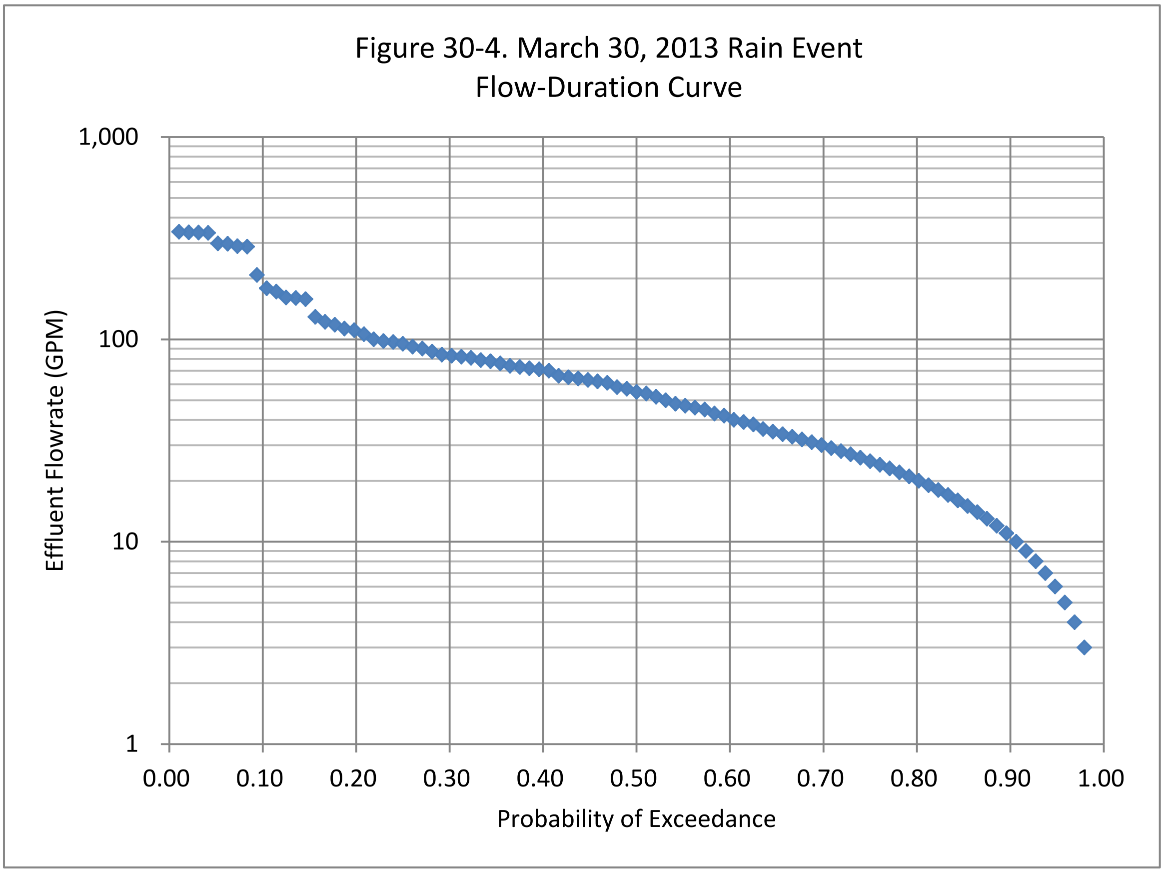
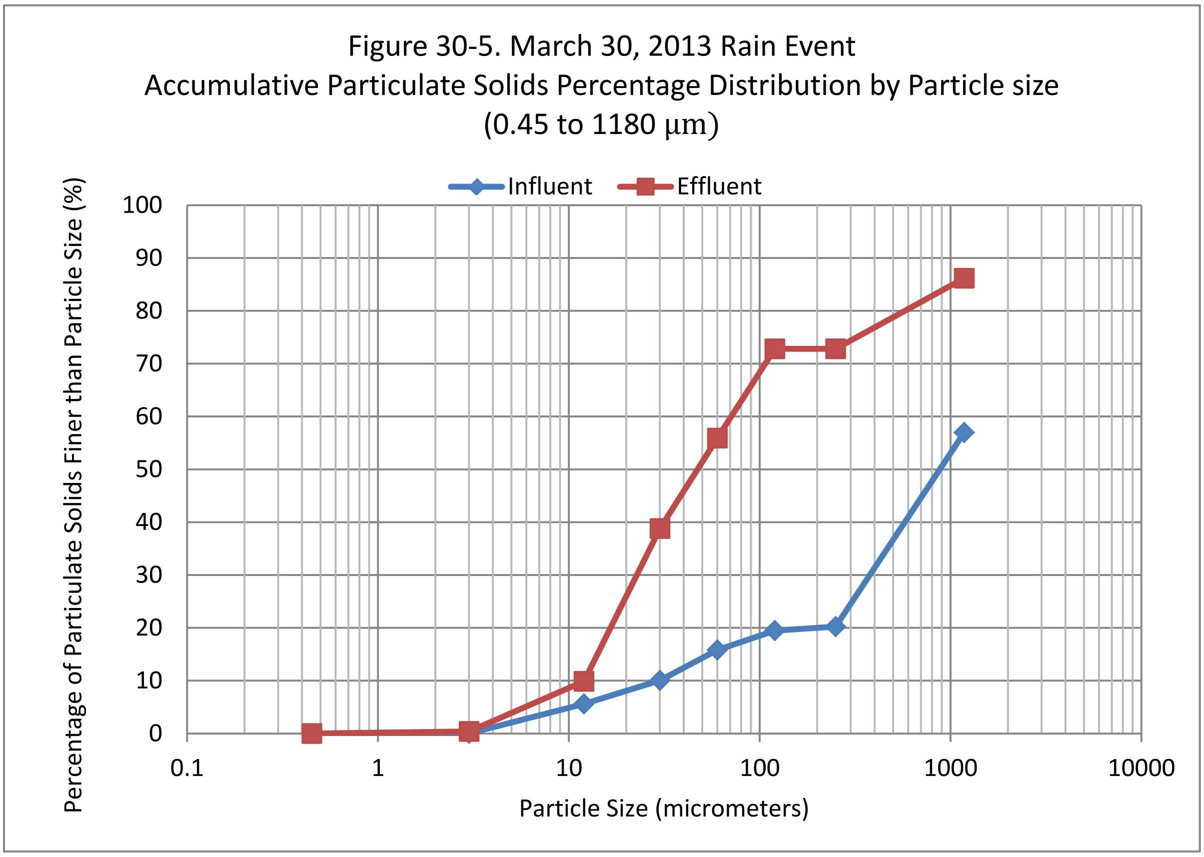
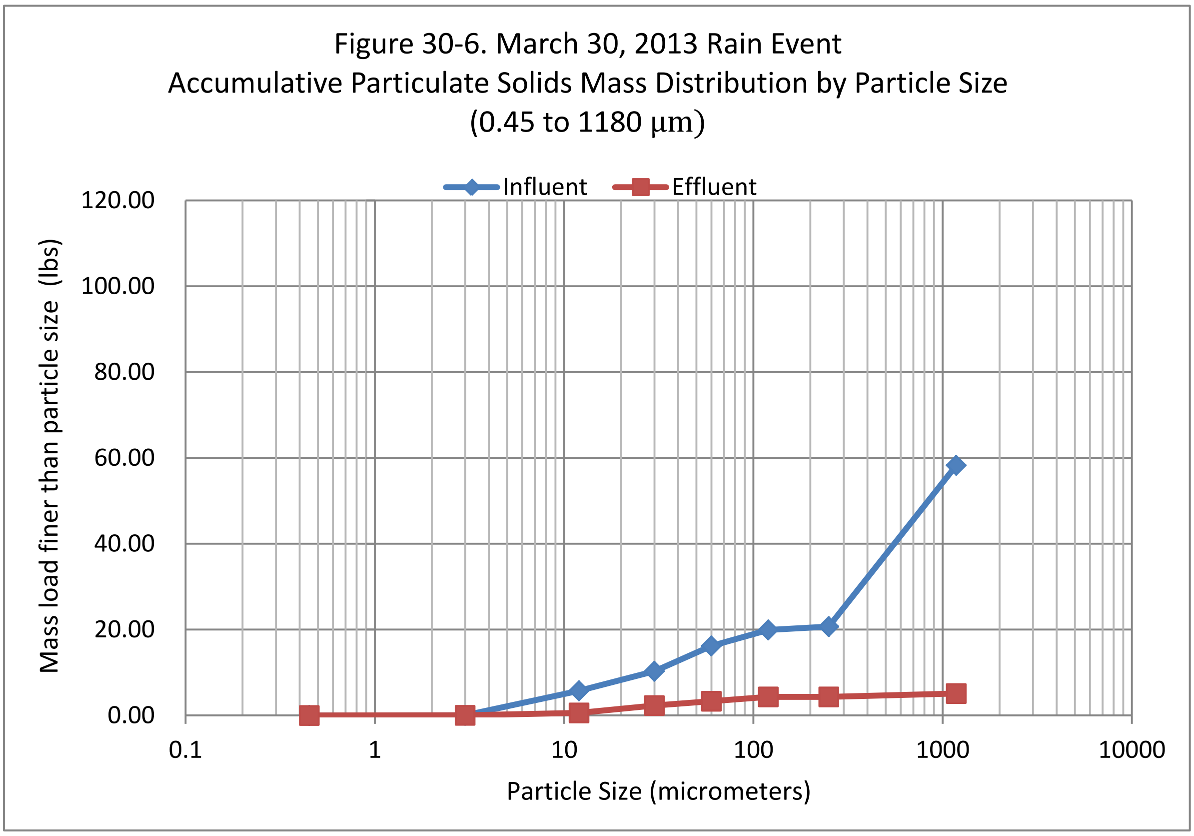


Figure 30-4. March 30, 2013 Rain Event
Flow-Duration Curve
Effluent Flowrate (GPM)
1,000
100
10
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Probability of Exceedance





Not shown: The influent sample had 44.01 lbs larger than 1180 µm and the effluent had 0.82 lbs larger than 1180 µm (43.02% and 13.84% of the total particulate solids load, respectively). The absolute largest particle sizes are not known due to their irregular shape.

Table 30-10. March 30, 2013 Rain Event Particle Size Distribution Information								
	Solids Conc. for the range (mg/L)		Mass Percentage (%)		Mass for the range (lbs)		Total Amount Captured (lbs)	Percentage Reduction by Mass (%)
Particle Size (um)	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent		
0.45 to 3	0.22	0.20	0.02	0.39	0.02	0.02	0.00	5.52
3 to 12	51.93	4.86	5.57	9.48	5.70	0.56	5.14	90.16
12 to 30	41.50	14.86	4.45	28.94	4.55	1.71	2.84	62.40
30 to 60	53.77	8.78	5.77	17.10	5.90	1.01	4.89	82.85
60 to 120	34.10	8.67	3.66	16.90	3.74	1.00	2.74	73.29
120 to 250	7.20	0.00	0.77	0.00	0.79	0.00	0.79	100.00
250 to 1180	342.65	6.86	36.74	13.36	37.58	0.79	36.79	97.90
>1180	401.23	7.10	43.02	13.84	44.01	0.82	43.19	98.14
Total	933	51	100.00	100.00	102.30	5.91	96.38	94.22

Table 30-11. March 30, 2013 Rain Event Particle Size Distribution Information				
Particles Size (μm)	Accumulative Mass Percentage (%)		Accumulative Mass (lbs)	
	Influent (Without Sump)	Effluent	Influent (Without Sump)	Effluent
<0.45	0.00	0.00	0.00	0.00
<3	0.02	0.39	0.02	0.02
<12	5.59	9.86	5.72	0.58
<30	10.04	38.81	10.27	2.30
<60	15.81	55.91	16.17	3.31
<120	19.46	72.80	19.91	4.31
<250	20.24	72.80	20.70	4.31
<1180	56.98	86.16	58.29	5.10
>1180	100.00	100.00	102.30	5.91

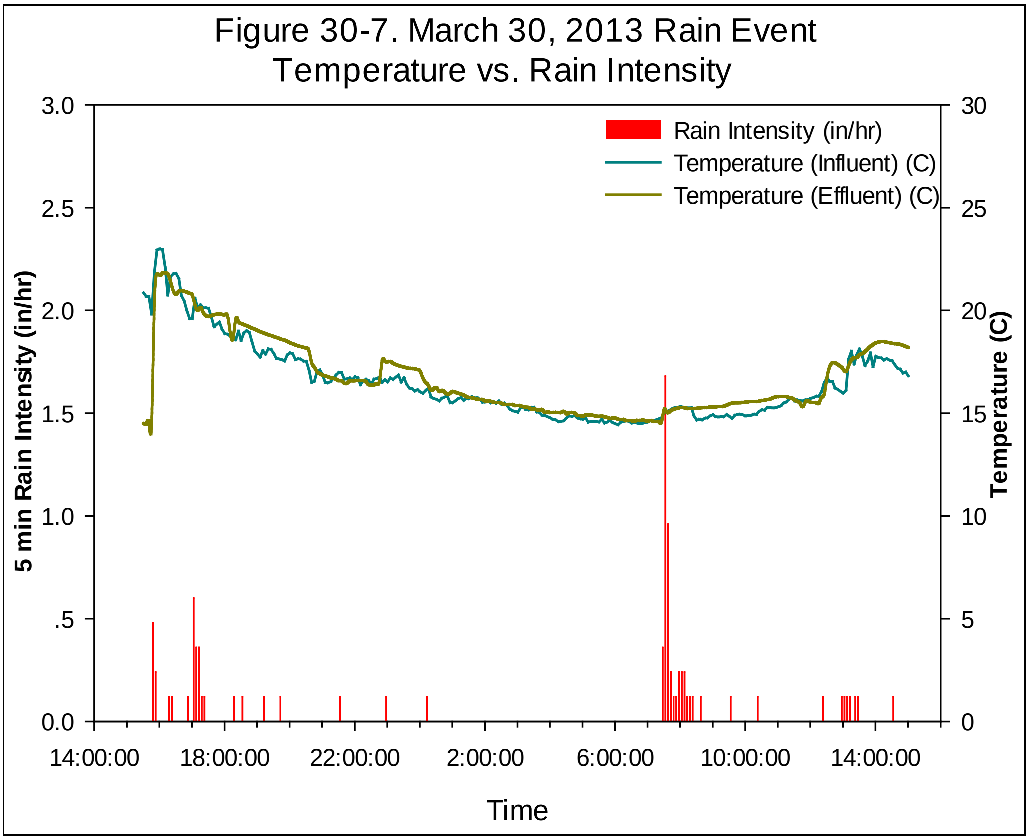


Figure 30-7. March 30, 2013 Rain Event
Temperature vs. Rain Intensity
Rain Intensity (in/hr)
Temperature (Influent) (C)
Temperature (Effluent) (C)
5 min Rain Intensity (in/hr)
Temperature (C)
3.0
2.5
2.0
1.5
1.0
.5
0.0
30
25
20
15
10
5
0
14:00:00
18:00:00
22:00:00
2:00:00
6:00:00
10:00:00
14:00:00
Time

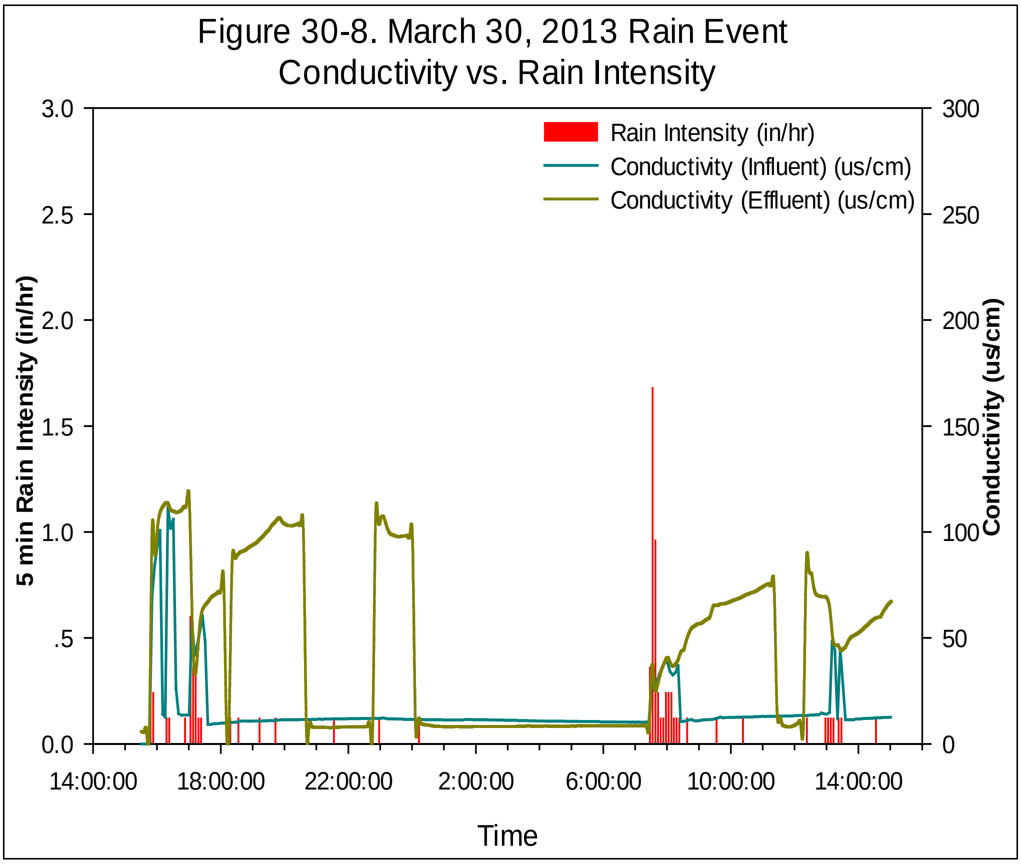


Figure 30-8. March 30, 2013 Rain Event
Conductivity vs. Rain Intensity
Rain Intensity (in/hr)
Conductivity (Influent) (us/cm)
Conductivity (Effluent) (us/cm)
5 min Rain Intensity (in/hr)
Conductivity (us/cm)
3.0
2.5
2.0
1.5
1.0
.5
0.0
300
250
200
150
100
50
0
14:00:00
18:00:00
22:00:00
2:00:00
6:00:00
10:00:00
14:00:00
Time

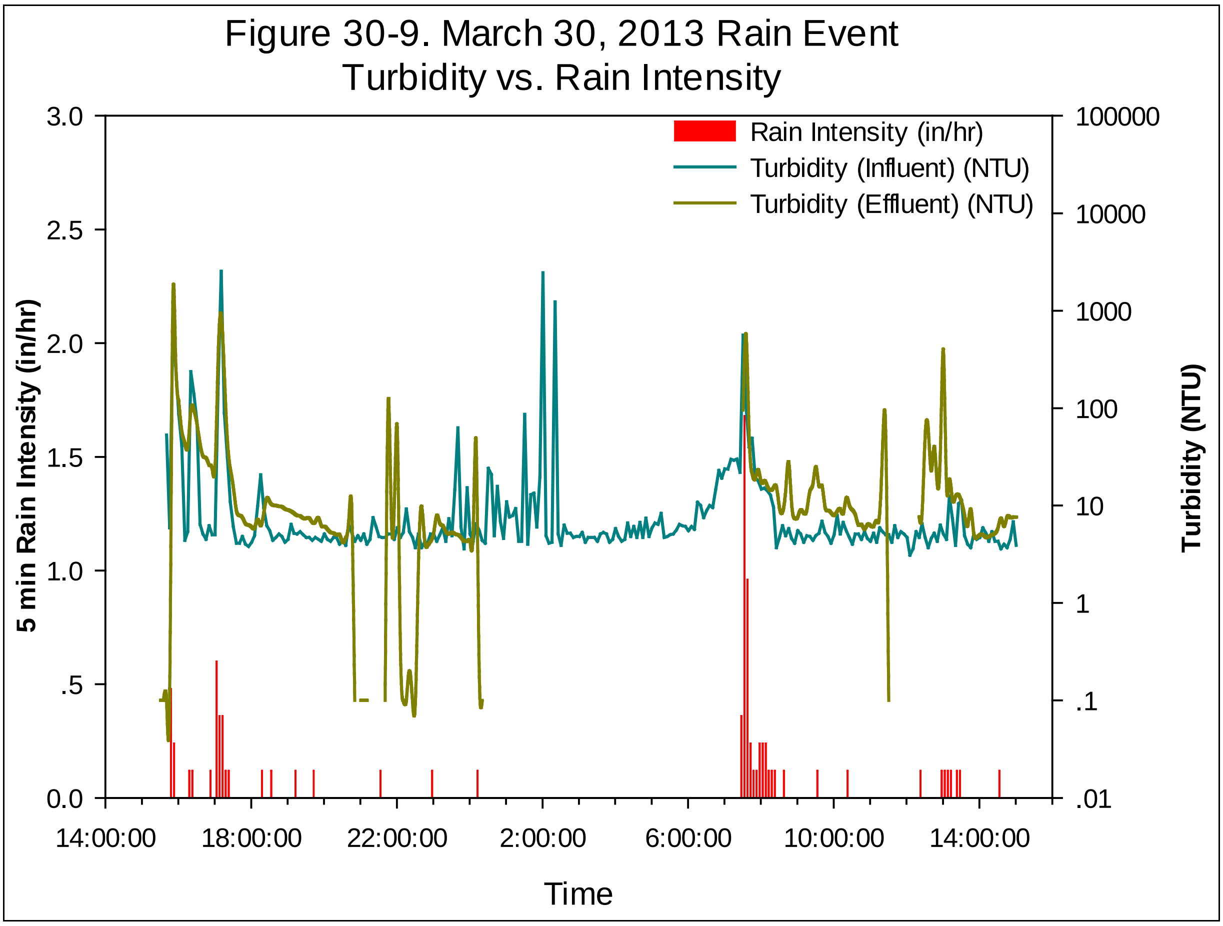


Figure 30-9. March 30, 2013 Rain Event
Turbidity vs. Rain Intensity
5 min Rain Intensity (in/hr)
3.0
2.5
2.0
1.5
1.0
.5
0.0
Rain Intensity (in/hr)
Turbidity (Influent) (NTU)
Turbidity (Effluent) (NTU)
100000
10000
1000
100
10
1
.1
.01
Turbidity (NTU)
14:00:00
18:00:00
22:00:00
2:00:00
6:00:00
10:00:00
14:00:00
Time

Appendix G.1: June 28, 2012 Field and Laboratory Blank Water Quality Analysis

All units are in mg/L except pH, Bacteria in MPN/100mL, Turbidity in NTU, Conductivity in µS and Temperature in °C					
Constituent	Field Blank Influent	Field Blank Effluent	Laboratory Blank	MDL	Laboratory
TSS	1	BDL	BDL	1 mg/L	UA Lab
SSC	BDL	BDL	BDL	1 mg/L	UA Lab
TDS	6	3	BDL	1 mg/L	UA Lab
VSS	1	BDL	BDL	1 mg/L	UA Lab
Total N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Dissolved N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Total P as P	0.09	0.12	BDL	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Nitrate as N	0.03	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Coliform	4839	31	1	<1	UA Lab
E. Coli	< 1	< 1	< 1	<1	UA Lab
Enterococci	4	< 1	< 1	<1	UA Lab
pH	6.58	6.71	6.87	-2.00	UA Lab
Turbidity	0.493	0.351	0.086	0 NTU	UA Lab
Conductivity	1.89	1.88	0.56	0 µS	UA Lab
Temperature	29.8	29.7	25.1	5 °C	UA Lab

Correction Analyses:

Total P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Coliform	602	31	1	<1	UA Lab

Appendix G.2: September 13, 2012 Field and Laboratory Blank Water Quality Analysis

All units are in mg/L except pH, Bacteria in MPN/100mL, Turbidity in NTU, Conductivity in µS and Temperature in °C					
Constituent	Field Blank Influent	Field Blank Effluent	Laboratory Blank	MDL	Laboratory
TSS	2	BDL	BDL	1 mg/L	UA Lab
SSC	BDL	BDL	BDL	1 mg/L	UA Lab
TDS	1	BDL	BDL	1 mg/L	UA Lab
VSS	BDL	BDL	BDL	1 mg/L	UA Lab
Total N as N	0.1	BDL	BDL	0.1 mg/L	Stillbrook Lab
Dissolved N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Total P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Nitrate as N	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Coliform	816	236	3	<1	UA Lab
E. Coli	40	31	BDL	<1	UA Lab
Enterococci	25	20	BDL	<1	UA Lab
pH	6.78	6.93	6.95	-2.00	UA Lab
Turbidity	2.10	0.34	0.05	0 NTU	UA Lab
Conductivity	1.30	1.03	0.44	0 µS	UA Lab
Temperature	28.3	27.8	20.3	5 °C	UA Lab

Appendix G.3: November 2, 2012 Field and Laboratory Blank Water Quality Analysis

All units are in mg/L except pH, Bacteria in MPN/100mL, Turbidity in NTU, Conductivity in µS and Temperature in °C					
Constituent	Field Blank Influent	Field Blank Effluent	Laboratory Blank	MDL	Laboratory
TSS	1	BDL	BDL	1 mg/L	UA Lab
SSC	1	0	BDL	1 mg/L	UA Lab
TDS	1	1	BDL	1 mg/L	UA Lab
VSS	BDL	BDL	BDL	1 mg/L	UA Lab
Total N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Dissolved N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Total P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Nitrate as N	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Coliform	201	210	1	<1	UA Lab
E. Coli	3	2	< 1	<1	UA Lab
Enterococci	< 1	< 1	< 1	<1	UA Lab
pH	6.78	6.88	6.96	-2.00	UA Lab
Turbidity	0.17	0.14	0.05	0 NTU	UA Lab
Conductivity	1.63	0.97	0.42	0 µS	UA Lab
Temperature	26.2	26.0	24.8	5 °C	UA Lab

Appendix G.4: January 11, 2013 Field and Laboratory Blank Water Quality Analysis

All units are in mg/L except pH, Bacteria in MPN/100mL, Turbidity in NTU, Conductivity in µS and Temperature in °C					
Constituent	Field Blank Influent	Field Blank Effluent	Laboratory Blank	MDL	Laboratory
TSS	BDL	BDL	BDL	1 mg/L	UA Lab
SSC	BDL	BDL	BDL	1 mg/L	UA Lab
TDS	1	1	BDL	1 mg/L	UA Lab
VSS	BDL	BDL	BDL	1 mg/L	UA Lab
Total N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Dissolved N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Total P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Nitrate as N	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Coliform	157	56	<1	<1	UA Lab
E. Coli	<1	1	<1	<1	UA Lab
Enterococci	2	< 1	< 1	<1	UA Lab
pH	6.89	6.91	6.96	-2.00	UA Lab
Turbidity	0.21	0.17	0.06	0 NTU	UA Lab
Conductivity	4.23	4.48	1.15	0 µS	UA Lab
Temperature	11.0	10.8	10.0	5 °C	UA Lab

Appendix G.5: April 3, 2013 Field and Laboratory Blank Water Quality Analysis

All units are in mg/L except pH, Bacteria in MPN/100mL, Turbidity in NTU, Conductivity in µS and Temperature in °C

Constituent	Field Blank Influent	Field Blank Effluent	Laboratory Blank	MDL	Laboratory
TSS	BDL	BDL	BDL	1 mg/L	UA Lab
SSC	BDL	BDL	BDL	1 mg/L	UA Lab
TDS	4	2	BDL	1 mg/L	UA Lab
VSS	BDL	BDL	BDL	1 mg/L	UA Lab
Total N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Dissolved N as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Total P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved P as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Ammonia as N	BDL	BDL	BDL	0.1 mg/L	Stillbrook Lab
Nitrate as N	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Dissolved Orthophosphate as P	BDL	BDL	BDL	0.02 mg/L	Stillbrook Lab
Total Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cd	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cr	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Cu	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Pb	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Dissolved Zn	BDL	BDL	BDL	0.005 mg/L	Stillbrook Lab
Total Coliform	5.2	7.4	2.0	<1	UA Lab
E. Coli	<1	<1	<1	<1	UA Lab
Enterococci	<1	< 1	< 1	<1	UA Lab
pH	6.91	6.92	6.97	-2.00	UA Lab
Turbidity	0.25	0.24	0.19	0 NTU	UA Lab
Conductivity	3.79	4.80	0.76	0 µS	UA Lab
Temperature	15.0	14.9	12.0	5 °C	UA Lab