PROJECT REPORT

FOR

Environmental Protection Agency (EPA)
Engineering Services Grant
Best Management Practice (BMP) Effectiveness
in Pollutant Reduction
and Impact on Receiving Stream Water Quality
Study

OCTOBER 2007

Prepared for:

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October 29, 2007

Mrs. Alisa Max, P.E.
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Re: Best Management Practice (BMP) Effectiveness in Pollutant Reduction and Impact on Receiving Stream Water Quality Study
C&B Project Number 031384.100
Final Report

Dear Mrs. Max,

Please find enclosed the final report for the above project. In order to be consistent with your other projects, we tried to remain as consistent in format as possible to the draft report by PBS&J for the Basin K542-00-00 study.

Thank you for the opportunity to work on this project with you. If you have any questions concerning this report, or the development of this site, please call me at 713-803-2118.

Very truly yours,

CARTER & BURGESS, INC.

Dwayne E. Culp, P.E.
Senior Project Manager & Associate

DEC:dlm

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Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
AVFM	area velocity flow meter
BDL	below detection limit
BMP	best management practices
BOD_5	biochemical oxygen demand 5-day
CMP	corrugated metal pipe
COD	chemical oxygen demand
CV	coefficient of variation
DQO	data quality objective
EMC	event mean concentration
EPA	Environmental Protection Agency
FS	flow station
HCFCD	Harris County Flood Control District
HCWPG	Harris County Public Infrastructure Department Watershed Protection Group
H-GAC	Houston-Galveston Area Council
H&H	hydrology and hydraulic
ID	inside diameter
MS	monitoring station
NPDES	National Pollutant Discharge Elimination System
NURP	Nationwide Urban Runoff Program
O&M	operation and maintenance
PPCC	probability plot correlation coefficient
PSD	particle size distribution
SSC	suspended sediment concentration
SWMP	Storm Water Management Program
SWQMP	Storm Water Quality Management Plan
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TSS	total suspended solids

1.0 Introduction

In November 1990, the Environmental Protection Agency (EPA) of the United States Government published rules governing the discharge of municipal separate storm sewer systems (MS4s) requiring that operators serving a population of 100,000 or more obtain coverage under an individual permit for discharge of that stormwater into waters of the United States, (55 FR 47990). In December 1999, (64 FR 68722), EPA published their Phase II regulations which created a general permit for designated small MS4s. On August 13, 2007 Texas Commission on Environmental Quality signed into effect TXR040000 which implements the requirements for permits for Small MS4s in Texas. Among other things, these regulations require MS4s to reduce pollutants from areas of new development and significant redevelopment. Harris County and the City of Houston enacted regulations and ordinances requiring developers to treat storm water runoff. Many developers build detention ponds.

The purpose of this report is to provide storm water quality data for two storm water quality detention ponds designed for first flush treatment in Harris County. This will add to the knowledge of how storm water quality detention ponds function in. Harris County.

1.1 Contract

On December 20, 2004, Harris County Public Infrastructure Department Watershed Protection Group ("HCWPG") retained Carter & Burgess, Inc. under an Agreement for Professional Engineering Services (Harris County Purchase Order No. PO84178, PO89219, and P100917) to study the effectiveness of Best Management Practices (BMPs) implemented to reduce pollutants in receiving streams in support of a federal grant from EPA. Under these authorizations, Carter & Burgess, Inc. was to provide:

1. Best Management Practices Review

The Best Management Practice (BMP) Review consists of the following items.

1) Complete a Preliminary Screening of the Best Management Practices currently implemented in unincorporated Harris County. Screen implemented BMPs for design criteria. Keep all BMPs that are storm water quality detention ponds designed to treat the first ½ inch of storm water runoff. Prioritize the various ponds based upon accessibility, type of development, consistency in the serviced development, degree of on-going construction, location, and maintenance. Visit and photograph each site including inlet and outlet.
2) Based upon the prioritization, recommend candidate sites for sampling to Harris County. Prepare a letter report, and a short presentation as requested by Harris County. Through Harris County contact each of the candidate sites to request permission to operate a sampling system.
3) Complete a Detailed Review of all Best Management Practices implemented in Harris County and City of Houston. Categorize the BMPs by type, type of

development serviced, and design criteria. Attempt to procure as-built drawings for those BMPs that do not already have them. Review design characteristics as compared to land size, development type and expected pollutants.
4) Select, with the County's assistance, two ponds for field sampling and monitoring of approximately 12-18 runoff events per item 2.
5) Prepare a detailed report summarizing the findings.

2. Field Sampling and Monitoring

The field sampling consists of the following:

1) The field sampling will be completed under the review of a Quality Assurance Project Plan (QAPP) that has been previously approved by EPA. Carter & Burgess, Inc. will produce a Quality Assurance Plan (QAP) that complies with the QAPP, and assures that all components of the QAPP are implemented. Carter and Burgess will implement the QAP, and require all sampling and laboratory work to comply with it.
2) Carter & Burgess will provide for sampling and laboratory analysis necessary to comply with the QAPP. ESA, Inc. has been selected to provide sampling services. Accutest has been selected to provide laboratory services.
3) Automatic sampling equipment will be purchased, installed, and operated by ESA, Inc. Samples will be taken for the parameters listed in Section 3. Sample protocol will follow the QAP.

3. Water Quality Modeling

The water quality modeling consists of the following:

1) Determination of appropriate models.
2) Implementation of the model including site specific calibration for 66-75% of the events for each pond.
3) Verification of the model for each of the last 25-33% of the events.
4) Comparison of the models for the two ponds to remove site specific conditions if possible.
5) Justification of the use of the models (or not) for use elsewhere in Harris County.
6) Preparation of a summary report with recommendations.

4. Final Report

The final report shall be a compilation, and completion of all data gathered during this study. The final report will include all data in a format appropriate for publishing in the ASCE's BMP protocols entitled Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements, April 2002.

1.2 Background

Under its National Pollutant Discharge Elimination System ("NPDES") stormwater permit, Harris County must develop and implement a Storm Water Management Program ("SWMP") that addresses pollutant discharges from areas of New Development and

Significant Redevelopment. To address these discharges, the County requires land developers to design and implement a Storm Water Quality Management Plan ("SWQMP") for new properties that sometimes include the use of stormwater quality ponds or basins as stormwater best management practices ("BMP"). However, the effectiveness of these facilities has not been evaluated in Harris County through systematic BMP performance monitoring.

In order to address concerns over local BMP effectiveness, the HCWPG contracted Carter & Burgess, Inc. to conduct long-term systematic stormwater quality monitoring at two detention basins in Harris County serving two different land uses, and collect samples from a minimum of 12 events for each basin at the inlet and outlet of each of these ponds. Under a contract with the University of Houston, titled "Harris County Best Management Practices Characterization" a methodology for selecting optimal sites for sampling was developed. The results of their study are included in the Cleveland *et al.* report (2005) submitted previously.

1.3 Monitoring Goals

HCWPG desires comparative performance information for the two land uses. Sampling data will be submitted to the ASCE's National Storm Water BMP database. Twelve samples were to be collected from each of the sites at both the inlet and outlet; one at the detention pond servicing the Oak Landing subdivision, and one at the detention pond servicing the North Vista apartment complex. After repeatedly damaged sampling equipment, the Oak Landing site was abandoned, and the equipment relocated to the pond at Fairfax Village Section 2 (called Treaschwig Rd.).

The results of the program, for which the results are herein presented includes the sampling, laboratory notes, and modeling required above. The information obtained from this project should allow Harris County to evaluate the relative performance of each type of pond in Harris County. The results can be used to help Harris County evaluated the effectiveness of their regulations on ponds in Harris County, and determine minimum standards for treatment systems for both pond and non-pond systems.

1.4 Document Organization

This document is organized into eight sections as follows:

Section 1 – Introduction: Section 1 provides the background of the agreement between Harris County and Carter & Burgess, Inc., the purpose of the project, and document organization.

Section 2 – Site Information: Section 2 discusses the basin location, watershed characteristics, precipitation and hydrology information, and the basin purpose and design.

Section 3 – Sampling Activities: Section 3 summarized the sampling and analytical methods used in this study.

Section 4 – Monitoring Results: Section 4 summarizes the storm event data, the laboratory results, and the quality assurance findings of the monitoring activities.

Section 5 – Statistical Analysis: Section 5 presents the statistical analysis of the results, including summary statistics, analysis of variance, box-whisker plots, effluent probability plots, and grouped analysis.

Section 6 – Modeling: Section 6 describes the selection of models and the results of the modeling.

Section 7 – Discussion of Results: Section 7 discusses the results of the statistical analysis and general discussion of lessons learned.

Section 8 – References: Section 8 provides a comprehensive list of references cited in this report.

2.0 SITE SELECTION

Site selection was completed on the portion of the project summarized in the report by Cleveland *et al.* (2005). The selection criteria included ponds which closely resembled the design requirements from the two documents prepared by the City of Houston *et al.* (2001a, 2001b).

2.1 Selection Criteria

These documents define that a storm water quality pond should have one inlet, one outlet, length to width ratio of at least 3:1, and function during the post-construction project phase. In this study, we used time since the storm water quality permit was issued to estimate the degree of construction.

Based upon the results of the database analysis, ponds were weighted with the ponds most closely matching the design standards receiving the highest ratings. Ponds with the highest ratings were field inspected to determine if the degree of ongoing construction was low, and if the design drawings were accurate as compared to the constructed system.

Based upon the combination of high score and good field review, the two highest scoring ponds were selected for sampling.

2.2 Oak Landing Drive Site

The Oak Landing Pond scored extremely high based on the rating system.

Permitted as project 8-169-8 by Harris County on October 17, 2003 by Brown and Gay Engineering Inc. for Harris County MUD 157, the Oak Landing Pond consists of one inlet, one outlet, paved streets, and all land was stabilized even though home construction was on-going. The pond serves 42.54 acres, has a length to width ration of 4.0. The pond is designed to provide 1.77 ac-ft of storage which makes it a first flush storm water quality only pond. The pond is 8.25 ft deep. The outlet has a flow line of 127.53 ft, and is a 12" horizontal pipe with a 5 one inch holes as a restrictor. The outlet system is prevented from clogging through the use of 1" wire melded mesh screen.

The outlet device which made installation of the sampling equipment easy was a smooth walled concrete channel. Unbeknownst, this channel provided a perfect ramp system for local bicyclers and skate boarders. Due to this attractiveness, it became impossible to keep the sampling equipment on line for more than one to two days at a time. After missing 5 sample events, the equipment was removed, and a second residential site was selected.

2.3 North Vista Drive Site

The 311 North Vista Drive pond was constructed and is used by an apartment complex, and is considered multifamily residential development. The pond is maintained by the landscaping professionals who maintain the entire complex. The development was complete prior to implementation of the monitoring system. Photos of the operating pond are shown in Figure 2.4. Please see Exhibits 2.5 and 2.6 for the equipment installation documents for the sampling equipment and the drainage area for the pond.

The tract served is apartment complex (multifamily residential). The drainage area is 14.57 acres. The Rational C-factor is 0.65. The water quality volume is 26,444 cubic feet. The first flush water quality depth is 1.22 feet. The outlet restrictor (SWQ) is 3-inches. The proposed draw down time is 48 hours. The flow line of the pond is 100.2 ft, and the lower frequency storm spillway is 101.42. The 100-year restrictor is a 15-inch pipe; the carrier pipe is 36-inch. The receiving body is Turkey Creek, a tributary of Cypress Creek (Segment No. 1009). This pond provides for 100-year detention storage at an elevation of 108 feet, and a volume of 284,000 cubic feet.

2.4 Treaschwig Road Site

The 4910 Treaschwig Road pond is constructed for Fairfax Section 2 Subdivision, a residential single family home subdivision. The pond is maintained by HCWCID 136. More than half of the homes were constructed prior to the implementation of the monitoring. Photos of the operating pond are shown in Figure 2.7. Please see Exhibits 2.8 and 2.9 for the equipment installation documents for the sampling equipment and the drainage area for the pond.

The tract served is a single family residential subdivision (residential). The drainage area is 7.39 acres. The Rational C-factor is 0.55. The first flush water quality volume is 13,413 cubic feet. The water quality depth is 1.0 feet. The outlet restrictor (SWQ) is 3-inches. The proposed draw down time is 36 hours. The flow line of the pond is 83.53 ft, and the lower frequency storm spillway is 84.73. The 100-year restrictor is a 6-inch pipe, the carrier pipe is 24-inch. The receiving body is the Treaschwig Road Ditch which flows into Cypress Creek (Segment No. 1009). This pond is designed to provide storage for the 100-year event.

3.0 Sampling Activities

This section summarizes the sampling and analytical methods used as described in this study.

3.1 Sampling Methods

Water quality and flow data were collected from 12 storm events at each of the project sites from February 2006 to May 2007.

Basin inflow and outflow were sampled multiple times on a flow-proportional basis to obtain the constituent levels storm event as defined below (See Table 3.1).

Only storms meeting the criteria for qualifying storms were sampled for all constituents. Meteorological conditions were monitored in order to anticipate qualifying rain events. When qualifying rain events were expected, staff members were deployed to the site for the collection of samples. The qualifying event criteria were defined in the monitoring plan as follows:

> 1. Rainfall Volume: no minimum. Both inlet and outlet samplers needed to collect adequate volume to run samples.
>
> 2. Antecedent Dry Period: 24 hours minimum (later reduced to 12 hours)
>
> One set of grab samples were collected from each storm event at the inlet and the outlet. Grab samples were collected whether or not the storm met the qualifying conditions outlined above. The grab sample was collected within the first 2 hours of the inlet sampler triggering.
>
> A number of potentially qualifying events were not sampled due to the availability of the laboratory. When we determined that the laboratory availability was restricting our ability to collect samples, we provided incentives for them to stay open over a larger time period.
>
> Please see Appendix D for a summary of the rainfall events that occurred during the sampling time period and the success or lack of success in sampling for this project.

Table 3.1: Sample Parameters, Analytic Methods, and Storet Numbers		
ANALYTE	**Method**	**Storet #**
Grab		
E. coli	9223B	31648
Enterococcus	1106.1	90909
Fecal coliform	9222D	31611
Total coliform	9222C	31616
Oil and Grease	1664	00566
pH	150.1	00403
Composite		
Biochemical Oxygen Demand	405.1	80082
Chemical Oxygen Demand	410.1	00340
Nitrogen as Ammonia	350.1	00608
Nitrogen as Nitrate & Nitrite	353.2	00630
Total Kjeldahl Nitrogen	351.2	00625
Phosphorus, Ortho-phosphate	365.2	00671
Phosphorus, Total	365.3	00665
Total Hardness (CaCO3)	130.2	00900
Total Organic Carbon	415.1	00680
Total Suspended Solids	160.2	00530
Total Dissolved Solids	160.1	70300
Copper, Total	6010B	01042
Copper, Dissolved	6010B	01040
Lead, Total	6010B	01051
Lead, Dissolved	6010B	01049
Nickel, Total	6010B	01067
Nickel, Dissolved	6010B	01065
Silver, Total	6010B	01077
Silver, Dissolved	6010B	01075
Zinc, Total	6010B	01092
Zinc, Dissolved	6010B	01090
Particle Size		
SOLIDS % ON 74U FILT	ASTM D4464M	00101
SOLIDS % ON 14U FILT		00102
SOLIDS % ON 5U FILT		00103
SOLIDS % ON .45U FIL		00104
Watershed Parameters		
Precipitation		00193
Flow		00061

3.2 Sampling Equipment

Monitoring stations at the inlet and outlet collected water quality samples using Teledyne ISCO 6712C compact portable samplers (Exhibits 2.2, 2.5, and 2.8 for Post Oak Landing, North Vista, and Treaschwig Rd. ponds respectively). The locations of the monitoring stations for Oak Landing are shown in Exhibits 2.3, 2.6, and 2.9. The sampling stations utilized ISCO 6712C refrigerated automated sampling instruments. These instruments allowed the collection of flow-proportional samples of up to 10 Litres using a peristaltic pump. The ISCO 6712C has a programmable controller with a data logger and memory to allow the collection and storage of rainfall, level, velocity, and sample collection data. Data was downloaded from the sampler using a portable computer.

Level and velocity data were collected at the inlet stations; only level data were collected at outlet stations. Each station consisted of ISCO SPA 1074 low profile area velocity sensors connected to the ISCO 6712C controllers through ISCO 750 series modules. Both stations had an ISCO 674 rain gauge connected directly to the controller.

Aliquot samples were collected via a 3/8-inch diameter ("ID") Teflon™ suction line that extended from the collection point through a remote pump to the composite bottle at the ISCO 6712C. The sample collection point was slightly elevated off the bottom of the corrugated metal pipe ("CMP") with the intake tube opening facing downstream. A stainless steel floatables excluder was installed to prevent debris, such as pine needles, mulch, and other yard waste, from entering and clogging the suction line. (The floatables excluder's mesh allowed particles less than 200 μm to enter the suction line.)

The auto-samplers purged the 3/8-inch Teflon tubing before and after aliquot samples were collected by reverse pumping air through the line. The auto-sampler was programmed with four different activity modes: Inhibited, Enabled, Active, and Shut Down.

The auto-sampler began in "Inhibited" mode. When the area velocity meter measured level at a specific depth, the auto-sampler switched from "Inhibited" to 'Enabled" mode. Once the area velocity meter measured a qualifying volume of runoff flow, the auto-sampler became 'Active" and collected an aliquot. The ISCO 6712C collected an aliquot every time an additional qualifying volume of flow was measured.

The auto-sampler automatically "Shut Down" whenever the sample container became full or was manually "Shut Down" at the end of the flow event.

During the collection of grab samples, pH was measured at all stations using a multiprobe. The measurements were taken from the center of flow at the inlet and outlet. (The multiprobe was calibrated prior to collecting measurements in the flow stream.)

Grab samples were collected downstream of the inlet pipe and upstream of the storm water quality restrictor for the pond.

3.3 Sampling Equipment Maintenance

Maintenance on the sampling equipment at the basins was performed after each storm event and once a month. Maintenance checklists were developed to guide the maintenance activities. All sampling and maintenance was completed per the QAPP.

Major maintenance activities included inspecting the sample intake ports, replacing defective suction tubing, addressing vandalism to the sample shelters, checking all connections to the ISCO 6712C controller, replacing defective pump tubing, cleaning the strainer and the floatables excluder, and addressing error messages on the ISCO 6712C controller.

3.4 Laboratory Methods

Constituents monitored at the project sites are listed in Table 3.1.

Grab samples were collected at inlet and outlet. Grab samples were analyzed by the laboratory whether or not the storm met the qualifying conditions. The grab samples were collected early in each storm event.

Bacteria samples were collected using a sterilized dipping cup. Samples were collected from the surface of the center of the flow at the inlet and outlet. Sample water was poured into a 120-mL plastic container preserved with $Na_2S_2O_3$ and ice in accordance with the analytical methods (see Table 3.1).

Oil and grease samples were collected by partially submerging the sampling container directly into the flow stream. Samples were collected from the surface of the center of the flow at the inlet and outlet. The sample containers were removed from the water flow as soon as they were completely filled. The oil and grease containers were preserved with H_2SO_4 to reduce the sample pH to 2, and were sealed with a PTFE-lined cap in accordance with the analytical methods (see Table 3.1).

The pH samples were collected using a sterilized dipping cup from the center of flow at the inlet and outlet. Sample water was poured into 100-mL plastic containers in accordance with the analytical methods (see Table 3.1).

Grab samples were placed on ice and shipped to the laboratory within the required analytical holding time. Accutest Laboratories was used to analyze all the constituents, excluding bacteria and particle size distribution. Bacteria samples were analyzed by EMSL Analytical, Inc., and particle size distribution analyses were conducted by PTS Laboratories.

3.5 QA/QC Field Activities

Quality assurance/quality control ("QA/QC") of field samples were performed as defined in the QAPP. QA/QC field samples included field duplicates, equipment blanks, and equipment calibration. The laboratory quality assurance results are included in the data sheets for each sample. Please see the attached CD (Appendix I) for the laboratory quality assurance results. Please see Appendix F for the results of the field quality control.

4.0 MONITORING RESULTS

This section presents the data obtained during the sampling activities. The data includes monitoring equipment measurements and laboratory results.

4.1 Storm Event Data

Rainfall data were recorded by a tipping bucket rain all storm events at both the inlet and outlet sampling stations.

4.2 Water Quality Data

Water quality data associated with the storm events are summarized in Tables 5.1(a) through 5.3(u). Inlet values represent data collected at the inlet pipe entering the basin; and outlet values represent data collected at the outlet pipe leaving the basin.

4.3 Quality Assurance Findings

Data validation procedures defined in the QAPP were performed. These included laboratory data quality objectives ("DQO's"), collection of QA/IQC field samples, laboratory quality control checks, QA samples, and verification of holding times. All analytical results reported were accepted under this quality assurance program.

The tables in Appendix F include the duplicate results of the composite samples collected for the duplicate results of the grab samples.

The results of all equipment blanks conducted during the monitoring period are presented in Appendix I (CD). According to Clesceri, et al. (1998), the pH of DI water is rarely detected at 7.0 due to the difficulty in measuring pH in a solution with an absence of ions.

5.0 STATISTICAL ANALYSIS

For the purposes of this report, statistical analysis will be completed using the Statistical Program R (R Development CoreTeam, 2006). R is a public domain statistical software.

Prior to completing any analysis of the sample data, the data should be tested for normality. Looney and Gulledge (Helsel, 2002) proposed using a Probability Plot Correlation coefficient ("PPCC") test to determine normality. If the PPCC is significantly less than 1, the data should not be assumed to be normal. At confidence limit corresponding to 90% confidence limit, and twelve data points, a PPCC value less than 0.942 indicates that an assumption of normality should not be made.

Data below the detection limit causes difficulty in the analysis. For all calculations, except probability plots the minimum value used for concentration is assumed to be half the detection limit of the laboratory method. For probability plots, the plotting position for the data with real concentrations is plotted assuring an appropriate plotting position, and all data with non-detection levels ignored in determining the best fit lines.

Statistical analysis of the results, including: summary statistics; correlation (inlet vs. outlet) values for both concentration and load; box-whisker plots; and probability plots are presented in this section. Load is determined by multiplying the concentration by the flow and converting the units to appropriate standard units.

Data were included from all events regardless of the presence of missing data that prevented complete paired sample sets in some cases. Data are not presented, if for some reason the standards set in the QAPP could not be met.

5.0.1 Statistical Calculations

The formulas used to determine the various values used in this report are determined as follows.

Load=Concentration*Total Flow x Conversion Factors

Total Flow is measured in cubic feet. Concentration is measured in three units: µg/L, mg/L, and colonies/100 mL.

Load will be determined for the same constituents as mg, g, and colonies.

The conversion factors will therefore be:

$\frac{28.316847}{1000}$, $\frac{28.316847}{1000}$, and $\frac{28.316847}{10}$ for µg/L to mg, mg/L to g, and colonies/ 100mL to colonies.

The Looney coefficient is determined using the method of Looney and Gulledge (Helsel & Hirsch, 2002). Looney values which are lower than the probability plot correlation coefficient (PPCC) allow the rejection of normality. For the purposes of this project, a confidence level of 90% is utilized.

The correlation coefficient is measured using the Kendall's Tau method, which is a ranked-based procedure and is therefore more robust for non-parametric (not normal) data. Correlations above 0.5 indicate strong linear correlation between inlet and outlet concentrations.

The Wilcoxon signed-rank test is used to determine if the differences in means could be zero. The 90% confidence ranges were determined for the differences in the means. If zero is included in the range, then at 90% level of confidence, the means should not be considered to be different.

The first quartile is the value determined to be the lowest number with 25% of the data below it. Median, also known as the second quartile, represents the value of the data with 50% of the data below it. For data with an odd number of points, it represents the middle number in the sorted data. For even numbered data, it represents a point between the two middle numbers in the sorted data. The third quartile is the value determined to be the highest value with 25% of the data above it. When necessary the computer interpolates to determine these values.

The inter-quartile range (IQR) is the first quartile subtracted from the third quartile and measures the spread of the data away from the median. This is similar to the variance for parametric data.

The inter-quartile skew measures the symmetry of the data, with values closer to zero showing high symmetry. Inter-quartile skew (IQS) is determined by:

$$\text{IQS} = \frac{(\text{3rd Quartile} - \text{Median}) - (\text{Median} - \text{1st Quartile})}{(\text{3rd Quartile} - \text{1st Quartile})}$$

values of IQS greater than 0.5 or less than -0.5 show very highly skewed data.

5.0.2 Correlation Plots

Correlation plots help compare trends in the inlet as compared to the outlet levels. If the outlet level can be predicted by the inlet level, the correlation plot will show an approximate straight line. When there is not a good prediction, the plots will have a scattered appearance. Correlation plots can also identify potential outliers impacting the calculation of the correlation coefficient. See Appendix B for the plots.

5.0.3 Box Whisker Plots

Box-whisker p1ots were created in order to summarize the median, upper, and lower quartiles, minimum and maximum data values, and 90 percent confidence levels of the median. The boxes represent the middle 50 percent of the data drawn between the lower and upper quartiles following Helsel & Hirsch (2002). Notches on the box demonstrate the 90 percent confidence level. The whiskers are vertical lines drawn from the top and bottom of the boxes to the nearest data point that is less than 1.5 times the inter-quartile range from the bottom of the box, or more than 1.5 times the inter-quartile range from the top of the box. These data points are represented by horizontal dashes or "┴ or ┬" at the top or bottom of the line. Suspected outliers and outliers are also represented in the box-whisker plot. Suspected outliers are designated by circles and are identified as points that are more than 1.5 times the inter-quartile range from the top of the box, or less than 1.5 times the inter-quartile range from the bottom of the box. When the notches of different systems do not overlap, there is strong evidence that the values are not of similar distribution. Box-whisker plots show how the medians compare, as well as give visual representations of the spread and skewness of the results. See Appendix B for the plots.

5.0.4 Quantile-Quantile Plots

Quantile-quantile plots are used to see if the data have a statistical relationship based upon frequency of occurrence. The value predicted is shown as a straight line. The sorted data is presented as points. If the data is close to the line, the line is a relatively good predictor of the relative probability of occurrence. See Appendix B for the plots.

5.0.5 Summary of Statistics

Based upon a review of the bulk parameters described in section 5.2.1 through 5.2.6, there is only two parameters that shows at a 90% significance level treatment or degradation caused by the North Vista ponds. The pond at North Vista shows a reduction in fecal coliform load and total suspended solids. The Treaschwig Road pond shows reductions in load for pH, nitrogen as nitrate + nitrite, total Kjeldahl nitrogen, copper, dissolved copper, and dissolved lead at 90% confidence level.

Please see Table 5.0.1 and 5.0.2 for a summary of constituents with significance at 90% level and the results of the Wilcoxon Rank Sign Test.

Table 5.0.1 Wilcoxon Significance on Concentration

#	Constituent	Inexact P-Value Wilcoxon Signed Rank Test		Are Difference Significant at 90%	
		North Vista	Treaschwig	North Vista	Treaschwig
Table 5.1(a)	Total Rainfall (in)	0.0415	0.1164	Inlet > Outlet	NO
Table 5.1(b)	Total Flow (cubic ft)	0.3505	0.1099	NO	NO
Table 5.2(a)	Oil & Grease (mg/L)	-	-	-	-
Table 5.2(b)	pH	0.5513	0.0207	NO	Inlet > Outlet
Table 5.2(c)	Total Coliform (colonies)	0.2340	0.0998	NO	Inlet < Outlet
Table 5.2(d)	Fecal Coliform (colonies)	0.0244	0.4800	Inlet > Outlet	NO
Table 5.2(e)	*E. coli* (colonies)	0.5294	0.3981	NO	NO
Table 5.2(f)	*Enterococcus* (colonies)	0.2664	0.3463	NO	NO
Table 5.3(a)	5 Day Biochemical Oxygen Demand (mg/L)	0.8586	0.0576	NO	Inlet < Outlet
Table 5.3(b)	Chemical Oxygen Demand (mg/L)	0.1088	0.0559	NO	Inlet < Outlet
Table 5.3(c)	Hardness Total as CaCO3 (mg/L)	0.0750	0.1677	Inlet < Outlet	NO
Table 5.3(d)	Nitrogen as Ammonia (mg/L)	0.1410	0.1964	NO	NO
Table 5.3(e)	Nitrogen as Nitrate+Nitrite (mg/L)	0.6228	0.0146	NO	Inlet > Outlet
Table 5.3(f)	Nitrogen, Total Kjeldahl (mg/L)	0.3081	0.2128	NO	NO
Table 5.3(g)	Phosphate, Ortho (mg/L)	0.0998	0.3463	NO	NO
Table 5.3(h)	Phosphorus, Total (mg/L)	0.7551	0.0248	NO	Inlet < Outlet
Table 5.3(i)	Solids, Total Suspended (mg/L)	0.1263	0.7334	NO	NO
Table 5.3(j)	Solids, Total Dissolved (mg/L)	0.0144	1.0000	Inlet < Outlet	NO
Table 5.3(k)	Total Organic Carbon (mg/L)	0.0140	0.6359	Inlet < Outlet	NO
Table 5.3(l)	Copper (ug/L)	0.3066	0.0206	NO	Inlet > Outlet
Table 5.3(m)	Dissolved Copper (ug/L)	0.8588	0.1424	NO	NO
Table 5.3(n)	Lead (ug/L)	0.3066	0.3460	NO	NO
Table 5.3(o)	Dissolved Lead (ug/L)	1.0000	0.5633	NO	NO
Table 5.3(p)	Nickel (ug/L)	-	0.6103	-	NO
Table 5.3(q)	Dissolved Nickel(ug/L)	-	0.7995	-	NO
Table 5.3(r)	Silver (ug/L)	-	-	-	-
Table 5.3(s)	Dissolved Silver (ug/L)	-	-	-	-
Table 5.3(t)	Zinc (ug/L)	0.0039	0.2661	Inlet < Outlet	NO
Table 5.3(u)	Dissolved Zinc (ug/L)	0.0051	0.3066	Inlet < Outlet	NO

Table 5.0.2 Wilcoxon Significance on Load

#	Constituent	Inexact P-Value Wilcoxon Signed Rank Test		Are Difference Significant at 90%	
		North Vista	Treaschwig	North Vista	Treaschwig
Table 5.1(a)	Total Rainfall (in)	0.8241	0.0122	Inlet > Outlet	NO
Table 5.1(b)	Total Flow (cubic ft)	0.0415	0.1164	NO	NO
Table 5.2(a)	Oil & Grease (mg/L)	-	-	-	-
Table 5.2(b)	pH	0.2664	0.4238	NO	Inlet > Outlet
Table 5.2(c)	Total Coliform (colonies)	0.0367	0.7334	NO	NO
Table 5.2(d)	Fecal Coliform (colonies)	0.9645	0.1682	Inlet > Outlet	NO
Table 5.2(e)	*E. coli* (colonies)	0.5049	0.1514	NO	NO
Table 5.2(f)	*Enterococcus* (colonies)	0.1973	0.0005	NO	NO
Table 5.3(a)	Biochemical Oxygen Demand (5 day) (mg/L)	0.5633	0.8501	NO	NO
Table 5.3(b)	Chemical Oxygen Demand (mg/L)	0.8241	0.6772	NO	NO
Table 5.3(c)	Hardness Total as CaCO3 (mg/L)	0.1682	0.2661	NO	NO
Table 5.3(d)	Nitrogen as Ammonia (mg/L)	0.4498	0.0015	NO	NO
Table 5.3(e)	Nitrogen as Nitrate+Nitrite (mg/L)	0.8939	0.0640	NO	Inlet > Outlet
Table 5.3(f)	Nitrogen, Total Kjeldahl (mg/L)	0.1000	0.1099	NO	Inlet > Outlet
Table 5.3(g)	Phosphate, Ortho (mg/L)	0.3983	0.6772	NO	NO
Table 5.3(h)	Phosphorus, Total (mg/L)	0.2664	0.4697	NO	NO
Table 5.3(i)	Solids, Total Suspended (mg/L)	0.7557	0.9097	Inlet > Outlet	NO
Table 5.3(j)	Solids, Total Dissolved (mg/L)	0.0454	0.5186	NO	NO
Table 5.3(k)	Total Organic Carbon (mg/L)	0.1973	0.0034	NO	NO
Table 5.3(l)	Copper (ug/L)	0.1424	0.6772	NO	Inlet > Outlet
Table 5.3(m)	Dissolved Copper (ug/L)	0.2664	0.0923	NO	Inlet > Outlet
Table 5.3(n)	Lead (ug/L)	0.8241	0.4238	NO	NO
Table 5.3(o)	Dissolved Lead (ug/L)	0.6891	0.6772	NO	Inlet > Outlet
Table 5.3(p)	Nickel (ug/L)	-	1.0000	-	NO
Table 5.3(q)	Dissolved Nickel(ug/L)	-	0.0161	-	NO
Table 5.3(r)	Silver (ug/L)	-	-	-	-
Table 5.3(s)	Dissolved Silver (ug/L)	-	-	-	-
Table 5.3(t)	Zinc (ug/L)	0.5633	0.9097	Inlet < Outlet	NO
Table 5.3(u)	Dissolved Zinc (ug/L)	0.0000	0.0000	Inlet < Outlet	NO

5.1 Statistical Results for Watershed Parameters

Two watershed parameters were collected in order to develop models. These included total rainfall and total flow.

5.1.1 Total Rainfall

Rainfall data was collected at both the inlet and outlet samplers. Since the devices were only approximately 400 feet apart, it should be anticipated that the rainfall from each of the devices should be similar at the inlet and outlet.

In addition, as the two sampling sites were only two miles apart, we should observe trends showing approximately the same rainfall for both locations.

North Vista

The Looney values indicated that the rainfall did not follow a normal distribution which is expected as rainfall has a very strong lower limit of 0. There cannot be negative rainfall but, there is no real upper limit to the amount of rainfall that can occur during a single event.

The correlation coefficient for the North Vista Site is relatively high and indicates general conformance with the expected result of inlet and outlet rainfall volumes being equal. Some of the variance can be explained by the more sheltered location of the outlet sampler. It was against a wooden fence which would shelter it from wind blown rainfall from the east.

The median and maximum total rainfall was approximately equal. It should be noted that the rainfall sampler did not work at the outlet for the first event which turned out to be the minimum event at the inlet. The 1st and 3rd quartile values were similar for inlet and outlet. The outlet sampler showed more negative skew than did the inlet sampler which had almost no skewness. Since rainfall is limited by a minimum value of 0, it is more common for rainfall to have a significant positive skew with the first quartile value being closer to the median than the 3rd quartile value.

At 90% level of confidence, the Wilcoxon test demonstrates that the inlet and outlet rainfall volume are not significantly different. The box plots (Figures 5.1(a)) show that the notches virtually overlap. There appears to be one event with both high inlet and outlet rainfall volume.

The quantile-quantile plots (Figure 5.1 (a)) show that the data can be reasonably predicted by a probability curve, and that the highest event is probably an outlier or more extreme event. More rainfall data would likely bring the outlier into the distribution.

Treaschwig Road

The Looney values show that rainfall should be analyzed using a non-parametric approach as the normal distribution does not apply.

The correlation coefficient for the Treaschwig site is lower than the North Vista Site, but still shows relatively high correlation. The sampler for the inlet was more in the open, while the sampler for the outlet was near a long line of trees on its southern side, which could cause it to be subject to more interception losses prior to measurement.

The median at the inflow sampler is 0.1 inches higher than at the outlet sampler. The minimum has about the same difference. The maximum is 0.2 inches higher at the inlet sampler. These consistent differences indicate that there may be a systematic bias of the sheltered system to underestimate the rainfall. Since interception is one of the main methods for storage by vegetation (trees), this finding is not unexpected.

The inter-quartile range and inter-quartile skew are both higher for the outlet sampler than the inlet sampler (Figure 5.1(b2) box plots). The inter-quartile skew is positive as expected for rainfall data for both inlet and outlet. At 90% level of confidence there is no significant difference in total rainfall volume at the inlet and outlet. The quantile-quantile plots show that the data can be reasonably predicted by probability, and that the highest event is probably an outlier or more extreme event.

Comparison of North Vista and Treaschwig Road

Only two rainfall events were collected at both the inlet and outlet samplers for the same storm for both North Vista and Treaschwig Rd. The January 4, 2007 event measured 1.07 inches, 1.1 inches, 1.01 inches, and 1.19 inches at North Vista inlet and outlet, and Treaschwig inlet and outlet respectively. The January 27, 2007 event measured 1.13 inches, 1.09 inches, and 0.55 inches, and 0.53 inches at North Vista inlet and outlet, and Treaschwig inlet and outlet respectively. The January 27, 2007 event shows almost twice the rainfall at North Vista than at Treaschwig Road. Since there are not enough points for statistics, it is difficult to determine quantitatively if they are different.

5.1.2 Total Flow

Total flow was measured using two different devices. For the inlet devices, both velocity meters and depth meters were used to calculate flow. The outlet flow rates and volumes did not allow for most events adequate velocity to allow a velocity meter to work. Therefore, the outlet devices relied on measuring the depth of water and determining the flow based only upon depth using a calibrated weir equation.

Both methods can result in good measurements of flow; however, the velocity meter works better when the downstream water surface is high.

It is expected that all flow that comes into the pond leaves the pond, or is stored in the pond. The flow out of the pond is expected to be equal to or less than the flow into the pond.

North Vista

The Looney coefficients for inlet and outlet data indicate that runoff (or flow) data is not normal in distribution. A low Looney value is expected due to the strong lower limit in flow data since flow generally only goes into the pond at the inlet, and only goes out of the pond at the outlet.

Although the general trends (minimum, medium, and maximum) show concurrence with the concept that all flow leaving the pond must enter the pond via the inlet, three events for the North Vista pond show outlet flow volumes exceeding inlet flow volumes.

This could be due to reasons including: the back slope interceptors collecting rainfall from the 30 foot maintenance berm at the top of the ponds; the direct rainfall on the pond; ground water infiltration; back water from the outlet channel interfering with the flow measurement weir; differences in accuracy of the two measuring methods; and direct irrigation of the pond via the automated sprinklers during the rainfall event. Since there is no documentation to determine if any or all these occurred during the sampling, we are using the measured results to determine load.

The correlation coefficient indicates that inlet flow rate has only partial correlation between inlet and outlet, and inflow rate, therefore, cannot be an accurate predictor of outlet flow rate. The inter-quartile range is significantly larger for outlet flow than inlet flow, which may explain why the correlation coefficient is so low. There appears to be a slight negative inter-quartile skew.

Examining the box plot (Figure 5.1(b)), the correlation plot, and the Q-Q plot, we see that the one extreme point could be unduly influencing the correlation coefficient calculation. Both the figures and the Wilcoxon value show that there is no reason to suspect inlet and outlet flow rates are not the same.

Treaschwig Road

Similar to the North Vista data, the Treaschwig Road flow rates show that for four events the outlet flow volume is slightly higher than the inlet flow volume. This is unexpected and unexplained. The most likely cause for the Treaschwig pond is back water impacts from the outlet ditch. This phenomena occurs only for events with higher than median flows.

The Looney coefficients indicate that non-parametric statistical methods should be used as normality is rejected at 90% level of confidence. The median, minimum, first quartile and third quartile values for the inlet are all higher than for the outlet.

The inter-quartile skew shows a positive skewness which is expected from runoff data. The inter-quartile skew range is much smaller for the Treaschwig runoff than the North Vista runoff, even though the rainfall data had similar differences in inter-quartile range. Is something occurring in the watershed that reduces runoff volumes more in the Treaschwig watershed? Does type or level of development show an impact? Please see Section 6.2 for some of the predictive modeling.

5.2 Statistical Results for Bulk Parameters

The bulk parameters collected for this study are oil and grease, pH, total coliform, fecal coliform, *Escherichia coli*, and *Enterococcus*.

Grab samples were collected according to the methods described in Section 3.2.

5.2.1 Oil and Grease

Oil and grease were collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 1664.

The results of sampling for both North Vista and Treaschwig Road ponds are found in Table 5.2(a). Based upon the laboratory results, a majority of the samples did not detect oil and grease as a pollutant. Statistical results were not computed due to the limited data available. Based upon visual review of the data, the median and 3rd Quartile (75%) were both below the detection limit. Please see Figure 5.2(a) for a graphical representation of the sample data.

Statistics were not presented for oil and grease due to the limited number of points that were above the detection limit. Load is also not evaluated for oil and grease due to the limited data.

5.2.2 pH

pH was collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 150.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.2(b), and represented graphically in Figure 5.2(b). Based upon the Looney coefficient, pH can be analyzed using parametric methods, as the Looney values do not reject a hypothesis of normality; however, non-parametric methods will be used for the statistical analysis in order to be consistent with the other parameters which for the most part cannot be considered to be normal.

Because pH is a true bulk parameter, the measurement gives a true measurement of pH regardless of whether it is measured in a 500 mL sample or a 5000 cubic foot sample. Therefore, no load equivalent statistics are required.

North Vista Statistics

The correlation coefficient shows a strong degree of correlation between the inlet and outlet pH which means outlet pH can be predicted from inlet pH. The correlation plots show a good relationship between inlet and outlet pH. The 1st Quartile, 3rd Quartile, and Median levels all closely match for both the inlet and outlet. The minimums and maximums are identical. The inter-quartile range is very similar. The inter-quartile skew is very close to 0, which indicates the data is symmetrical about the median for both inlet and outlet levels. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet levels are not identical at a 90% level of confidence.

Treaschwig Road Statistics

The correlation coefficient indicates low correlation between inlet and outlet levels for pH.

The median, maximum, and minimum pH levels are all higher for the inlet as compared to the outlet. The inter-quartile range is very similar for the inlet and outlet. The inter-quartile skew is relatively small, indicating that the data is symmetrical about the median.

Based upon a Wilcoxon signed rank test, there is no good evidence to suspect inlet and outlet pH levels are not identical at a 90% level of confidence (see Box Plots). Based upon the data, the pond at Treaschwig appears to decrease pH.

The inlet pH at Treaschwig may have two outliers (9.5 and 6.3).

Comparison of North Vista & Treaschwig Road pH

The pH at North Vista and Treaschwig Road for both the inlets and outlets have a high Looney coefficient and cannot reject normality.

The pH for North Vista is in a relatively small range. The pond at North Vista appears to have no impact on pH. The pH for the watershed at Treaschwig has both very high and very low data points. The value of 9.5 at the inlet for the January 14, 2007 event is reduced to 7.0 by the pond.

5.2.3 Total Coliform

Total coliform was collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed and analyzed in accordance with EPA approved method SM 9222C. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.2(c), and represented graphically in Figure 5.2(c). Based upon the Looney coefficients, total coliform should not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality. Therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total coliform concentrations. Based upon the correlation plot, the weak correlation does not appear to be caused by one data point; rather it appears to be a general finding.

The median is three times higher at the inlet than the outlet. The first and third quartile values have about the same difference. Even though these huge differences in summary statistics exist, the Wilcoxon test does not demonstrate that the inlet and outlet concentrations are different.

North Vista Statistics (load)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total coliform load. As with concentration, the correlation plot shows no apparent trends.

The median is three times higher at the inlet than the outlet. The first and third quartile values have about the same difference. Even though these huge differences in summary statistics exist, the Wilcoxon test does not demonstrate that the inlet and outlet loads are different.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates that there is a high degree of correlation between inlet and outlet concentration for total coliform. The correlation plot shows a relatively straight line with one potential outlier on either side of the line.

The median, maximum, and minimum total coliform levels are all higher for the outlet as compared to the inlet. The inter-quartile range is about double for the outlet as compared to the inlet. The inter-quartile skew is very large and positive, indicating that the data is not symmetrical about the median, and that the upper limb has a larger distance from the median. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentrations are not identical at a 90% level of confidence.

Treaschwig Road Statistics (load)

The correlation coefficient indicates a relatively high degree of correlation between inlet and outlet load for total coliform.

The median, maximum, and minimum total coliform loads are all higher for the outlet as compared to the inlet. The inter-quartile range is very similar for the inlet and outlet. The inter-quartile skew is relatively small, indicating that the data is symmetrical about the median. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet loads are not identical at a 90% level of confidence.

Comparison of North Vista & Treaschwig Road

The total coliform data show some interesting trends. Even though there is no statistically significant difference, 9 of the 11 events at North Vista show large reductions of total coliform when inlet and outlet pairs are examined.

The Treaschwig data shows a diametrically opposed result with 9 of the 12 events showing increases in total coliform.

The inter-quartile range for the North Vista concentration data is very small. For the Treaschwig Road samples, it is approximately an order of magnitude higher. When load is considered, the difference in inter-quartile range is 5 orders of magnitudes from North Vista to Treaschwig.

Although beyond the scope of the project, it would be interesting to review if the two watersheds and ponds have the same distributions.

5.2.4 Fecal Coliform

Fecal coliform was collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 9222D. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.2(d), and represented graphically in Figure 5.2(d). Based upon the Looney coefficient, fecal coliform can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet fecal coliform concentration. The weakness of the correlation is likely due to the extremely larger spike of fecal coliform on 10/12/2006 in the inlet which is more than six times the level for any other sample. It is interesting to note, the second largest fecal coliform concentration was found three days after the highest observation.

Per the summary calculations, inlet concentrations are consistently higher than outlet concentrations. The Wilcoxon test states that at 90% confidence, the data sets do not come from the same distribution and that, therefore, the pond has a positive reduction in fecal coliform concentration. The inter-quartile skew is very large and positive, which indicates many points occur a long distance away from the median on the upper side of the graph. The box plot shows the summary statistics very well.

North Vista Statistics (load)

The correlation coefficient shows a higher degree of correlation between the inlet and outlet fecal coliform load than did the concentration data. The results closely match the trends in the concentration data. Based upon a Wilcoxon signed rank test, there is reason to suspect inlet and outlet load are not identical at a 90% level of confidence, and that the pond does provide for a reduction in fecal coliform load.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong degree of correlation between inlet and outlet concentration for fecal coliform.

The minimum and maximum concentrations of fecal coliform are smaller for the outlet than inlet even though the median is larger. The first quartile outlet concentration is lower for the outlet. The third quartile concentration is higher for the outlet. The inter-quartile range is similar for the inlet and outlet. The inter-quartile skew is very large (almost 1) indicating that the data above the median is a lot further away from the median than are the observations below the median.

Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

Treaschwig Road Statistics (load)

The correlation coefficient indicates high correlation between inlet and outlet load for fecal coliform.

The median, maximum, and minimum fecal coliform load are all higher for the inlet as compared to the outlet. The inter-quartile range is very similar for the inlet and outlet. The inter-quartile skew is very large, indicating that the data is not symmetrical about the median. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

Comparison of North Vista & Treaschwig Road

Similar to the total coliform, the fecal coliform concentrations and loads for North Vista and Treaschwig have much higher inter-quartile ranges for Treaschwig than for North Vista. The box plots show this as well. The finding can be observed at both inlet and outlet.

5.2.5 *E. coli*

E. coli was collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 9223B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.2(e), and represented graphically in Figure 5.2(e). Based upon the Looney coefficient, *E. coli* can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality, and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a very low degree of correlation between the inlet and outlet *E. coli* concentration. The 4/21/06 concentration of *E. coli* at the inlet is very high (34 times the inter-quartile range). When the extreme outlier is removed, the correlation appears higher.

Almost half the measurements were unable to detect *E. coli*. Therefore, the minimum and lower quartile will be defined as non-detect. The inter-quartile range when the lower quartile is not detected is defined as the upper quartile value subtract half the detection limit. The Wilcoxon signed rank test could not detect a difference in inlet and outlet concentration.

North Vista Statistics (load)

The correlation coefficient shows a low degree of correlation between the inlet and outlet *E. coli* load. This could be caused by the extreme outlier.

As with concentration, the non-detects have an impact on the statistics. Since concentration is defined as half the detection limit in order to allow determination of load, the load will have values for each of the data elements. Care must be taken in utilizing these load statistics for modeling. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a higher degree of correlation between inlet and outlet concentration for *E. coli*. There do not appear to be any obvious outliers causing reduced correlation based on the correlation plot. The box plot shows two possible outliers for inlet concentration, but the outlet concentration increased as inlet concentration did.

The inlet, median, and maximum are about 1/3 higher than the outlet concentrations. The inter-quartile range shows about the same difference. The inter-quartile skews are high and positive, indicating a strong skewness towards the right. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

Treaschwig Road Statistics (load)

The correlation coefficient indicates a low correlation between inlet and outlet load for *E. coli*. The summary statistics all show similar trends to concentration. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

5.2.6 *Enterococcus*

Enterococcus was collected through grab sampling as part of the bulk samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 1106.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.2(f), and represented graphically in Figure 5.2(f). Based upon the Looney coefficient, *Enterococcus* should not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality, and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a low degree of correlation between the inlet and outlet *Enterococcus* concentration. The correlation plot shows a couple of competing points at the high concentrations. The summary statistics show no trends that need to be explained. Based upon a Wilcoxon signed rank, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet *Enterococcus* load. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics do not show any trends.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong correlation between inlet and outlet concentration for *Enterococcus*. There appears to be one very large event (March 27, 2007) with both high inlet and outlet concentrations. There is a relatively high positive inter-quartile skew in both inlet and outlet concentrations. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

Treaschwig Road Statistics (load)

The correlation coefficient indicates strong correlation between inlet and outlet load for *Enterococcus*. No summary statistics show unexpected trends. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

5.3 Statistical Results for Composite Samples

The flow weighted composite samples collected in this study include: 5 day biochemical oxygen demand ("BOD_5"); chemical oxygen demand (COD); Hardness as $Ca(CO_3)$; Nitrogen as Ammonia; Nitrogen as Nitrate + Nitrate; Nitrogen as Total Kjeldahl; Total Suspended Solids; Total Dissolved Solids; Total Organic Carbon (TOC); Total & Dissolved Copper; Total & Dissolved Lead; Total & Dissolved Nickel; Total & Dissolved Silver; and Total & Dissolved Zinc.

The summary information for the metals shows a very large spike in observed heavy metals on the January 4th, 2007 sample from North Vista. This spike may be due to the New Year's Eve fireworks and the heavy metals used to create the beautiful colors.

5.3.1 Biochemical Oxygen Demand

Biochemical oxygen demand was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed and analyzed in accordance with EPA approved method SM 405.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(a), and represented graphically in Figure 5.3(a). Based upon the Looney coefficient, biochemical oxygen demand can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality, and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet biochemical oxygen demand concentration. The correlation plot confirms the high degree of correlation. All summary statistics for inlet and outlet showed limited trends. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet biochemical oxygen demand load. The correlation plot shows that the inlet load and outlet load show similar behavior. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. Review of the summary statistics for the inlet and outlet show no unusual trends.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a low correlation between inlet and outlet concentration for biochemical oxygen demand. The scatter in the correlation plot does not indicate that the low correlation is due to a potential outlier. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. Review of the summary statistics does not show any unusual trends.

Treaschwig Road Statistics (load)

The correlation coefficient indicates limited correlation between inlet and outlet load for biochemical oxygen demand. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. Review of the summary statistics show no unusual trends.

5.3.2 Chemical Oxygen Demand

Chemical oxygen demand was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 410.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(b), and represented graphically in Figure 5.3(b). Based upon the Looney coefficient, chemical oxygen demand can be analyzed using parametric methods, as the Looney value does not reject a hypothesis of normality; however, non-parametric methods will be used for the statistical analysis in order to be consistent with the remainder of the data.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet concentration. The correlation plot shows this too. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet chemical oxygen demand load. Looking at the correlation plot shows that there is one point with very high load at both inlet and outlet. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

Even though the October 15, 2006 sample from North Vista had a relatively low inlet and outlet concentration (32, 34 mg/L) at both inlet and outlet, it showed very high load (154, 637 / 133,827 g). This is due to the high flow storm event.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong correlation between inlet and outlet concentration for chemical oxygen demand. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that outlet concentration is higher than inlet concentration. The summary statistics show no interesting characteristics.

Treaschwig Road Statistics (load)

The correlation coefficient indicates good correlation between inlet and outlet load for chemical oxygen demand. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

5.3.3 Hardness as $CaCO_3$

Hardness as $CaCO_3$ was collected through composite sampling as part of the flow averaged` samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 130.2. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(c), and represented graphically in Figure 5.3(c). Based upon the Looney coefficient, hardness as $CaCO_3$ can be analyzed using parametric methods for 3 of the 4 sample locations, as the Looney value does not reject a hypothesis of normality; however, non-parametric methods will be used for the statistical analysis in order to not misrepresent the North Vista outflow.

North Vista Statistics (concentration)

The correlation coefficient shows a low degree of correlation between the inlet and outlet for concentration hardness. The correlation plot shows one extreme outlier (January 4, 2007) which may be reducing the correlation coefficient. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that inlet concentration is less than outlet concentration.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet for load hardness. The correlation plot shows the same extreme outlier. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics do not show any unusual trends.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates no correlation between inlet and outlet concentration for hardness as $CaCO_3$. The correlation plot indicates no coherent line. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics do not indicate any unexpected results.

Treaschwig Road Statistics (load)

The correlation coefficient indicates low correlation between inlet and outlet load for hardness as $CaCO_3$. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics do not show any unexpected results.

5.3.4 Nitrogen as Ammonia

Nitrogen as ammonia was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 350.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(d), and represented graphically in Figure 5.3(d). Based upon the Looney coefficient, ammonia can not be analyzed using parametric methods, as the Looney value rejects the hypothesis of normality; and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a strong degree of correlation for concentration of inlet and outlet nitrogen as ammonia. The correlation plot also shows limited correlation between inlet and outlet concentration. Based upon a Wilcoxon signed rank test, there is reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that inlet concentration is higher than outlet concentration. The summary statistics do not show any interesting results.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation for load between the inlet and outlet nitrogen ammonia. The correlation plot shows higher load as the vertical columns are removed. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics show no unusual trends.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong correlation between inlet and outlet concentration for nitrogen as ammonia. The correlation plot shows a potential outlier in the May 10, 2007 data. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics do not show anything unusual.

Treaschwig Road Statistics (load)

The correlation coefficient indicates weak correlation between inlet and outlet load for nitrogen as ammonia. The May 10, 2007 load may be an outlier. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics show no unusual trends.

5.3.5 Nitrogen as Nitrate + Nitrite

Nitrogen as nitrate + nitrite were collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 353.2. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(e), and represented graphically in Figure 5.3(e). Based upon the Looney coefficients, nitrogen as nitrate + nitrite could be analyzed using parametric methods for the outlet at North Vista and both inlet and outlet at Treaschwig Road, as the Looney value would not reject a hypothesis of normality; however, non-parametric methods will be used for the statistical analysis for consistency with the other sample.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet nitrogen as nitrate + nitrite concentration. The correlation plot shows vertical and horizontal columns of data which indicates differentiation of the concentration is limited by the detection levels. There does not appear to be any outlier data. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet nitrogen as nitrate + nitrite load. The correlation plot shows strong concentration and low possibility of outliers. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics show nothing unusual.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates low correlation between inlet and outlet concentration for nitrogen as nitrate + nitrite. The correlation plot shows that there are not any immediately discernable trends. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that the Treaschwig pond reduces the concentration from inlet to outlet. The box plot confirms this. The summary statistics show no unusual trends.

Treaschwig Road Statistics (load)

The correlation coefficient indicates high correlation between inlet and outlet load for nitrogen as nitrate + nitrite. The single large point shown in the correlation plot gives the plot a distinct slope. Should this point be neglected in the analysis due to its leverage? Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence and that load is reduced in the Treaschwig pond. The box plots confirm that the notches do not overlap.

5.3.6 Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 351.2. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(f), and represented graphically in Figure 5.3(f). Based upon the Looney coefficient, total Kjeldahl nitrogen can not be analyzed using parametric methods, as the Looney value rejects the hypothesis of normality; and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet total Kjeldahl nitrogen concentration. The correlation plot shows a high level of correlation and the January 4, 2007 data point as a possible outlier. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics and box plot do not show significant differences in values.

North Vista Statistics (load)

The correlation coefficient shows a low degree of correlation between the inlet and outlet total Kjeldahl nitrogen load. The correlation plot shows that there is an upward trend as the inlet increases. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The correlation plot shows that there maybe an upward trend in outlet concentration as inlet concentration increases.

Treaschwig Road Statistics (concentration)

The correlation coefficient of indicates a low correlation between inlet and outlet concentration for total Kjeldahl nitrogen. The correlation plot shows that there may be an upward trend in outlet concentration as inlet concentration increases. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The outlet inter-quartile range is much lower than the inlet inter-quartile range (see box plot).

Treaschwig Road Statistics (load)

The correlation coefficient indicates low correlation between inlet and outlet load for total Kjeldahl nitrogen. The correlation plot may show a slight positive trend.

Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

5.3.7 Ortho Phosphate

Ortho phosphate was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 365.2. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(g), and represented graphically in Figure 5.3(g). Based upon the Looney coefficient, ortho phosphate can be analyzed using parametric methods, as the Looney value rejects the hypothesis of normality; and therefore, non-parametric methods will be used for the statistical analysis. Note that the Treaschwig data could be considered normal, but was analyzed using non-parametric methods.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet ortho phosphate concentration. The correlation plot shows that there appears to be an increase in outlet concentration with inlet concentration. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. There is nothing unusual in the summary statistics.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet ortho phosphate load. The correlation plot confirms this. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. There is nothing unusual in the summary statistics.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates weak correlation between inlet and outlet concentration for ortho phosphate. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. There is nothing interesting in the summary statistics.

Treaschwig Road Statistics (load)

The correlation coefficient indicates strong correlation between inlet and outlet load for ortho phosphate. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics do not show any unusual values.

5.3.8 Total Phosphorus

Total phosphorus was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 365.3. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(h), and represented graphically in Figure 5.3(h). Based upon the Looney coefficient, total phosphorus can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality; and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a low degree of correlation between the inlet and outlet total phosphorus concentration. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet total phosphorus load. The correlation plot shows that the data appears to match the coefficient. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot shows that inlet and outlet distributions are very similar. The summary statistics do not show any unusual distributions.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong correlation between inlet and outlet concentration for total phosphorus. The correlation plot shows that there appears to be a trend to have output get larger as input concentration gets larger. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that outlet concentration is greater than inlet concentration. The box plot does show overlapping notches, but the medians of inlet or outlet are not within the area of the notches of the others. The summary statistics do not reveal any unusual conditions.

Treaschwig Road Statistics (load)

The correlation coefficient indicates weak correlation between inlet and outlet load for total phosphorus. The correlation plot shows that as inlet load increases, so does outlet load. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. Considering that concentration shows that inlet and outlet load are different, inlet and outlet load have very similar distributions with median, upper and lower quartiles being very similar.

5.3.9 Total Suspended Solids

Total suspended solids were collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 160.2. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(i), and represented graphically in Figure 5.3(i). Based upon the Looney coefficient, total suspended solids should not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total suspended solids concentration. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics show no unusual distribution.

North Vista Statistics (load)

The correlation coefficient shows a stronger degree of correlation between the inlet and outlet total suspended solids load than does concentration. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence and that inlet load is higher than outlet load.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates very weak negative correlation between inlet and outlet concentration for total suspended solids. The correlation plot shows one extreme outlier which may be causing this negative correlation. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics and box plot do not show any unusual distributive properties.

Treaschwig Road Statistics (load)

The correlation coefficient indicates weak correlation between inlet and outlet load for total suspended solids. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics show that the inter-quartile range for the inlet load is much larger than that for the outlet load.

5.3.10 Total Dissolved Solids

Total dissolved solids were collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 160.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(j), and represented graphically in Figure 5.3(j). Based upon the Looney coefficient, total dissolved solids should not be analyzed using parametric methods, as the Looney value of three of the four sampling devices rejects a hypothesis of normality; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total dissolved solids concentration. The correlation plot confirms that in general, as inlet concentration increases so does outlet concentration. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that inlet concentration is lower than outlet concentration. The box plot shows that the median for inlet concentration is not within the notch for outlet concentration. The summary statistics show the same thing.

North Vista Statistics (load)

The correlation coefficient shows a very high degree of correlation between the inlet and outlet total dissolved solids load. The correlation plot shows a very linear relationship. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence. Both the box plot and the summary statistics show that total dissolved solids load are similar at inlet and outlet.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates low correlation between inlet and outlet concentration for total dissolved solids. No outliers jump out on the correlation plot. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. Both the box plot and the summary statistics show no significant differences in inlet and outlet concentration.

Treaschwig Road Statistics (load)

The correlation coefficient indicates a slight negative correlation between inlet and outlet load for total dissolved solids. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. Neither the box plot nor the summary statistics show significant differences in inlet and outlet concentrations.

5.3.11 Total Organic Carbon

Total organic carbon was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 415.1. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(k), and represented graphically in Figure 5.3(k). Based upon the Looney coefficient, total organic carbon can be analyzed using parametric methods, as the Looney value of rejects a hypothesis of normality for three of the four sample stations; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a high degree of correlation between the inlet and outlet total organic carbon concentration. The correlation plot shows no outliers unduly influencing the correlation calculation. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that outlet concentration medians are just slightly within the notch.

North Vista Statistics (load)

The correlation coefficient shows a low degree of correlation between the inlet and outlet total organic carbon load. The correlation plot shows one extreme event that makes the correlation appear stronger than it really is. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics do not show any unexpected results.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a low positive correlation between inlet and outlet concentration for total organic carbon. The correlation plot shows no presence of a dominating outlier. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90%

level of confidence. The summary statistics and box plot do not show any significant trends.

Treaschwig Road Statistics (load)

The correlation coefficient indicates a very low correlation between inlet and outlet load for total organic carbon. The correlation plot does not indicate the presence of a strong outlier set. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics do not show any peculiar results.

5.3.12 Total Copper

Total copper was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(l), and represented graphically in Figure 5.3(l). Based upon the Looney coefficient, total copper can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality for two of the four sampling stations; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak negative correlation between the inlet and outlet total copper concentration. The correlation plot shows one very large outlet level (January 4, 2007) which could be impacting the evaluation of the correlation coefficient. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plot and summary statistics do not reveal any surprises.

North Vista Statistics (load)

The correlation coefficient shows a non-existent degree of correlation between the inlet and outlet total copper load. The correlation plot shows the same outlier as for the concentration plot. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plots and summary statistics show no unusual trends.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates strong correlation between inlet and outlet concentration for total copper. The correlation plot shows no obvious outliers. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. See the box plot.

Treaschwig Road Statistics (load)

The correlation coefficient indicates strong correlation between inlet and outlet load for total copper. The correlation plot demonstrates the correlation. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics show no unusual trends.

5.3.13 Dissolved Copper

Dissolved copper was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(m), and represented graphically in Figure 5.3(m). Based upon the Looney coefficient, dissolved copper can be analyzed using parametric methods, as the Looney value does not reject a hypothesis of normality; however, non-parametric methods will be used for the statistical analysis to be consistent with the other substrates.

North Vista Statistics (concentration)

The correlation coefficient shows a strong degree of correlation between the inlet and outlet dissolved copper concentration. The correlation plot nicely confirms this trend. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plots and summary statistics show almost identical results at inlet and outlet.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet dissolved copper load. The correlation plot shows this well. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. As with concentration, inlet and outlet summary statistics on load are almost identical.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates non-existent correlation between inlet and outlet concentration for dissolved copper. The correlation plot shows a general increasing trend as inlet concentration increases. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The summary statistics at the outlet show three points with concentration below detection limit which makes the lowest quartile value also undetectable.

Treaschwig Road Statistics (load)

The correlation coefficient indicates non-existent correlation between inlet and outlet load for dissolved copper. The correlation plot shows generally increasing outlet load as inlet load increases. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The summary statistics do not show any unusual values for load. The box plot does show the lower part of the notch below zero which is physically unrealistic.

5.3.14 Total Lead

Total lead was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(n), and represented graphically in Figure 5.3(n). Based upon the Looney coefficient, total lead can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality for two of the four samples; and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total lead concentration. The correlation plot shows one potential outlier (January 4, 2007). Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plot and summary statistics do not show anything unusual.

North Vista Statistics (load)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet total lead load. The correlation plot shows two potential outliers (January 4, 2007 and October 15, 2006) which may have an impact on the value of the correlation coefficient. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics show no unusual information.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates weak correlation between inlet and outlet concentration for total lead. The correlation plot shows a great deal of scatter but no obvious outliers. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plot and summary statistics show nothing unusual or unexpected.

Treaschwig Road Statistics (load)

The correlation coefficient indicates strong correlation between inlet and outlet load for total lead. The correlation plot shows a strong point (April 25, 2007) which could be extreme. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics do not show any unusual tendencies.

5.3.15 Dissolved Lead

Dissolved lead was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(o), and represented graphically in Figure 5.3(o). Based upon the Looney coefficient, dissolved lead should not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality for two of the four sample stations; and therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet dissolved lead concentration. The correlation plot shows no potential outliers which impact the estimate of correlation coefficient. Based upon a Wilcoxon signed rank test there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plot and summary statistics show no unusual trends.

North Vista Statistics (load)

The correlation coefficient shows a weak degree of correlation between the inlet and outlet dissolved lead load. The correlation plot shows one load (October 15, 2006) which may be extreme. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics show the same outlier and, otherwise, they show nothing unusual.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a low correlation between inlet and outlet concentration for dissolved lead. The correlation plot shows no potential outliers which are causing the weak correlation. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. The box plot and summary statistics do not reveal any unexpected results.

Treaschwig Road Statistics (load)

The correlation coefficient indicates weak correlation between inlet and outlet load for dissolved lead. The correlation plot shows no strong candidates as extreme values. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence. The box plot and summary statistics do not reveal any unusual trends.

5.3.16 Total Nickel

Total nickel was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results of sampling for both North Vista and Treaschwig Road ponds are found in Table 5.3(p).

North Vista Statistics

Based upon the laboratory results, a majority of the samples did not detect total nickel as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (p) for a graphical representation of the data.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a high degree of correlation between the inlet and outlet total nickel concentrations. The correlation plot shows lots of scatter for higher inlet concentration. Based upon a Wilcoxon signed rank test, there is no reason to suspect that inlet and outlet total nickel concentration are not identical. The box plot and summary statistics do not show any interesting trends.

Treaschwig Road Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet total nickel load. The correlation plot shows a great deal of scatter. Based upon a Wilcoxon signed rank test, there is no reason to suspect that inlet and outlet total nickel load are not identical. The box plot and summary statistics do not show any unusual trends.

5.3.17 Dissolved Nickel

Dissolved nickel was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results of sampling for both North Vista and Treaschwig Road ponds are found in Table 5.3(q).

North Vista Statistics

Based upon the laboratory results, a majority of the samples did not detect dissolved nickel as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (q) for a graphical representation of the data.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a low degree of correlation between the inlet and outlet dissolved nickel concentrations. The correlation plot shows lots of scatter. Based upon a Wilcoxon signed rank test, there is no reason to suspect that inlet and outlet dissolved nickel concentration are not identical. The box plot and summary statistics do not show any interesting trends.

Treaschwig Road Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet dissolved nickel load. The correlation plot shows a great deal of scatter. Based upon a Wilcoxon signed rank test, there is no reason to suspect that inlet and outlet dissolved nickel load are not identical. The box plot and summary statistics do not show any unusual trends.

5.3.18 Total Silver

Total silver was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results of sampling for both North Vista and Treaschwig Road ponds are found in Table 5.3(r).

North Vista Statistics

Based upon the laboratory results, a majority of the samples did not detect total silver as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (r) for a graphical representation of the data.

Treaschwig Road Statistics

Based upon the laboratory results, a majority of the samples did not detect total silver as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (r) for a graphical representation of the data.

5.3.19 Dissolved Silver

Dissolved silver was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(s), and represented graphically in Figure 5.3(s).

North Vista Statistics

Based upon the laboratory results, a majority of the samples did not detect dissolved silver as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (s) for a graphical representation of the data.

Treaschwig Road Statistics

Based upon the laboratory results, a majority of the samples did not detect dissolved silver as a pollutant. Statistical results and load analysis were not computed due to the limited data. Please see figure 5.3 (s) for a graphical representation of the data.

5.3.20 Total Zinc

Total zinc was collected through composite sampling as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(t), and represented graphically in Figure 5.3(t). Based upon the Looney coefficient, total zinc can not be analyzed using parametric methods, as the Looney value rejects a hypothesis of normality for two of the four sampling stations; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a low degree of correlation between the inlet and outlet total zinc concentration. The correlation plots show lots of scatter with a potential outlier (January 4, 2007) for outlet concentration. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that outlet concentration is higher than inlet concentration. No trends are observed in the box plot or summary statistics.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet total zinc load. The correlation plots show lots of scatter with one potential outlier (January 4, 2007) for outlet load. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence and that outlet concentration is higher than inlet concentration. No trends are observed in the box plot or summary statistics.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates a low negative correlation between inlet and outlet concentration for total zinc. The correlation plot shows lots of scatter with no obvious outliers. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence. No trends are observed in the inlet or outlet summary statistics or the box plot.

Treaschwig Road Statistics (load)

The correlation coefficient indicates non-existent correlation between inlet and outlet load for total zinc. The correlation plot shows lots of scatter with no obvious outliers. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence. No trends are observed in the inlet or outlet summary statistics or the box plot.

5.3.21 Dissolved Zinc

Dissolved Zinc was collected through composite as part of the flow averaged samples collected. The samples were collected and analyzed in accordance with EPA approved method SM 6010B. The results for both the North Vista site and Treaschwig Road site are shown in Table 5.3(u), and represented graphically in Figure 5.3(u). Based upon the Looney coefficient, dissolved zinc can not be analyzed using parametric methods, as the Looney value rejects the hypothesis of normality for all stations; therefore, non-parametric methods will be used for the statistical analysis.

North Vista Statistics (concentration)

The correlation coefficient shows a low degree of correlation between the inlet and outlet dissolved zinc concentration. The correlation plot shows a slight upward trend with no obvious outliers. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence and that outlet concentration exceeds inlet concentration. The summary statistics and box plot show that the inter-quartile range is about three times larger for outlet concentration than inlet. The box plot also shows the median for inlet is not in the outlet's inter-quartile range which also indicates that inlet and outlet concentrations are not equal.

North Vista Statistics (load)

The correlation coefficient shows a high degree of correlation between the inlet and outlet dissolved zinc load. The correlation plot indicates a trend for outlet load to increase with inlet load. Based upon a Wilcoxon signed rank test, there is good reason to suspect inlet and outlet load are not identical at a 90% level of confidence and that outlet load exceeds inlet load. The summary statistics show that the inter-quartile range is quite a bit larger for the outlet. The median for the outlet is barely within the inter-quartile range for the outlet and vice-versa which verifies visually the Wilcoxon test results.

Treaschwig Road Statistics (concentration)

The correlation coefficient indicates low correlation between inlet and outlet concentration for dissolved zinc. The correlation plot shows that no obvious outliers exist. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet concentration are not identical at a 90% level of confidence.

Treaschwig Road Statistics (load)

The correlation coefficient indicates non-existent correlation between inlet and outlet load for dissolved zinc. Based upon a Wilcoxon signed rank test, there is no reason to suspect inlet and outlet load are not identical at a 90% level of confidence.

5.4 Particle Size Distribution

Insufficient particles were present in either the inlet samples or outlet samples at North Vista to adequately characterize the particle size distribution. No sample events resulted in data for particle size distribution. Also, no outlet samples from Treaschwig resulted in characterization of the particle size. The particle data for the five events at Treaschwig Road which resulted in data are not included in Exhibit 5.4. For all data more than 50% of the particles are 10 microns or smaller. For all data, more than 75% of the particles are 19 microns or smaller. Particles of 5 microns or smaller represent 25% of the particles for all events.

6.0 MODELING

6.1 Evaluation of Storm Water Quality Runoff Models for Harris County

6.1.1 Introduction

A review of available water quality models was performed for Task 400 of the Harris County BMP Efficiency Study. The purpose of this review was to select an appropriate water quality model to simulate the effectiveness of detentions ponds in reducing pollutants in urban storm water runoff in Harris County and assess the impacts on receiving streams. According to the USEPA work plan for this project, "developing a computer program is not anticipated as part of the deliverables; however it is anticipated that one of the existing models such as EPA's BASINS program package or other appropriate model for the intended task will be used to evaluate watershed management practices and impact of BMPs on receiving streams water quality".

6.1.2 Model Selection Criteria

The selection of models is based on the intended purpose of the modeling exercise and is governed by several factors. The primary factor is the capability to simulate the desired pollutants. Pollutants that were considered in the model selection were limited to those that were reduced by detention BMPs as evidenced by statistically significant load reductions measured during this study.

At the North Vista Site, the following pollutants displayed significant load reductions:

- fecal coliform
- orthophosphate phosphorus
- total suspended solids

Monitoring results indicated load reductions associated with suspended sediment, nutrients, metals, pH, and bacteria. At the Treaschwig Site, statistically significant reductions in the following pollutants were observed:

- oil and grease
- total and dissolved copper
- nitrate + nitrate nitrogen and total Kjeldahl nitrogen
- dissolved silver
- lead

The fact that the monitoring program did not yield consistent results between the two detention ponds seems to indicate differing conditions exist at the two sites. The differences may be associated with the catchments or the detention ponds themselves. These differences may be explored through modeling of the catchments and BMPs.

The following general criteria were used in the selection process:

- Ability to simulate urban catchments
- Some deterministic basis for predicting pollutant build-up and wash-off
- Ability to physically represent storm water piping systems and storm sewers
- Capability of sub-daily or event-based simulations
- Ability to model the BMP of interest (i.e., detention ponds)
- Capability of simulating selected pollutants (i.e., those determined through monitoring to be reduced by detention basins
- Degree of peer acceptability
- Model is readily available (non-proprietary or minimal cost)
- Model is currently supported and maintained
- Ease of use

6.1.3 Model Selection

The capabilities of available water quality models are summarized in Table 6.1 (Appendix C). Based on a review of the model capabilities, availability, and cost, the following five models were selected for further review:

- Loading Simulation Program in C++ (LSPC)
- Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds-Urban Catchment Model (P8-UCM)
- Source Loading and Management Model (SLAMM)
- Storm Water Management Model (SWMM)
- Watershed Assessment Model with an ArcView Interface (WAMView)

Fact sheets for each of these models are included in Appendix C. A comparison of these models is summarized below.

	LSPC	P8-UCM	SLAMM	SWMM	WAMView
Sewer system flow routing	Y	Y	Y	Y	N
Storage analysis	Y	Y	Y	Y	Y
Treatment analysis	Y	Y	Y	Y	Y
Data and personnel requirements	High	Moderate	Moderate	High	High
Overall model complexity	High	Moderate	Moderate	High	High
Supported	Y	Y	Y	Y	Y
Proprietary (Cost)	N	N	Y ($300)	N	N

Based on the review, it is recommended that the P8-UCM model be selected for modeling urban storm water runoff and pollutant removal efficiencies of detention basins in Harris County.

6.2 Modeling Results

Rainfall and temperature data was downloaded from National Climatic Data Center of the US Department of Commerce (NCDC, 2007). The years 2006 and 2007 were downloaded. The program P8 Urban Catchment Model Version 3.2 (Walker, 2007) was used to model the theoretic performance of the detention ponds for North Vista and Treaschwig Road development. The temperature data was used as download from NCDC. The rainfall data was culled to include only the rainfall events captured in our study. Due to the possibility of timing issues, two hours either side of the events of interest were also included. The George Bush Intercontinental Airport is approximately 5 miles from the North Vista site, and 3.5 miles from the Treaschwig Road site. The hourly data was supplemented by pond specific information. Table 6.2 summarizes the input data. The results of the modeling are shown in tables 6.3 and 6.4 in comparison with the actual measured data.

The resulting modeling shows that the predicted levels of pollutant removal are significantly higher for the empirical model than is actually observed based upon the field data.

6.2.1 North Visita Pond

The model predicts significant removal rates for the various pollutants modeled that the sample data does not support. The sample data concurs that total suspended solids and total phosphorus will be reduced. The total Kjeldahl nitrogen, copper, lead and zinc all showed increases in load as a result of the pond. It is possible that the very high sample results for metals for the January 4, 2007 event influence this value. Was the pond used to launch fireworks with reds, greens, and blue colors? Please see Table 6.3 for direct comparisons.

Table 6.3: Pollutant Removal in North Vista Pond

Constituent	Est. Load	Model Est. Removal	Model Est. Removal	Data Est. Removal	Data Est. Removal
	lbs/year	lbs/year	%	lbs/year	%
TSS	13853.4	11953.4	86.3%	7380.5	53.3%
TP	47.1	24.7	52.4%	3.8	8.0%
TKN	216.3	96.3	44.5%	-103.1	-47.7%
CU	6.8	4.1	60.3%	-0.8	-11.3%
PB	2.8	2.2	78.6%	-0.5	-18.0%
ZN	111	10.3	9.3%	-688.0	-619.8%

6.2.2 Treaschwig Road Pond

The model predicts significant removal rates for the various pollutants modeled that the sample data does not support. The sample data concurs that total suspended solids, total Kjeldahl nitrogen, copper, lead and zinc all will be reduced by Treaschwig Road detention pond. Total phosphorus load was shown to increase.

Table 6.4: Pollutant Removal in Treaschwig Road Pond

Constituent	Est. Load	Model Est. Removal	Model Est. Removal	Data Est. Removal	Data Est. Removal
	lbs/year	lbs/year	%	lbs/year	%
TSS	5239.40	4498.00	85.8%	1505.6	28.7%
TP	17.30	9.30	53.8%	-2.6	-15.0%
TKN	78.90	36.00	45.6%	28.1	35.6%
CU	2.50	1.50	60.0%	1.1	44.4%
PB	1.00	0.80	80.0%	0.0	1.8%
ZN	38.90	3.80	9.8%	-14.6	-37.7%

7.0 Discussion of Results

7.1 Results

Considering the wide range of storm events sampled, it is interesting to note that the data is reasonably coherent in nature. The results show that the ponds are mostly ineffective at pollutant removal. The North Vista pond reduced fecal coliform and total suspended solids at 90% confidence level and increased zinc and dissolved zinc. The Treaschwig Road pond reduced pH, nitrogen as nitrate and nitrite, total Kjeldahl nitrogen, copper, dissolved copper, and dissolved lead.

Based upon the review of the modeling data, the P8 Urban Catchment Model does not very accurately predict the removal rates of the various pollutants. More representative partition rates and more accurate settling information would result in better approximations, but still would not result in good representation of our specific watersheds as the data collected do not really show even close to ideal performance.

7.2 Lessons Learned

The original schedule for selection of candidate sites, negotiation with the owners of the storm water quality devices, and permitting the devices takes a minimum of one year. Our schedule originally scheduled four months for this process. In the City of Houston, the permitting process may be even longer.

It was surprising that none of the organizations approached were reluctant to allow the county to sample from their ponds, and their only real requirement was that we have liability insurance for any injuries to people caused by our equipment.

Sampling was more difficult than expected. Our first candidate site (Oak Landing Drive) appeared to be optimally located and convenient with good access to the inlet and outlet. The difficulty was that the pond was located in the front of the subdivision and readily visible from the publicly accessed flood control channel. Due to the design, the outlet device was a popular play area for bicycles and skateboarders. After four months of trying, it became apparent that sampling was not going to occur. Adding a more secure sampling equipment box did not reduce the damage as the boarders just used it as a jumping off point. Our recommendations are, if possible, to find a pond that:

1. Is fenced
2. Has no paved inlet or outlet channel
3. Is located with some obscurement of the sampling equipment
4. Is lined with vegetation
5. The boxes holding the equipment are painted green or brown

The North Vista pond was fenced for both inlet and outlet sampling equipment. The Treaschwig Road pond was not fenced, but was obscured by trees from the public right-of-way and by the yard fences on the north side. Neither of these sites included any consistent vandalism problems.

The budget for laboratory did not vary from the proposed original budget. There needs to be a significant budget item for the project engineer and the sampling equipment operators for the installation, calibration, and operation of the equipment prior to successful sample events. North Vista required from December 2005 to February 2006 before the first successful sample occurred, and Treaschwig Road took from May 2006 to October 2006 until its first successful event occurred. I recommend three months of maintenance budget and six sample events without laboratory costs to be provided as budget.

The flow data should have been transmitted as hard copies and spreadsheets as soon as possible after the data was collected. Due to computer error, the spreadsheet (or raw data) was overwritten during download for a number of events. The paper copy is still available. The laboratory data should be transmitted as soon as it is available and not in a monthly fashion. The original pdf from the lab should be sent to the project manager.

This project did not result in enough data for the large sample approximation to result due to limited sample and equipment rental budget. Sample equipment budget should be doubled from the project budget. If twelve months of sampling is to occur, then sample equipment budget should include an extra 6 months of lease. I would recommend that a future project of this nature include a minimum of 24 samples and a minimum of two years in which to collect data.

Non-parametric methods were used for the sample analysis. Non-parametric methods are used for data that does not have a normal distribution. Per-se, the use of non-parametric methods is not worse than using parametric tests, but the ability to reject data as not being part of the distribution is lower. The results of the sampling data analysis show a large number of the samples should not be considered normal according to the Looney-Gulledge probability plot correlation coefficient. Q-Q plots which show a straight line when there is a high degree of agreement do not show straight lines for the parameters analyzed. (Please see appendix B.) More samples may increase the chance of load data becoming parametric and, therefore, increase the probability of detecting outliers.

8.0 References

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