FINAL REPORT TO THE CITY OF SPRINGFIELD

JORDAN CREEK
BASELINE WATER QUALITY PROJECT
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ABSTRACT

This report describes the baseline water quality trends for the upper Wilson-Jordan Creek watershed in southwest Missouri. The study area includes Jordan Creek, the primary stream draining the central downtown area of Springfield, Missouri, and also Fassnight and upper Wilson Creeks. Ten sample sites were established within the watershed and water samples and were collected during base flow and storm runoff events between August 1, 2004 and July 31, 2005. Samples were tested for total nitrogen (TN), total phosphorus (TP) and selected heavy metals (zinc, arsenic, lead, copper and cadmium) and the parameters pH, specific conductivity, turbidity, temperature and dissolved oxygen. Rating curves were used to correlate discharge and water quality variables. Separate rating curves were developed for base flow and storm runoff conditions. A significant negative correlation between base flow TN and water temperature indicated that variation in TN could be due to seasonal trends in plant activity. A negative correlation between TP and specific conductivity was probably due to increased TP loading during storm runoff. Concentrations of TP and TN at the study watershed outlet were found to be below proposed MODNR TMDL limits for 86 % and 55 % of the study period respectively. Nutrient levels in Jordan Creek are similar to those of other Ozark watersheds not influenced by waste-water treatment plants including some draining relatively rural areas. Annual loads from the study watershed, based on daily average flow frequency, were 26.8 and 2.2 metric tons/year for TN and TP respectively. Concentrations of TN were relatively similar among sample sites at storm runoff, and base flow variations appear to be related to karst spring discharge. Concentrations of TP were also similar among sites at base flow, but storm levels were more variable due to the influence of land use and channel condition.

INTRODUCTION

PROJECT RATIONALE AND SCOPE

The US Army Corps of Engineers (USACE) is currently in the second (or feasibility) phase of a project to improve flood control on Jordan Creek in Springfield, Missouri. The project intends to reduce potential damage from floods on Jordan Creek and possibly also to restore the stream ecosystem and improve water quality (USACE, 2006). In order to evaluate progress toward these secondary project goals it is necessary to have an accurate assessment of pre-project conditions, including both pollutant concentrations and the stream and watershed conditions that affect those concentrations.

PURPOSE

This project was intended to support the USACE project by developing methods and using those methods to monitor pre-project water quality trends in Jordan Creek, thereby establishing a baseline to use for evaluating future flood control improvements to water quality.

OBJECTIVES

Individual objectives for the Jordan Creek Baseline Water Quality Project include:

1. Locate sampling/monitoring sites and monitor those sites for a 1-year period.

2. Collect data on water chemistry including temperature, pH, DO, specific conductivity and turbidity.

3. Collect data on typical urban pollutants including nutrients (total nitrogen and total phosphorus) and metals (arsenic, cadmium, copper, lead and zinc).

4. Collect 2 to 4 samples monthly at each site, about equally divided between base flow and storm runoff.

5. Determine sub-watershed conditions for each site (drainage area, flow frequency tables, impervious area/land use).

6. Determine the discharge at the time of each sampling.

7. Interpret the monitoring results in terms of degree, hydrology, and source of water chemistry pollutants in the Wilson-Jordan watershed.

STUDY AREA

WATERSHED LOCATION

The study watershed is almost entirely contained within the city limits of Springfield, Missouri and includes the Jordan Creek and Fassnight Creek watersheds and the part of the Wilson Creek watershed that is above the USGS gage located on Scenic Avenue (USGS Gage 07052000 “Wilson Creek at Scenic”) (Figure 1). The drainage area was mapped from a USGS 10 m DEM using the Arc Hydro extension of Arc Map (Maidment, 2002). This procedure provided an estimate of area for the study watershed as well as the area of subwatersheds for each of the ten sample sites within the study area. The total watershed area, as defined by Arc Hydro, is approximately 50.2 km^2 (19.4 mi^2). This value is larger than the 17.8 mi^2 published on the homepage for the gage (USGS), but the same as the gage watershed area published in Richards and Johnson (2002).

Geology and Soils of Study Area

Rocks within the study area are mainly limestones and dolostones of Mississippian age, composed nearly entirely of the calcareous body parts of benthic sea creatures, with varying percentages of secondary chert. The bedrock erodes quickly when exposed and is very poorly represented in coarse alluvial sediment, which is nearly all residual chert (Adamski et al, 1995). The carbonate nature of the bedrock produces many karst features in the area such as caves, sinkholes and springs, which are common within the study area. These features complicate surface drainage by producing “losing” and gaining” sections of streams in which water either enters the stream from springs or leaves the stream at karst fissures or swallow holes. Many springs are located within the study area and sinkholes are present as well, especially in the south eastern quarter of the study area (Bullard, 2000) (Figure 2).

Soils within the study area are primarily developed from the red clay residuum that results from the weathering of the underlying limestone bedrock, although some glacial loess does occur as a parent material in some upland area soils, although the study area is south of the primary area of loess deposition (GSA, 1949; Hughes, 1982). Different soils are produced by differing vegetation coverage, by slope aspect and hydrology. The soils within the study area reflect its oak savannah prehistory with some originating under prairie grasses and others under deciduous forest (Figure 3, Table 1).

Climate and Hydrology

The study area climate is humid temperate, averaging 114 cm total precipitation per year as measured at the Springfield Airport gage and compiled in the NOAA 30 year average and available from the National Climate Data Center (NCDC). Cold winter temperatures allow some precipitation in the form of snow, but it is rare for snow to accumulate in large quantities or to persist on the ground. Precipitation is distributed fairly evenly throughout the year with the greatest amount coming in the spring and early summer with a minor peak in the fall. Extreme rainfall events can occur at any time of the year, however. Air temperatures vary greatly over the course of a year with the lowest temperatures occurring in January and the highest in July (Figure 4).

The USGS Gage at Scenic Avenue provides a discharge record for the study area. The gage was in operation from 1933 to 1939 and then from 1999 to the present. A duration curve for daily average flow that separates the first and second periods of operation seems to show that the study area has undergone the classic hydrologic response to urbanization over time, that is, lower base flows and higher flood flows (Figure 5).

Land Use

The City of Springfield 2001 land use classification was used to create a land use map for the study area (City of Springfield, 2001). The study area contains the highly urbanized core of the city and the resulting classification is highly skewed towards commercial and residential uses (Figure 6, Table 2). Pasture and forest exists only in the far eastern headwaters area of the study area and in the riparian zone near the watershed outlet along Fassnight Creek.

Land use for the study area and each subwatershed was calculated using the City of Springfield 2001 Land Use Map (City of Springfield, 2001). The watershed polygons created in Arc Hydro were used to clip portions of the land use map and the land use areas were calculated using those clipped polygons (Table 2, Figure 6). Land uses among the watersheds were quite similar and were highly skewed toward urban types such as residential and commercial. The land use map did not classify roadways and the area difference between classified land use and total watershed area for each watershed was classified as “Roadway area” for the purposes of the study.

METHODS

SAMPLE SITE SELECTION

Ten sample sites were chosen within the study watershed. The sites were established at bridges for easy access and to allow sampling during storm runoff conditions. One site (WC1) is located near the USGS gage at the watershed outlet on Wilson Creek at Scenic Avenue, four sites (JC1 – 4) are located along the main stem of Jordan Creek, two sites are located on the north (NB1 – 2) and south (SB1 – 2) branches of Jordan Creek, and one site (FC1) is located on Fassnight Creek (Figure 7, Table 3).

HYDROLOGY

Discharge Measurement

Discharge at all sites except site WC1 was estimated directly by using survey and flow velocity measurements to produce a discharge rating curve. Each site cross section was surveyed and a staff gage installed. Water levels on the staff gages were recorded at each time a sample and discharge measurement was taken. At some sites (JC1, SB2, FC1) the staff gages were normally dry during low flows. For these sites, low flow gauging was measured at a prescribed location marking the deepest part of the channel and the stage and sample location was recorded at the sampling time. Care was taken to include the elevation of these alternate low flow gage sites in cross-sectional surveys. Velocity discharge was gauged with a *Global Water FP 201* velocity meter set in velocity-averaging mode. Sample sites are located at bridge crossings of Jordan, Fassnight or Wilson Creeks and during event flows, the velocity was measured from the bridges, while at base flow, velocity was measured from within the stream. Some low flows were insufficient to measure with the *Global Water* meter, usually because the propeller could not be completely immersed. In these cases estimates were made using a timed float test along a measured length (usually 1-2 m) of straight channel length. The float method is modified from the USGS method for high flows, which is assumed to be accurate to within 10% of actual average velocity (Rantz, 1982). Site cross-sections are included in Appendix A.

Rating Curves

For each sample date, stage (in meters from staff-gage reading) was plotted against discharge to produce a discharge rating curve. A second-order curve was fitted to the resulting distribution with correlation coefficients (R^2) ranging from 0.997 (NB1) to 0.936 (JC4). The curve formulae were then used to estimate discharge from stage measurements alone. The flows sampled during the study were clustered at either the low (base flow) or the high (storm runoff) end of the range leaving a range of discharge values un-sampled. Headwater and urban streams typically respond quickly to precipitation events with little transitional time between base flow and runoff peak (Schueler and Holland, 2000). The data clusters are probably an artifact of the “flashy” nature of these streams, and since the calculated curves seemed to correspond well with sampled flows this did not appear to be a severe defect. Rating curves and equations are included in Appendix A.

City of Springfield 1-year Flood

The City of Springfield Storm Water Services Department assisted the project by providing the estimated peak discharge for a 1-year recurrence rainfall event at each sample site (Table 4). This estimate was useful as a comparison to experimentally determined discharge at each site, and for creating an independent estimate for loads and yields within the study area.

WATER CHEMISTRY

Water chemistry parameters were collected at each sample time with a *Horiba U-22XD Multi-parameter* water quality meter (Horiba, 2001). Parameters measured include pH, Specific Conductivity (mS/cm), Turbidity (NTU), Temperature (˚C), Dissolved Oxygen (mg/L) and sample time and day (Table 5). The procedure entailed placing the sensor into the stream at the sample site taking care to ensure that free-flowing water from the stream was able to move freely over the sensor. The sensor readings were allowed to stabilize before collecting the reading (usually 3-5 minutes). After sampling, readings were downloaded into a spreadsheet and site and stage information added. Instrument accuracy was maintained by using the auto-calibration procedure before each sample run and by re-conditioning and manually calibrating each sensor every few months.

WATER SAMPLE COLLECTION

Water samples were collected at each site at each sample time in 500 ml polyethylene bottles using one of two methods. In addition, each sample run was classified as either "baseflow" or "storm" depending on the general runoff conditions (i.e. the continuing presence of rain during the sample period). Baseflow samples or any samples collected when the stream could be safely entered on foot, consisted of grab samples: bottles and lids were rinsed three times in free-flowing stream water and then a sample was collected by inverting the bottle to approximately 0.6 of depth and then turning up the opening to allow water to enter while sweeping the bottle across the stream width to achieve a horizontally-integrated flow sample. Care was taken to insure that bottom sediment was not disturbed by sampling activity: the bottle was not allowed to contact the bottom, and sampling occurred upstream of the technician and upstream of or previous to other data-gathering activities. When the stream was dangerous to enter due to swift or deep water, samples were collected from bridges at each site using a DH-48 suspended sediment sampler with handle extensions. These samplers are designed to use the same 500 ml bottles used throughout the study, and fill at a constant rate that is dependent on flow velocity. Care was taken not to allow the sample bottle to fill completely as water will continue to cycle through the bottle which may cause the sample to become artificially enriched in suspended sediment. Extension rods allow the sampler to reach from the bridge deck to the stream. Samples collected with this secondary method were “horizontally integrated” by moving the sampler across the current as the bottle filled.

Field duplicates and field blanks were collected for each batch for quality assurance and quality control purposes. The duplicate sample was collected at different sampling sites each time. De-ionized (DI) water was transferred to a 500 ml sample bottle in the field for each blank. The field duplicates and field blanks were preserved and processed in the same manner as other samples. All samples, including blanks and duplicates, were acidified with HNO_3 or H_2SO_4 in the field to less than pH 2 to stop all biological processes and preserve metal or nutrient concentrations. Samples were stored on ice in a cooler while in the field and were transferred to a refrigerator maintained at 20º C at Missouri State University.

NUTRIENTS

Water samples were analyzed in the MSU laboratory for concentrations of TP, TN and the metals arsenic, copper, lead, and zinc. The analytical methods for this project were either standard methods or were standard methods adapted by Mary Krause. Any adaptations of the standard methods are described in detail in the Krause thesis (Krause, 2005). Method descriptions are below.

Total Phosphorus

The method used to measure total phosphorus is based on converting all forms of phosphorus to orthophosphate by an acid-persulfate digestion process described in EPA method 365.2 (JC-V1, 2004). The method detection limit is 0.01 mgP/L, and the applicable concentration range is 0.01 mgP/L to 0.5 mgP/L.

Total Nitrogen

The method used to measure total nitrogen is based on the oxidation of all nitrogen-containing compounds to nitrate followed by second derivative spectrophotometric analysis (TN-JC-1, 2004). Nitrate concentration is determined on a UV/Visible spectrometer by measuring the transmittance at 220, 225 and 230 nm and comparing that value to a second order calibration plot created by known standards. Second order calibration is used rather than a linear plot since the transmittance values over the range of 0 to 5.0 mg/L is slightly curved (Krause, 2005). The detection limit for the method is 0.1 mgN/L, and the applicable range is from 0.1 mgN/L to 5 mgN/L.

METALS

Inductively coupled plasma-optical emission spectroscopy (ICP-OES) was the method used to analyze for zinc, copper, and lead. Samples were prepared by microwave – assisted acid digestion to ensure that all adsorbed metals were dissolved before analysis according to Standard Method 3030K (APHA, 2005). This procedure “is a hot acid leach for determining available metals” in aqueous samples that may contain suspended solids. The method will digest into solution any adsorbed metals but will not completely digest the entire mineral component of suspended material and therefore corresponds to the "Total Recoverable" metal concentrations from the water samples.

A premade standard containing 0.1 mg/L copper, 0.1 mg/L lead, and 0.2 mg/L zinc and a reagent blank acidified with nitric acid was used to calibrate the ICP-OES. A laboratory control check containing 0.05 mg/L copper, 0.05 mg/L lead, and 0.1 mg/L zinc was used to verify the accuracy of the ICP-AES. A Varian Liberty 150 AX Turbo ICP Emission Spectrometer was used for analysis of all samples.

HYDROCARBONS (HEXANE-EXTRACTABLE MATERIAL)

The method used to analyze hydrocarbons actually measures the hexane-extractable material (HEM), or oil and grease, present in samples. The method employs solid-phase extraction and is a gravimetric method. The detection limit for the method is 1.4 mg/L, and the lower limit of quantification is 5.0 mg/L. EPA Method 1664 describes this technique; however, while it suggests solid phase extraction as a possible adaptation, it does not provide detailed instructions (Krause, 2005). For this reason, a set of instructions provided by CPI International was followed for the extraction steps. Solid phase extraction involves the use of a solid phase extraction (SPE) disk. The SPE disks employed here are made of 18 carbon chains with silica backing and are therefore hydrophobic. After preconditioning the disk with hexane and methanol, the sample is allowed to drip through the disk. As the water passes through, the hydrophobic hydrocarbons remain in the SPE disk. The disk is then extracted with hexane, which removes the HEM. After the extractions, the hexane is dried with sodium sulfate and evaporated, leaving behind the HEM. Samples for HEM analysis were collected in 1-liter glass bottles, acidified to less than pH 2 and refrigerated at 20° C.

Quality Assurance/Quality Control

Field quality control procedures for the project included collecting field duplicate and field blanks for each sample run, acidifying all samples to less than pH 2 to stop all biological processes that may affect nutrient concentrations and then refrigerating samples both in the field and in the lab until analysis. Field QA/QC results help to insure that field equipment is free from contamination and that sample collection procedures accurately reflect actual field conditions. Laboratory quality control procedures include preparation of laboratory duplicates, reagent blanks, spiked samples, digestion efficiency checks and laboratory control checks. Laboratory QA/QC procedures are designed to test the analysis procedure on various known quantities of analyte in order to insure the reliability of found concentrations in samples. In addition, the QA/QC required the use of acid-cleaned sample bottles for all sample collection to avoid cross-contamination, and proper labeling of all bottles with date, event, site and project to insure that proper laboratory results were attributed to the appropriate field site.

Nutrients

Data for the total nitrogen and total phosphorus QA/QC programs are included in Table 6 and Table 7, respectively. Field duplicate samples help to identify problems with sampling equipment contamination and with laboratory procedures, and are deemed acceptable if the relative percent difference (RPD) is less than 20 %. The RPD is the difference between the original and duplicate samples divided by the average of the original and duplicate.

$$RPD = \frac{|O - D| \times 100}{(O + D)/2}$$

Where:
O = original sample
D = duplicate sample

Field duplicates can also help to identify temporal variability in source waters if the duplicate samples fall outside the 20 % acceptance range but field blanks and laboratory QA/QC checks are also acceptable. All but two of the field duplicates for TN and TP fall within the 20 % RPD acceptance range, indicating that field techniques did not introduce nutrient contamination and that there is no significant short-term variation of concentration within the study area (Figure 8).

Laboratory QA/QC procedures include processing of laboratory duplicates, spiked samples and laboratory control checks (LCC) to monitor stability of results during analysis, quality control checks (QCC) which use independently produced reagents to evaluate laboratory procedures and reagents, and digestion efficiency checks (DEC) to evaluate the ability of the digestion reagent to convert all forms of nitrogen to nitrate. The LCC, matrix spike (MS) and QCC results are prepared to contain a known concentration of analyte and are deemed acceptable if the analyzed concentration is within 10 % of that concentration. The results of the analysis of these QA/QC products show that laboratory results for the nutrient analysis can be accepted (Table 6 and Table 7).

Reagent blanks (RBL) and field blanks (FB) are designed to test for contamination of laboratory and field equipment as well as to set the detection baseline for each sample batch (Table 6 and Table 7). These concentrations are acceptable if they are at or below the detection limit for the procedures, that is, 0.1 mg/L for TN and 0.001 mg/L for TP (Table 6 and Table 7). Negative values in these cases are considered to be below the detection limits of the instrument and sampling procedure. Total nitrogen RBLs were very consistently below the ideal limit although 58% of Field Blanks were above that limit. For TP, 52 % of RBLs and 76 % of FBs were above the ideal limits. These results indicate that there may be some contamination of field equipment with TN and TP and laboratory equipment with TP. Dr. Richard Biagioni has explored the possibility that double de-ionized water used in the laboratory procedures was contaminated by suspended particles from one of the in-line filters. These could be the source of TP contamination and a final filter has been installed to correct the laboratory TP problem. The actual detection limit for the method is three times the standard deviation of the RBL values. These values are 0.23 mg/L TN and 12 µg/L TP (Table 6 and Table 7).

Metals

The QA/QC procedure for metal concentration analysis mirrors that of the nutrient analyses. Field duplicates (FD), field blanks (FB), laboratory duplicates (LD), laboratory blanks (LRB), laboratory control checks (LCC), quality control checks (QCC), and vessel blanks (VB) were analyzed to determine the quality of the data. The laboratory blanks, standards, and checks were analyzed between each batch of 12 samples. Samples were collected in February and March 2007. February and March 2007 QA/QC data is illustrated in Table 8.

Laboratory reagent blanks (LRB) are used to determine if any laboratory procedures add analyte to the samples through reagent additions or the use of apparatus and instrumentation. The average copper concentration found in the LRB's was 0.000mg/L. Zinc and lead concentrations found in the LRB's were 0.000 mg/L and 0.007 mg/L respectively. The method detection limit was calculated by multiplying the standard deviation of the average of the laboratory reagent blanks by 3. The detection limit for copper was 0.000 mg/L, zinc was 0.001 mg/L, and lead was 0.012 mg/L (Table 8). The laboratory control check (LCC) for copper and lead should be 0.050 mg/L ±10%. LCC for copper was 0.050 mg/L and the LCC for lead was 0.054 mg/L. The LCC for zinc should be 0.1 mg/L ±10% and was 0.102 mg/L. The LCC data was within the acceptable limits for precision and accuracy. A separate premade standard from a different laboratory was used for the quality control check (QCC). The copper and lead concentrations should be 0.100 mg/L for the QCC and the average copper concentration was 0.102 mg/L and lead was 0.103 mg/L. The zinc concentration should be 0.200 mg/L ±10% for the QCC and the average concentration was 0.207 mg/L. The laboratory calibration standards were prepared correctly and did not vary throughout the analysis.

Field Blanks (FB) were determined to have 0.000 mg/L copper, 0.004 mg/L zinc, 0.009 mg/L lead. The standard deviation of the average of the field blanks was the same except for lead and the lead concentrations deviated by 0.004 mg/L. Vessel Blanks (VB) had 0.001 mg/L copper, 0.005 mg/L zinc, 0.012 mg/L lead and deviated by 0.002 mg/L, .004 mg/L, and 0.001 mg/L respectively. Vessel blanks were at or below detection limits, so the vessels did not add analytes to the samples during digestion. Because of the low concentrations of heavy metals in the samples the average percent relative difference of the Field Duplicates (FD) and Laboratory Duplicates (LD) did not mirror the actual concentration difference. Samples collected during stormwater events produced larger metal concentration differences in the laboratory duplicated due to the amount of suspended material in the sample bottles. All QA/QC results were acceptable for the samples collected in February and March of 2007.

Hexane-extractable Materials

The QA/QC for the hexane extractable material (HEM) method includes processing and analyzing laboratory and field blanks, a sample spiked with a known quantity of recoverable material, and an ongoing precision and recovery (OPR) sample. The OPR and spiked samples contain 40 mg of recoverable material. The QA/QC data for the HEM method shows some variability in OPR and spike recovery, which can be due to interference from materials present in the water or on the laboratory glassware, including detergents and particulates (Table 9). Because there was no significant recovery of HEM from any samples, except those from Dingledein Spring, sampling was discontinued and the study area was assumed to have no detectable HEM using this method.

RESULTS AND DISCUSSION

SUBWATERSHED CHARACTERISTICS

Watershed Area, Stream Segment Distance and Slope

The subwatersheds that contribute to each sample site were determined using the Arc Hydro extension of Arc Map and 10-meter resolution elevation data from the National Map (Table 3) (Maidment, 2002). In addition, lengths of stream segments were calculated by measuring the river distance between points in Arc Map (Table 10). The slopes of stream segments were measured as well using Arc Map and were generally very low, ranging from 0.003 to 0.005.

Land Use

The subwatershed polygons were also used to calculate land use based on the City of Springfield 2001 Land Use classification. The distributions of land uses are very similar for all of the study watersheds and were highly skewed toward urban types such as residential and commercial (Table 2). The land use map did not classify roadways and the area difference between classified land use and total watershed area for each watershed was classified as "Roadway area" for the purposes of the study.

DISCHARGE RATING CURVES AND FLOW FREQUENCY

Site WC1 Discharge Record and Flow Frequency

The flow records from the USGS Gage at Scenic Avenue provide a continuous discharge record for site WC1, and thus the net discharge from the study area. Figure 9 shows the site WC1 average daily discharge record for the study period with sample dates. The actual position of each storm event sample on the site WC1 hydrograph is shown in Appendix D.

The average daily discharge data was also used to create a flow exceedance graph for the study period (Figure 10). The flow exceedance graph shows the percent of the study period on the "X" axis and average daily discharge on the "Y" axis. Points on the curve represent the percent of time that a particular discharge was exceeded during the study period. Shown on the curve are the median discharge (0.2 m^3/s), the mean (0.57 m^3/s) and the approximate discharge threshold between base flow and storm runoff (0.8 m^3/s) during the study.

Discharge Rating Equations

Discharges for all other sample sites were estimated by using measured discharge and gauged water depth to create a second-order rating curve for discharge. The site discharge rating curves have an R^2 between 0.936 and 0.997, indicating a very regular pattern exists between gage depth and discharge (Table 11). Once the rating curves were created for each site, flow velocity gauging was discontinued and discharge was estimated using the staff gauge and rating curve at each site.

1-year Runoff Peak

The largest base flow and storm discharges measured either directly, estimated with a site rating curve, or measured at the USGS gage at site WC1, are shown in Table 12. The City of Springfield 1-year flood estimate greatly exceeds the largest study discharges at each site, with the 1-year discharges generally larger by a factor of at least three (Table 4, Table 12). Thus, a 1-year magnitude event probably did not occur during the study period.

WATER CHEMISTRY

A total of 27 samples were collected at each site during the study period, including 17 base flow and 10 storm runoff samples. Complete records for each sample site and date, including water quality parameters, concentrations of nutrients and metals, and discharge are included in Appendix B. Results are summarized below.

Water Quality Parameters

A summary of water quality parameters that includes the mean and standard deviation of sample measurements are presented in Table 13. Figure 11 illustrates the relationship between base flow and storm runoff water quality parameter means.

DO and pH values at site JC2 (Main stem of Jordan Creek at Fort Avenue) were lower at base flow. These low values are likely due to the addition of significant discharge from Dingledein Spring which is located about 100 m upstream from site JC2 (Bullard, 2000). Water quality parameters from Dingledein Spring were measured on four occasions and were found to be low in pH (6.8) and very low in DO (< 1 mg/L) (Figure 12). With the exception of site JC2, base flow pH appears to reflect carbonate buffering, with values between 7.5 and 8.1. Storm pH was very close to 7.5 at all sites which probably reflects the effect of lower-pH rainwater entering the stream. Sites JC2 and JC4 differed from the general trend within the study area and had higher storm than base flow pH. This is more an artifact of lower base flow pH at those sites than very high storm pH.

Specific conductivity was uniform across sites at both base flow and storm conditions with base flow being much higher, indicating the presence of higher concentrations of dissolved material. Base flow and storm values were very uniform across sites except for sites NB1 and SB1 which had lower base flow SC, and site NB2 which had high storm SC.

Turbidity was likewise fairly uniform between sites for base flow and storm runoff conditions, with storm runoff producing higher values. The high standard deviation indicates that turbidity was highly variable.

Dissolved oxygen was consistently high for all measured samples, with generally higher values measured at upstream sites and at base flow. Minimum values for each site were generally above the MODNR recommended minimum concentration for the health of aquatic life of 5 mg/L (Table 14).

Temperature was also very uniform between sites with storm water temperatures slightly higher than base flow. This may reflect a seasonal sampling bias, in that winter-time cold temperatures are likely to bring the stream close to 0 °C but winter time storm runoff is likely to be much warmer than that because cold storms produce snowfall rather than rainfall.

POLLUTANT CONCENTRATIONS

Pollutants measured included hydrocarbons (as HEM), nutrients and metals.

Hydrocarbon Concentrations

Hydrocarbons, as HEM, were measured in samples collected in 1 liter glass bottles on seven occasions including 2 base flow and 5 storm runoff events. Concentrations of HEM were found to be very similar to concentration in blanks and much less than the spiked samples created for QA/QC purposes (Table 15). It is perplexing that the HEM method used did not detect hydrocarbons even when a sheen was present on the water surface and a strong hydrocarbon odor permeated the air. This was the situation at site JC2 (Fort Avenue), and the sheen and odor was traced upstream about 100 meters to Dingledein Spring. However, it would not take a high concentration to cause this sheen to form on the surface, so the low concentrations of hydrocarbons present could have caused this. In addition, the extraction method is designed to measure only non-volatile hydrocarbons and any hydrocarbons volatile enough to evaporate during the extraction process, such as gasoline, would not be measured (Krause, 2005). The odor, unfamiliar to the author, did not seem to be gasoline or diesel fuel but may have been a solvent. Water flowing from the spring lacked significant levels of HEM, however the HEM method did recover 1,460 mg HEM /kg from sediment collected at the spring and 770 mg HEM /kg from Jordan Creek bed sediments immediately downstream of the confluence with the stream (Krause, 2005).

Metal Concentrations

Concentrations of the metals Pb, Cu, and Zn were measured in each of the samples collected and are illustrated in Table 16. These are typical urban pollutants which can be present in urban stormwater in toxic amounts, especially as sediment-bound pollutants in storm runoff. Graphic representation of each mean metal concentration for each site is shown in Figure 13. The current commended water quality criteria from the EPA are also included. The criteria maximum concentration (CMC) is the acute (severe affects) limit for the priority pollutant in freshwater. The CMC for copper is 0.013 mg/L, zinc is 0.120 mg/L, and lead is 0.065 mg/L. The criterion continuous concentration (CCC) is the chronic limit for the priority pollutant in freshwater. The CCC for copper is 0.009 mg/L, zinc is 0.120 mg/L, and lead is 0.0025 mg/L. The CCC represents the maximum concentration at which continuous exposure will have no deleterious effects on aquatic life (USEPA, 2006). When concentrations reach the CMC, effects occur. The method detection limit (MDL) was also included in Figure 13.

Copper concentrations varied from 0.000 mg/L to 0.023 mg/L and all concentrations were at or above the detection limit of 0.000 mg/L. Most copper concentrations were below the criterion continuous concentration (CCC). Sites JC3 and JC4 exceeded the criteria maximum concentration (CMC) for copper during storm flow. Zinc concentrations varied from 0.008 mg/L to 0.209 mg/L and all were above the detection limit of 0.001 mg/L. The CCC and CMC are the same for zinc and the only site to exceed both was JC4. Lead concentrations varied from 0.001 mg/L to 0.056 mg/L. Lead concentrations during base flow were routinely below detection (<0.012 mg/L). Lead concentrations at base flow exceeded the CCC, but none of the concentrations found at the sites were high enough to exceed the CMC of 0.065 mg/L. All metal concentrations were higher during storm flow.

Site JC4 continuously exhibited the largest metal concentrations within the watershed. Lower order sites such as NB1 and SB1 had the lowest concentrations of metals although NB1 had a higher concentration of zinc during storm flow than all of the sites except for JC3 and JC4.

Water chemistry parameters collected during the February and March 2007 sampling mirror water chemistry parameters collected prior. Table 17 illustrates the water chemistry parameters and corresponding discharge for water samples collected in February and March of 2007.

Nutrient Concentrations

Nutrients were measured as total nitrogen and total phosphorus using methods that aggregated all particulate-bound and dissolved forms of those nutrients into a single species for analysis.

Base flow and Storm Runoff Trends.

The mean and standard deviation for TN and TP concentrations at base and storm flow for each site are listed in Table 18. The full list of measured concentrations for each sample date and each site is found in Appendix B. Standard deviation is a measure of data dispersion and the standard deviation for TP was larger relative to concentration than for TN at base flow, indicating that TP was more variable than TN in base flow samples (Figure14). The upstream sample sites (NB1, NB2, SB1, SB2, and JC1) had higher standard deviations relative to sample mean than the downstream sites. Storm standard deviation of TP appears to be lower relative to concentration than storm TN, indicating less relative variability.

Discharge-Concentration Relationships.

Discharge is a relatively simple and convenient factor to measure in a stream compared to pollutant concentration. Therefore a “concentration rating curve” is often used to determine the relationship between discharge and concentration. The TN and TP concentration rating curves and equations for each site are presented in Appendix C. The R^2 values for the rating curves can be low due to the fact that discharge is not the only factor that controls pollution supply in streams (Ferguson, 1987; Thomas, 1989). Factors that can influence pollutant concentration independent of discharge include season (Mulholland, 2003; Zhang, and Schilling, 2005), availability of exposed sediment (Thomas, 1989, Bowes et al, 2005) and short-duration pulses of pollutants (Ferguson, 1987). The R^2 values for the nutrient concentration rating curves are very low. Base flow values for TP ranged from 0.001 (site JC3) to 0.462 (site NB1) and for TN from 0.001 (site NB1) to 0.632 (site JC2). Storm runoff values for TP ranged from 0.001 (site FC1) to 0.363 (site JC4) and for TN from 0.001 (site SB1) to 0.512 (site NB2). The base flow TP rating curves generally have negative slope, indicating that concentration tends to decrease with increasing discharge, at all sites except the upstream sites NB1, NB2 and SB2, and the upper main stem site JC1. Six TP concentration curves have positive slope, indicating that concentration increases with discharge while four have a negative slope, although all of the curves have slopes very close to zero. Base flow TN rating curves have positive slopes with the exception of site SB1, indicating TN concentration increases with base flow discharge. Storm runoff TN slopes have negative slopes with the exception of site SB1, indicating that TN concentration decreases with increasing storm runoff.

WATERSHED-SCALE WATER QUALITY TRENDS

In this section the study results are analyzed and reviewed for important trends including correlation analysis of results and concentration duration based on continuous flow records. Pollution sources within the watershed were examined by the spatial analysis of median base flow and storm values for each site. Load duration-based pollutant loads to lower Wilson Creek were calculated and compared to EPA "simple model"-based loads. Finally, study results were compared to other regional studies of concentration and loads.

Correlation Analysis

Correlation matrices for measured water quality parameters and nutrients for all samples, base flow samples, and storm runoff samples at site WC1 can help shed light on sources and controls for pollutants within the study area (Table 19, Table 20, and Table 21). Total nitrogen concentration at base flow is significantly positively correlated with DO and discharge, and significantly negatively correlated with water temperature and TP. Total phosphorus concentration at base flow is significantly negatively correlated with SC, DO and positively with temperature.

Seasonal TN Trend

The relationship between TN and water temperature and DO probably is related to seasonality. Water temperature is lowest during the winter months which is the time when surface plants are dormant and not using dissolved N in pore water and thus more is available to enter the stream as groundwater (Figure15). The similar correlation for TN and DO probably illustrates the same seasonality using the physical relationship between water temperature and DO concentration. The correlation between TN and discharge (Q) is probably due to the fact that the highest base flow Q at site WC1 and high TN concentrations both occurred in the cold season. The rest of the sample sites share the significant negative correlation between TN and temperature but not TN and Q (Table 22).

Concentration Exceedance

A concentration rating curve uses discharge to predict concentration and the concentration rating curves created for this study are split into base flow and storm runoff segments (Figure16). The threshold between the base flow and runoff is set midway between the largest measured base flow and the smallest measured storm and is 0.8 m^3/s at site WC1. The discharge records from the USGS gage at sample site WC1 allow concentration duration graphs to be constructed based on average daily discharge data and the concentration rating curve. These can be used to estimate the percent of time during which a particular TN or TP concentration was exceeded during a year (Figure17). The points on the curves represent the amount of time during the study period that a particular concentration was exceeded during the study period. The sharp increase in slope in the concentration exceedance curve for TP seems to show the dramatic effect that storm runoff has on concentration. The James River TMDL study recommended a limit of 75 µg/L for TP and 1.50 mg/L for TN. The concentration exceedance graph indicates that the recommended concentration limits for TN and TP were exceeded 45% and 14% of the time, respectively, during the study period (MODNR, 2001).

Watershed Source Analysis

Direct comparison of storm runoff concentrations between sites is problematic because the sampling method does not ensure that samples at all sites are taken from the same point on the hydrograph at all sites. Median values represent the “usual” conditions at each site and thus calculated median values for discharge and concentration are used to compare results for each site.

Specific Discharge

Comparisons are made for specific discharge using the City of Springfield 1-year modeled discharge and the median storm and base flow discharges for each site graphed according to stream distance from study area outlet at site WC1 (Figure18). “Specific discharge” is defined as “discharge per unit area” and is expressed as liters per second per km^2 ($L/ s / km^2$). Typically, specific discharge will decrease as watershed area increases due to the greater opportunities in larger watersheds for runoff to be stored in temporary storage areas, such as ponds, groundwater and vegetation, and thus reduce the runoff peak (Chorley, 1971). Urban impervious areas influence specific discharge in the same way that it influences the urban hydrograph. Increased impervious surface area reduces both stream recharge and specific discharge at base flow, and the increased surface runoff associated with impervious area increases both the peak of the hydrograph and the specific discharge for storm flows. Deviations from a predicted uniform specific discharge pattern would indicate increased or decreased flows in the stream unrelated to watershed surface area. Karst drainage features can either increase discharge in streams through springs or reduce discharge through swallow holes or "losing" stream reaches.

The pattern of 1-year specific discharges shows a very steady trend from the upper watershed on the North Branch sites to the outlet with a low specific discharge at site JC1. The "offline" South Branch sites have low specific discharge that may contribute to the low value at site JC1 since it is downstream of the confluence of the two branches. The South Branch watershed has many more mapped sinkholes than any other area in the study. High sinkhole density may explain the low specific discharge values from those sites since they may direct runoff away from the South Branch (Figure18). Sinkholes would probably have more influence during surface runoff events than during base flow conditions, which might explain why the South Branch sites are not dramatically different than the rest of the channel at base flow.

The median storm exhibits a similar steady pattern to the 1-year pattern with the exception of very high specific discharge at site JC3, and a low value at site FC1. The South Branch median storm specific discharges are low, similar to the pattern shown in the 1-year discharges. The high value at site JC3 may be due to storm water channels adding flow to the stream at that site, or to measurement errors. Site JC3 has a very natural channel and storm runoff at that site was often eddied and swirled as it passed under the bridge. The velocity meter used for discharge gauging registered upstream flow as zero velocity rather than negative and thus discharge at that site may have been overestimated.

Total Phosphorus

Median concentrations can be interpreted as the usual conditions that occur at a site and differences in median concentration can reveal differences in sources that affect that site most directly. Median TP concentrations are very consistent for base flow with values falling in the range of 25 to 45 µg/L (Figure19). The median storm TP concentrations were higher but consistently in the range 135 to 215 µg/L with the exceptions of site WC1 where the concentration is lower than the general watershed trend (116 µg/L) and site NB1 which is slightly higher than the range at 245 µg/L. The uniform base flow TP pattern seems to indicate a source for TP that is relatively uniform across the watershed. Site NB1, located on the North Branch at Smith Park, was unique among sites in having a dry channel for much of the study period; this may have allowed a large amount of sediment to accumulate that may have increased the TP concentration during storm runoff.

The different relative distribution of land use within the watersheds may explain the low storm TP median value at site FC1. All of the study watersheds have very similar land use percentages (Table 2), but the site FC1 watershed is unique in having a large percentage of vegetated areas close to the stream corridor (the area zoned "commercial" upstream of site FC1 is Parkview High School and Maple Cemetery).

Total Nitrogen

The median TN concentration for base flow is higher and has much more variation than the storm runoff median (Figure20). Median storm TN concentrations are all within the range of 0.9 to 1.3 mg/L. Base flow median TN concentration values appear to be generally within a range of 1.3 to 2.1 mg/L with the exceptions of site SB1 at the upper South Branch with a much lower concentration of 0.57 mg/L and site JC1 on the main stem with a higher concentration of 2.7 mg/L. Local reports have noted that spring-related discharge in the area is relatively high in TN and low in TP as compared to surface flow (Bowen, 2004; Pavlowsky, 2006). The combination of elevated discharge and elevated TN concentration, such as occurs at sites SB2 and JC1, could indicate the presence of a spring. Sites NB2, JC1 and FC1 seem to fit this pattern of high TN and low TP. Evidence for spring discharge at these sites is anecdotal; site NB2 had flow at every sample time yet is 2 km downstream from site NB1 which often had no flow and similarly site FC1 had flow at every sample time yet upstream in Fassnight Park the stream bed was often dry. Site JC1 is located at the end of the “underground” section of Jordan Creek and thus it is not possible to confirm the presence of a spring, although Bullard (2000) notes that the present-day traces of many historic springs in the downtown area are outflow pipes into Jordan Creek that are indistinguishable from storm culverts

NUTRIENT LOADS TO LOWER WILSON CREEK

Several methods were used to calculate the loads exported from the study watershed based on load duration curves created for site WC1. The first used the discharge duration graph for the USGS gage at site WC1, which produced a probable load based on 15 years of recorded discharge data. The second used actual average daily discharge data for the study period and produced an estimate of the actual load for the study period. The final method uses an EPA load estimate based on the land use characteristics of the watershed to create an annual load estimate.

Load-duration Method

The flow duration table was used to create a probability-based annual load for the study area (Table 23). The TN and TP load rating curves for site WC1 were used with flow exceedance discharges to calculate daily and annual loads based on probability. Because the record does not encompass 30 years of data (not necessarily consecutive), the agreed standard used by the USGS to conform to World Meteorological Organization methods, the results do not meet USGS standards for statistical validity; however they do provide the best available estimate of flow probability (Searcy, 1959). The estimates created from this record should be evaluated as “percent of flows during a 13-year period likely to be exceeded by a particular flow” rather than percent of a particular year’s flows that will be exceeded (Searcy, 1959). The flow duration annual load method indicates that 24.3 metric tons of total nitrogen and 1.2 metric tons of total phosphorus will be exported to the lower Wilson Creek each year.

Average Daily Discharge Method

Flow records from the USGS gage at this site include average daily discharge values. Average daily loads were calculated by inserting the average daily discharge into the WC1 load rating equation for each nutrient constituent and then summing each daily load (Table 24, Figure 21).

EPA Land Use-based Method

The EPA TMDL handbook outlines a “simple method” for estimating load based on total area and percent of land use type within the watershed (US EPA, 1999) (Table 24). The method outlined produces minimum, median and maximum expected loads of TP and TN based on expected yields from typical urban surfaces. A graphic comparison of simple method loads and the flow based loads shows that average daily flow – based and flow exceedance – based estimates were similar to EPA simple method estimates for TN and low for TP (Figure 21).

REGIONAL COMPARISONS

Comparisons can be made between the results of this study and important regional studies including the James River TMDL study (MoDNR, 2001) and the Richards and Johnson (2002) USGS water quality study of Wilson and Pearson Creeks.

James River TMDL

The TMDL study from 2001 is an important comparison for the present study because it includes long-term water quality data from streams in the immediate vicinity of Springfield (MoDNR, 2001). Samples were collected during base flows over the summer months of 2001-03, and included TN and TP. The TMDL sample sites affected by discharge from waste water treatment plants were removed from comparison, because no wastewater treatment plants exist within the study area, leaving 7 sites that have land-uses ranging from mixed urban-rural to mixed agricultural-forest (Table 25). Because the TMDL samples were taken exclusively during summer base flow conditions, and because the TMDL sites do not correspond exactly with the sites from the present study, the best comparison is the mean and standard deviation of TN and TP (Figure 22).

The mean base flow TP and TN concentrations found in this study fit well within the range of mean TN and TP for good quality streams from the TMDL study. Mean storm TN fits into this range as well although mean storm TP falls above the range of TMDL base flow TP means. This is evidence that Jordan Creek has similar nutrient content to other local streams at base flow, even some streams that drain relatively rural areas.

Wilson and Pearson Creek USGS Water Quality Study

This study is significant because the Wilson Creek sample site from the study is the same as site WC1 in the present study. The Wilson-Pearson (W-P) study examined water quality in the two streams that drain much of downtown Springfield to assess the toxicity of the water for aquatic life. Mean base flow concentration and storm EMC are critical for measuring this and the study did not assess annual loads. The concentration data is available at the USGS Gage 07052000 website under “Water

Quality: Discrete Samples", and includes concentrations of TN (nitrate plus nitrite) and TP as well as many others including specific conductivity (SC) measurements from the field and the laboratory. The W-P TP concentrations plot slightly higher than the WC1 base flow and storm TP data, probably due to sampling differences. The W-P samples were composites collected both on the rising and falling limbs of each storm hydrograph and then averaged while the present study managed to collect primarily falling limb samples (Figure 23). Sediment (and thus sediment-bound phosphorus) tends to be concentrated in the rising limb and depleted in the falling limb, the W-P samples include the rising limb which could account for the concentration differences between the studies.

CONCLUSIONS

The primary goal of the present study was to 1) determine the concentration of key pollutants in Jordan Creek and 2) estimate the loads and yields of nutrients from the watershed into Wilson Creek. To create these estimates water samples were collected during both base flow and storm runoff conditions. Samples for nutrient analyses were collected between July 2004 and July 2005 and samples for metal analyses were collected between February and March 2007. Discharge measurements were taken under both base flow and storm runoff conditions during nutrient sample collection. Water quality parameters were collected with each sample to explore the stream conditions that may contribute to pollutant concentrations. The watershed load was calculated by using base flow and storm runoff water samples and instantaneous discharges to create a load rating curve for each of ten sample sites, and then calculating annual loads by using that load rating curve with average annual flows or flow frequencies. The WC1 sample site, located at the USGS Gage on Wilson Creek at Scenic Avenue has the discharge records to support these load and yield estimates. The other sample sites were compared to each other by using regional runoff equations and City of Springfield flood modeling to calculate equivalent discharges for each site.

- **DISCHARGE TRENDS**

The hydrographs collected from the USGS gage at site WC1 during the study show that the streams in the study area seem to exhibit a very flashy response to precipitation. In addition, the changes in the discharge duration graphs between the 1930's and 2000's provide evidence that the study watershed has undergone urbanization that has in turn affected the hydrology of the watershed by reducing base flow discharge and increasing the peak runoff discharges (Figure 5). Analysis of median specific discharges measured at the study sample sites shows that base flow discharge at site JC1 may be increased due to spring discharge in the "underground" section of Jordan Creek and that storm runoff measured during the study closely follows the pattern of the 1-year flood discharge modeled by the City of Springfield (Figure 18).

- **CONCENTRATIONS OF POLLUTANTS**

Hydrocarbons, measured as HEM, were not detected in significant quantities in the water of the study area, although sediment collected at Dingledein Spring and from Jordan Creek downstream of the spring confluence contained significant levels of HEM. Metal concentrations were detected in samples collected during both base flow and storm flow. Metal concentrations were consistently higher in samples collected during storm flow. Zinc was found in the highest concentrations, followed by lead concentrations, then copper concentrations. Zinc concentrations exceeded the criteria maximum concentration (CMC) during storm flow at site JC4. Copper concentrations exceeded the CMC during storm flow at sites JC 3 and JC4.

- **SOURCE PATTERNS**

Based on analysis of the median concentration of TN and TP samples collected at each sample site, base flow TN concentrations appear to follow a "point source" pattern with high values occurring at sites influenced by spring discharge. Base flow TP follows a "nonpoint" pattern with a uniform pattern of values. Storm TP median concentration patterns suggest that the pattern of land use within a watershed, rather than merely percent of land use, may control TP concentration. Storm median loads indicate that the downtown core area is a major source of TP for the study watershed. Concentration and load differences were not attributable to land use differences between watersheds based on the land use classification used in the study. The City of Springfield used hydraulic models to determine the 1-Year Recurrence discharge at each sample site. This discharge provides a basis for common comparison between the sites that isn't provided by comparing loads per event, because the sampling procedure doesn't guarantee that each sample was taken from the same point on the hydrograph. These discharges were put in to the TN and TP load rating curves for each site and the resulting loads compared to an EPA "simple model" of land use-based TN and TP loading. The results were very similar, but did not single out a particular land use category or watershed as being a source for nutrient loads

- **REGIONAL SIGNIFICANCE**

The James River TMDL study collected samples from sites within the James River Basin at base flow (MODNR, 2001). The TMDL site watersheds had land uses that were much less urban than the land use within the current study area. Base flow TN and TP means for the present study at site WC1 are 2.28 mg/L and 28 µg/L and storm concentrations are 1.25 mg/L and 177 µg/L, respectively. The base flow TP values are similar to TMDL sites not influenced by wastewater treatment plants (WWTP) and much less than those with influence from WWTPs. The mean storm event TP concentrations are higher even than sites with WWTP influence. Both base flow and storm TN concentrations are within the range of values from the TMDL study indicating that, despite urbanization within the study area, base flow nutrient concentrations are generally similar to those in Ozark rural watersheds. Concentration exceedance data for the study indicates that TMDL target concentration for TN (1.5 mg/L) and TP (75 µg/L) were exceeded at the watershed outlet at site WC1 45 % and 14 % of the study period, respectively.

TABLES

Table 1. Relative abundance and some characteristics of soil types found in the study area.
(Hughes, 1982).

Soil Symbol	Soil Name	Percent Area	Slope (%)	Landform	Parent Material	Infiltration rate (in/hr)	Depth to impervious layer (in)
6B	Creldon silt loam	31.4	1 to 3	uplands	loess/ residuum	0.6 - 2	24
81B	Viraton silt loam	19.1	2 to 5	Upland /terrace	loess/ residuum	0.6 - 2	22
2B	Pembroke silt loam	12.9	1 to 5	upland/ terrace	loess/ residuum	0.6 - 2	72+
5C	Wildernes s cherty silt loam	6.9	2 to 9	uplands	residuum	2.0 - 6	10
33B	Keeno and Eldon cherty silt loams	5.1	2 to 14	uplands	residuum	2.0 - 6	19-28
21B	Peridge silt loam	3.8	2 to 5	upland/ terrace	loess/ residuum	0.6 - 2	72+
1B	Newtonia silt loam	3.8	1 to 3	uplands	loess/ residuum	0.6 - 2	72+
43D	Goss cherty silt loam	3.4	2 to 20	uplands	residuum	2.0 - 6	20
76	Hepler silt loam	2.9	0 to 2	stream terrace	alluvium	0.6 - 2	30
54	Lanton silt loam	2.7	0 to 2	flood plain	alluvium	0.6 - 2	10
53B	Wildernes s & Goss cherty silt loam	2.6	2 to 9	uplands	residuum	2.0 - 6	24
11B	Sampsel silty clay loam	2.3	1 to 5	uplands	residuum	0.6 - 2	13
Trace	< 2.3 % Area	3.1					

	Area (km²)										Percent Area									
Land Use	**NB1**	**NB2**	**SB1**	**SB2**	**JC1**	**JC2**	**JC3**	**JC4**	**FC1**	**WC1**	**NB1**	**NB2**	**SB1**	**SB2**	**JC1**	**JC2**	**JC3**	**JC4**	**FC1**	**WC1**
Single Family	1.56	2.15	3.47	4.04	6.38	7.75	8.05	9.24	5.32	15.31	21.8	25.0	28.8	28.2	24.9	26.0	26.0	27.4	43.7	30.5
Duplex	0.06	0.10	0.12	0.14	0.26	0.35	0.36	0.45	0.14	0.66	0.9	1.2	1.0	1.0	1.0	1.2	1.2	1.3	1.1	1.3
Agriculture and Grazing	0.42	0.42	0.01	0.01	0.43	0.43	0.43	0.43	0.06	0.62	5.9	4.9	0.1	0.1	1.7	1.4	1.4	1.3	0.5	1.2
Education and Cultural	0.22	0.27	0.13	0.36	0.95	0.97	0.97	1.00	1.02	2.03	3.1	3.1	1.1	2.5	3.7	3.3	3.1	3.0	8.4	4.1
Group Quarters	0.01	0.01	0.03	0.06	0.11	0.11	0.12	0.16	0.04	0.28	0.1	0.1	0.2	0.4	0.4	0.4	0.4	0.5	0.3	0.6
Heavy Commercial	0.35	0.40	0.50	0.57	0.07	0.09	0.09	0.09	0.07	2.09	5.0	4.6	4.1	4.0	0.3	0.3	0.3	0.3	0.6	4.2
Light Commercial	0.26	0.30	0.47	0.60	1.09	1.25	1.43	1.48	0.18	2.14	3.6	3.4	3.9	4.2	4.3	4.2	4.6	4.4	1.5	4.3
Multi-family	0.005	0.07	0.22	0.39	1.10	1.32	1.35	1.43	0.58	1.45	0.1	0.8	1.8	2.7	4.3	4.4	4.3	4.2	4.8	2.9
Manufacturing	0.30	0.31	0.72	0.79	0.54	0.62	0.63	0.87	0.53	1.89	4.2	3.6	6.0	5.5	2.1	2.1	2.0	2.6	4.4	3.8
Mobile-home park	0.03	0.03	0.06	0.06	1.20	1.34	1.53	1.53	0.20	0.13	0.4	0.3	0.5	0.4	4.7	4.5	4.9	4.5	1.6	0.3
Office	0.06	0.06	0.37	0.40	0.09	0.09	0.09	0.10	0	1.16	0.8	0.7	3.0	2.8	0.3	0.3	0.3	0.3	0	2.3
Public Building	0.09	0.09	0.17	0.25	0.57	0.64	0.65	0.68	0.39	1.43	1.3	1.1	1.4	1.7	2.2	2.2	2.1	2.0	3.2	2.8
Quasi-public (church)	0.05	0.08	0.23	0.24	0.56	0.58	0.58	0.59	0.25	0.95	0.6	1.0	2.0	1.7	2.2	2.0	1.9	1.7	2.0	1.9
Parks and Recreational	0.14	0.24	0.92	0.92	0.41	0.55	0.58	0.61	0.26	1.94	1.9	2.7	7.6	6.5	1.6	1.8	1.9	1.8	2.2	3.9
Right of Way	0.01	0.01	0.02	0.02	1.24	1.30	1.30	1.41	0.31	0.16	0.1	0.1	0.2	0.2	4.8	4.4	4.2	4.2	2.5	0.3
Transport, Comunication	0.70	0.72	0.44	0.46	0.04	0.10	0.13	0.14	0.02	1.61	9.7	8.4	3.6	3.2	0.1	0.3	0.4	0.4	0.2	3.2
Vacant and Forest	1.07	1.11	1.31	1.40	1.23	1.42	1.42	1.49	0.06	4.25	15.0	12.9	10.9	9.7	4.8	4.8	4.6	4.4	0.5	8.5
Warehouse and Storage	0.94	0.96	1.01	1.21	2.59	2.82	2.85	3.05	0.44	2.86	13.2	11.2	8.4	8.5	10.1	9.4	9.2	9.0	3.6	5.7
Hospital	0	0	0	0	2.36	2.62	2.69	2.70	0.11	2.09	0	0	0	0	9.2	8.8	8.7	8.0	0.9	4.2
Quarry and Mining	0	0	0	0.04	0.04	0.04	0.04	0.04	0	0.04	0	0	0	0.3	0.1	0.1	0.1	0.1	0	0.1
Roadway area	0.88	1.28	1.85	2.37	4.31	5.44	5.72	6.27	2.17	7.05	12.4	14.9	15.4	16.5	16.8	18.2	18.5	18.6	17.8	14.1
Total Area (km²)	7.15	8.59	12.03	14.33	25.56	29.84	31.00	33.74	12.17	50.16	100	100	100	100	100	100	100	100	100	100

Table 2. Land use total area and percent of total for study area and subwatersheds. (From 2001 City of Springfield Land Use).

Table 3. Sample site name, description and location.

	Name	Description	Lat	Lon	Area (km^2)
Jordan Creek	NB1	North Branch at Smith Park	37.22492516	-93.27042826	7.2
	NB2	North Branch at OTC	37.21805334	-93.28116246	8.6
	SB1	South Branch at Fremont Ave	37.21250653	-93.27076086	12.0
	SB2	South Branch at Harry Cooper Supply	37.21264064	-93.28185447	14.3
	JC1	Main Ave bridge	37.21080065	-93.29666027	25.6
	JC2	Fort Ave bridge	37.20955074	-93.30781289	29.8
	JC3	Mt. Vernon bridge near Kansas Expwy	37.20453501	-93.31416973	31.0
	JC4	Grand Ave bridge near Kansas Expwy	37.19705164	-93.31887432	33.7
Other	FC1	Fassnight Creek at Fort Ave	37.18735814	-93.30865511	12.2
	WC1	Wilson Creek at Scenic (USGS gage)	37.18687534	-93.33149143	50.2

Table 4. City of Springfield 1 - year flood estimate.

				Discharge (m^3/s)						
	NB1	NB2	SB1	SB2	JC1	JC2	JC3	JC4	FC1	WC1
City 1-year	10.6	12.6	11.6	15.1	31.0	42.2	43.0	47.4	16.9	69.2

Table 5. Horiba U-22XD parameter measurement range and accuracy.

Parameter	Range	Accuracy	Method
pH	0 - 14	± 0.1	Glass Electrode
DO	0 - 19.99 mg/L	± 0.2 mg/L	Diaphragm Galvanic Battery
SC	0 - 9990 mS/cm	± 3 %	4 AC Electrode
TURB	0 - 800 NTU	± 5 %	Penetration and Scattering
TEMP	0 - 55 ˚C	± 1.0 ˚C	Thermistor

Date	MS1				MS2				Field Duplicate				Lab Duplicate				QCC	LCC	RBL	Field blank	DEC
	Site	orig	spiked	diff	Site	orig	spiked	diff	Site	orig	dup	diff	Site	orig	dup	diff					
8/28/2004	SB1	1.13	2.15	1.02	SB1	1.13	2.31	1.18	JC2	1.05	1.12	0.07	JC3	1.41	1.21	0.20	1.12	1.02	-0.07	0.08	2.26
9/5/2004	NB1	2.97	3.69	0.72	NB1	2.97	3.55	0.57	JC2	1.55	1.48	0.07	SB2	1.68	1.61	0.07	"	0.97	0.06	-0.07	"
9/7/2004	NB2	1.13	2.43	1.29	NB2	1.13	2.49	1.36	JC1	1.06	1.00	0.06	JC4	1.11	0.98	0.12	"	1.00	-0.15	0.11	"
9/24/2004	JC1	1.41	2.04	0.63	JC1	1.41	2.33	0.92	FC1	0.46	0.44	0.03	JC2	1.10	1.14	0.04	"	1.05	-0.10	N/A	"
10/8/2004	JC1	1.19	2.10	0.91	JC1	1.19	2.08	0.88	NB2	1.51	1.48	0.03	SB2	1.13	1.12	0.01	1.02	0.99	-0.06	0.16	1.97
10/11/2004	JC4	0.70	1.70	1.00	JC4	0.70	1.67	0.97	JC1	0.70	0.56	0.14	JC2	0.58	0.58	0.01	"	1.10	0.04	0.08	"
10/14/2004	WC1	1.26	2.07	0.80	WC1	1.26	2.14	0.88	FC1	0.84	0.88	0.05	JC3	1.09	0.94	0.14	"	0.94	0.02	0.14	"
10/26/2004	NB2	1.07	1.95	0.87	NB2	1.07	2.18	1.11	NB1	0.86	1.04	0.17	SB1	0.66	0.65	0.01	"	1.04	0.02	0.13	"
11/23/2004	JC1	1.71	2.41	0.70	JC1	1.71	2.59	0.87	WC1	1.68	1.78	0.10	SB2	1.50	1.62	0.12	0.99	1.09	-0.01	n/a	2.41
11/29/2004	SB1	1.11	1.98	0.87	SB1	1.11	1.97	0.86	JC2	1.03	1.01	0.02	JC3	1.16	1.16	0.01	"	1.02	-0.06	0.13	"
12/14/2005	JC3	2.37	3.23	0.86	JC3	2.37	3.30	0.93	SB2	2.16	2.12	0.04	JC1	2.92	2.86	0.07	1.13	0.97	-0.03	0.11	2.47
12/21/2005	FC1	3.95	4.93	0.98	FC1	3.95	4.16	0.22	SB2	1.73	1.78	0.05	JC4	2.56	2.65	0.09	1.13	1.00	0.08	0.25	"
1/4/2005	JC4	0.42	1.38	0.96	JC4	0.42	1.32	0.90	JC2	0.35	0.58	0.23	NB2	0.57	0.63	0.06	1.00	0.79	0.11	0.04	2.49
1/5/2005	JC2	1.64	2.23	0.59	JC2	1.64	2.37	0.73	SB1	1.50	1.38	0.11	NB2	1.35	1.36	0.02	1.00	0.83	0.11	0.08	"
1/21/2005	JC3	3.56	5.32	1.76	JC3	3.56	5.04	1.48	NB2	3.57	3.51	0.06	JC4	4.55	4.87	0.32	1.03	0.90	-0.04	0.05	2.95
2/10/2005	SB1	1.06	2.22	1.16	SB1	1.06	2.32	1.26	FC1	5.15	4.92	0.23	JC1	3.46	3.55	0.09	1.03	0.98	0.07	0.10	2.95
2/24/2005	WC1	3.09	3.96	0.88	WC1	3.09	3.96	0.87	JC1	2.42	2.09	0.33	NB2	2.12	2.24	0.13	1.03	1.06	-0.01	0.15	2.95
3/15/2005	JC2	1.31	2.69	1.39	JC2	1.31	2.17	0.86	JC4	1.71	1.82	0.11	FC1	2.92	2.06	0.87	1.12	0.94	0.01	0.11	2.43
3/24/2005	NB2	1.75	2.57	0.81	NB2	1.75	2.57	0.81	JC3	1.69	1.50	0.19	NB1	0.94	1.18	0.23	1.12	0.85	0.12	-0.01	2.43

Table 6. Total Nitrogen QA/QC data (mg/L).

Date	MS1				MS2				Field Duplicate				Lab Duplicate				QCC	LCC	RBL	Field blank
	Site	orig	spiked	diff	Site	orig	spiked	diff	Site	orig	dup	diff	Site	orig	dup	diff				
8/28/2004	SB1	232	426	194	SB1	232	437	205	JC2	188	187	1	JC3	201	197	4	222	195	6	13
9/5/2004	JC3	183	367	184	JC3	183	364	181	JC2	219	232	13	SB2	244	203	41	222	201	10	15
9/7/2004	FC1	69	255	186	FC1	69	257	188	JC1	66	48	18	JC4	50	51	1	222	206	7	12
9/24/2004	JC1	76	260	184	JC1	76	262	186	FC1	48	45	3	JC2	115	126	11	189	192	2	N/A
10/8/2004	JC1	221	416	195	JC1	221	420	199	NB2	230	233	3	SB2	233	238	5	196	198	-4	13
10/11/2004	JC4	204	386	182	JC4	204	403	199	JC1	253	256	3	JC2	164	167	3	196	200	10	-1
10/14/2004	WC1	118	308	190	WC1	118	309	191	FC1	124	121	3	JC3	146	145	1	196	191	0	6
10/26/2004	NB2	202	389	187	NB2	202	401	199	NB1	252	252	0	SB1	142	140	2	196	194	2	1
11/23/2004	JC1	41	241	200	JC1	41	237	196	WC1	51	53	2	SB2	434	443	9	204	198	6	n/a
11/29/2004	SB1	238	426	188	SB1	238	430	192	JC2	219	213	6	JC3	236	231	5	204	206	7	19
12/14/2005	JC3	23	223	200	JC3	23	231	208	SB2	49	36	13	JC1	17	19	2	202	203	0	4
12/21/2005	FC1	11	211	200	FC1	11	207	196	SB2	31	29	2	JC4	20	20	0	202	200	0	7
1/4/2005	JC4	242	425	183	JC4	242	414	172	JC2	121	134	13	NB2	130	131	1	200	199	1	8
1/5/2005	JC2	272	481	209	JC2	272	467	195	SB1	222	190	32	NB2	167	169	2	200	198	2	9
1/21/2005	JC3	29	230	201	JC3	29	233	204	NB2	25	24	1	JC4	27	28	1	199	198	0	3
2/10/2005	SB1	39	230	191	SB1	39	240	201	FC1	7	8	1	JC1	49	50	1	199	199	-1	3
2/24/2005	WC1	20	226	206	WC1	20	224	204	JC1	28	26	2	NB2	19	19	0	199	199	-2	4
3/10/2005	JC2	47	251	204	JC2	47	247	200	JC4	16	16	0	FC1	5	6	1	200	201	-1	-1
3/24/2005	NB2	16	218	202	NB2	16	222	206	JC3	41	38	3	NB1	55	55	0	200	204	2	-1

Table 7. Total Phosphorus QA/QC data (µg/L).

	Cu (mg/L)	Zn (mg/L)	Pb (mg/L)
Avg LRB	0.000	0.000	0.007
Std Dev LRB	0.000	0.000	0.004
MDL	**0.000**	**0.001**	**0.012**
Avg LCC	0.050	0.102	0.054
	LCC should be 0.05 mg/L ± 10%	LCC should be 0.1 mg/L ± 10%	LCC should be 0.05 mg/L ± 10%
Avg QCC	0.102	0.207	0.103
	QCC should be 0.1 mg/L ± 10%	QCC should be 0.2 mg/L ± 10%	QCC should be 0.1 mg/L ± 10%
Avg FB	0.000	0.004	0.009
Std Dev FB	0.000	0.004	0.004
Avg LRB/VB	0.001	0.005	0.012
Std Dev LRB/VB	0.002	0.004	0.001
FD (base flow) avg % rel dif	-53.3	-11.0	62.6
FD (storm flow) avg % rel dif	18.2	15.0	16.1
LD (base flow) avg % rel dif	11.4	-34.2	5.0
LD (storm flow) avg % rel dif	-9.5	-2.4	110.2

Table 8. Metal QA/QC data (mg/L).

Table 9. Hydrocarbon (HEM) QA/QC data.

Date	Event	OPR	Lab blank	Field blank	MS Site	Unspiked	MS
8/28/2004	storm	28.6	0.1	0	SB2	0	21.7
9/24/2004	Base	30	0	0.6	FC1	0	30.3
10/11/2004	storm	40.5	0.2	0.1	JC2	2.8	39.6
10/14/2004	storm	37.1	0	n/a	FC1	0.3	28.6
10/26/2004	storm	37.1	0.2	0	NB1	2.8	40.6
11/23/2004	Base	39.5	0.2	n/a	JC4	2.8	40.8
1/4/2005	storm	35	0	1.3	JC2	0.7	26.1

OPR: Ongoing precision and recovery sample (40.0 mg/L)
MS: Matrix spike sample (40.0 mg/L)

Table 10. Study area stream segment and slope.

Segment	River Distance (km)[1]	Slope[1]
JC4 - WC1	1.8	0.003
JC3 - JC4	1.0	0.003
JC2 - JC3	0.8	0.005
JC1 - JC2	1.0	0.004
SB2 - JC1	1.4	0.003
SB1 - SB2	1.1	0.005
NB2 - JC1	1.8	0.004
NB1 - NB2	1.3	0.004
FC1 - WC1	2.3	0.004
North/South Confluence - WC1	5.8	
South Headwater - WC1	8.1	
North Headwater - WC1	11.7	
Fassnight Headwater - WC1	12.0	

[1]Distances and slopes measured using Arc Map

Table 11. Discharge rating curve equations and coefficients of determination.

Site	a	b	c	R^2
NB1	23.701	-0.4061	0.033	0.997
NB2	21.147	1.1377	-0.0702	0.973
SB1	8.3886	-4.1802	0.5584	0.996
SB2[1]	5.8552	0.6048		0.992
JC1	14.75	2.8242	0.6023	0.951
JC2[1]	21.587	2.0606		0.962
JC3	14.791	0.2547	-0.1199	0.944
JC4	3.1269	14.205	-1.1915	0.936
FC1	8.4407	-1.9238	0.1187	0.984

[1] Equation forced through zero to avoid predicting negative discharges

Equation form: $Q = a(\text{stage})^2 + b(\text{stage}) + c$

Where: Q = m^3/s

Stage = gauge reading in meters

Table 12. Maximum baseflow and storm runoff discharge measured at each site.

	BASE		STORM	
	Min	**Max**	**Min**	**Max**
NB1	0	0.04	0.04	3.61
NB2	0.01	0.09	0.01	3.54
SB1	0	0.13	0.09	5.89
SB2	0.01	0.51	0.10	2.41
JC1[1]	0.02	1.58	0.39	8.15
JC2	0.02	0.30	0.56	12.05
JC3	0.02	0.71	0.50	15.07
JC4[2]	0.03	0.28	0.59	8.90
FC1	0.01	0.17	0.12	3.38
WC1	0.05	0.74	0.85	17.32

Table 13. Summary of mean values and standard deviations for measured water quality parameters by site.

Site	Event		pH	SC (µS/cm)	TURB (NTU)	DO (mg/L)	Temp (°C)
NB1	Base (n = 15)	Mean	7.60	703.2	73.4	13.55	12.22
		Std Dev	0.51	178.91	85.71	3.30	8.08
	Storm (n = 9)	Mean	7.50	169.1	101.58	10.35	14.15
		Std Dev	0.35	39.29	69.02	2.20	7.68
NB2	Base (n = 17)	Mean	7.62	841.6	60.6	12.46	14.57
		Std Dev	0.22	124.06	51.60	3.24	5.06
	Storm (n = 10)	Mean	7.45	348.4	91.04	9.76	14.42
		Std Dev	0.28	250.30	78.19	2.44	6.60
SB1	Base (n = 17)	Mean	7.56	643.3	77.1	11.25	13.29
		Std Dev	0.29	65.20	125.83	1.91	7.08
	Storm (n = 10)	Mean	7.43	201.4	74.96	10.70	14.66
		Std Dev	0.33	152.23	69.18	2.36	6.84
SB2	Base (n = 17)	Mean	7.65	777.2	74.8	11.28	13.44
		Std Dev	0.38	88.31	63.41	2.09	6.08
	Storm (n = 10)	Mean	7.53	177.8	122.48	10.68	14.86
		Std Dev	0.41	108.75	97.01	2.13	7.18
JC1	Base (n = 17)	Mean	8.07	793.9	74.4	12.26	13.46
		Std Dev	0.18	100.69	77.38	1.68	6.07
	Storm (n = 10)	Mean	7.70	173.3	100.28	10.65	14.93
		Std Dev	0.29	64.40	76.18	2.02	7.18
JC2	Base (n = 17)	Mean	7.31	852.0	55.1	10.19	14.25
		Std Dev	0.09	215.86	32.59	2.67	5.17
	Storm (n = 10)	Mean	7.63	199.0	99.13	10.07	15.39
		Std Dev	0.27	75.96	79.29	2.08	6.83
JC3	Base (n = 17)	Mean	7.78	878.3	52.7	11.02	13.63
		Std Dev	0.12	82.67	36.93	2.38	5.96
	Storm (n = 10)	Mean	7.71	188.5	113.27	10.03	15.19
		Std Dev	0.23	58.26	81.74	2.07	7.09
JC4	Base (n = 17)	Mean	7.60	845.3	61.1	11.21	13.89
		Std Dev	0.07	79.19	42.16	2.25	5.63
	Storm (n = 10)	Mean	7.75	191.5	111.97	10.13	15.19
		Std Dev	0.21	57.43	72.05	2.00	7.03
FC1	Base (n = 17)	Mean	8.03	803.9	63.8	11.53	13.26
		Std Dev	0.18	146.17	43.10	3.65	6.61
	Storm (n = 10)	Mean	7.70	171.6	73.94	9.63	15.57
		Std Dev	0.22	72.26	52.00	2.20	6.61
WC1	Base (n = 17)	Mean	7.72	854.8	74.1	11.32	13.74
		Std Dev	0.07	97.70	69.58	2.89	6.12
	Storm (n = 10)	Mean	7.64	245.4	107.09	9.82	15.24
		Std Dev	0.20	99.09	65.35	2.03	6.76

			Minimum DO Concentrations (mg/L)							
	NB1	NB2	SB1	SB2	JC1	JC2	JC3	JC4	FC1	WC1
Base	7.65	7.01	7.41	7.91	9.44	6.12	6.79	7.69	5.04	4.88
Storm	7.68	6.53	7.31	8.15	8.10	7.25	7.41	7.68	6.44	7.54

Table 14. Minimum recorded DO values for each site.

					HEM concentrations (mg/L)						
Date	**Event**	**NB1**	**NB2**	**SB1**	**SB2**	**JC1**	**JC2**	**JC3**	**JC4**	**FC1**	**WC1**
8/28/2004	storm	0.65	1.5	1.9	0	0.25	2.3	2.4	2	2.48	3.5
9/24/2004	base	N/A	5.68	0.6	0.65	0	4.9	3.9	4.3	0	1.6
10/11/2004	storm	N/A	1.7	N/A	0.9	6.9	2.8	4.1	4.1	N/A	N/A
10/14/2004	storm	0.6	3.3	1.9	4.4	3.9	2.2	0.7	6.9	0.3	5.5
10/26/2004	storm	2.8	1	N/A	2.6	0	0.6	0.6	N/A	N/A	N/A
11/23/2004	base	N/A	0	N/A	0.1	5.5	1.2	0.8	2.8	N/A	N/A
1/4/2005	storm	1.4	7.3	0.5	2.9	0.3	0.7	1	0.4	1.5	0.6

Table 15. Measured HEM concentrations.

	NB1	SB1	SB2	NB2	JC1	JC2	JC3	JC4	WC1	FC1
Copper (mg/L) detection limit = 0.000 mg/L										
Base										
Run 1 (2/14/2007)	0.005	0.005	NA	0.003	0.003	0.003	0.002	0.003	0.005	0.002
Run 2 (2/15/2007)	0.002	0.003	0.002	0.001	0.003	0.000	0.001	0.003	0.002	0.000
Storm										
Run 1 (2/24/2007)	0.009	0.004	0.014	0.009	0.008	0.011	0.018	0.017	0.003	0.008
Run 2 (3/1/2007)	0.006	0.008	0.007	0.006	0.010	0.011	0.015	0.023	0.014	0.008
Zinc (mg/L) detection limit = 0.001 mg/L										
Base										
Run 1 (2/14/2007)	0.031	0.029	NA	0.060	0.030	0.025	0.022	0.028	0.027	0.013
Run 2 (2/15/2007)	0.020	0.019	0.024	0.012	0.016	0.015	0.025	0.026	0.024	0.008
Storm										
Run 1 (2/24/2007)	0.100	0.026	0.057	0.066	0.042	0.066	0.088	0.112	0.026	0.046
Run 2 (3/1/2007)	0.084	0.066	0.063	0.064	0.097	0.104	0.145	0.209	0.127	0.057
Lead (mg/L) detection limit = 0.012 mg/L										
Base										
Run 1 (2/14/2007)	0.012	0.011	NA	0.011	0.012	0.010	0.007	0.012	0.009	0.005
Run 2 (2/15/2007)	0.004	0.009	0.006	0.010	0.012	0.013	0.011	0.010	0.001	0.011
Storm										
Run 1 (2/24/2007)	0.013	0.017	0.015	0.018	0.008	0.021	0.025	0.024	0.012	0.015
Run 2 (3/1/2007)	0.015	0.015	0.021	0.022	0.001	0.028	0.041	0.056	0.044	0.012

Table 16. Metal concentrations (mg/L).

	NB1	SB1	SB2	NB2	JC1	JC2	JC3	JC4	WC1	FC1
2/15/2007										
Q (m^3/s)	NA	0.038	NA	0.156	below gage	0.223	0.421	0.260	0.396	0.011
pH	7.18	7.40	7.41	7.62	7.97	8.06	7.96	8.03	8.13	8.22
Cond. (S/cm)	0.900	0.900	0.900	1.130	0.900	0.900	0.900	0.900	0.900	0.990
Turb (NTU)	94.2	97.9	86.0	434.0	431.0	94.9	365.0	286.0	309.0	545.0
DO (g/L)	11.95	10.96	12.07	12.98	12.85	11.87	12.76	12.62	12.22	13.41
Temp (°C)	1.46	2.22	5.07	6.32	3.52	6.34	4.38	4.68	4.43	2.98
TDS (g/L)	0.70	0.85	0.96	0.71	0.86	0.96	0.99	0.92	0.91	0.89
2/24/2007										
Q (m^3/s)	NA	0.141	NA	0.371	0.476	0.591	0.814	0.858	0.765	0.015
pH	6.84	6.96	7.33	7.41	7.71	8.08	8.02	8.07	7.98	8.16
Cond. (S/cm)	0.900	0.880	0.900	0.910	0.960	0.970	1.160	1.430	0.990	2.310
Turb (NTU)	69.5	48.9	63.2	192.0	99.0	87.7	102.0	133.0	634.1	106.0
DO (g/L)	10.22	9.76	11.59	9.60	10.42	10.07	10.35	9.35	9.91	9.12
Temp (°C)	9.12	9.98	10.01	10.05	9.84	10.36	9.52	9.62	9.63	9.15
TDS (g/L)	0.99	0.56	0.84	0.60	0.60	0.60	0.80	0.90	0.60	1.50
3/1/2007										
Q (m^3/s)	NA	0.653	NA	0.371	0.528	0.749	1.135	1.161	0.906	0.020
pH	6.90	7.46	7.56	7.59	7.96	8.03	8.10	8.12	8.09	8.27
Cond. (S/cm)	0.584	0.706	0.428	0.648	0.456	0.566	0.576	0.594	0.673	0.515
Turb (NTU)	591.0	661.0	208.0	404.0	466.0	464.0	682.0	error	546.0	589.0
DO (g/L)	9.07	9.63	10.43	10.34	10.58	10.94	9.67	9.91	9.92	9.63
Temp (°C)	8.48	8.13	8.54	8.79	9.21	9.13	8.91	9.35	9.06	9.87
TDS (g/L)	0.37	0.48	0.28	0.43	0.30	0.37	0.38	0.38	0.45	0.33

Table 17. Water quality parameter data with discharge at time of metal sample collection. No water quality parameters were collected 2-14-07.

Table 18. TN and TP summary statistics for all, base flow, and storm samples. Sample size (n): Total = 27, Base = 17, Storm = 10.

		TP (µg/L)									
		NB1	NB2	SB1	SB2	JC1	JC2	JC3	JC4	FC1	WC1
Total	Mean	175	82	97	185	139	106	97	103	87	83
	Std. Dev.	229	83	75	251	194	78	84	102	87	77
	Median	55	33	50	114	66	67	47	37	55	40
	Max	966	286	287	1097	983	311	308	382	390	246
	Min	18	6	24	25	14	25	18	16	5	9
Base	Mean	101	38	47	176	92	52	36	30	36	28
	Std. Dev.	233	63	12	315	224	24	14	12	30	11
	Median	30	20	44	45	28	49	33	27	29	25
	Max	966	286	83	1097	983	115	74	63	127	51
	Min	18	6	24	25	14	25	18	16	5	9
Storm	Mean	286	157	184	200	220	196	200	227	172	177
	Std. Dev.	171	55	55	43	76	51	43	59	84	45
	Median	245	175	179	198	209	197	190	215	136	166
	Max	781	230	287	269	404	311	308	382	390	246
	Min	167	55	101	128	115	121	146	161	82	116

		TN (mg/L)									
		NB1	NB2	SB1	SB2	JC1	JC2	JC3	JC4	FC1	WC1
Total	Mean	1.59	1.79	0.81	1.39	1.74	1.56	1.66	1.73	2.38	1.90
	Std. Dev.	1.16	0.80	0.50	0.63	0.80	0.79	1.14	0.95	1.67	1.15
	Median	1.21	1.65	0.66	1.21	1.56	1.31	1.42	1.67	2.08	1.68
	Max	5.14	3.99	2.68	3.60	3.46	3.85	5.89	4.55	7.78	5.52
	Min	0.38	0.57	0.09	0.40	0.40	0.35	0.45	0.42	0.46	0.44
Base	Mean	1.87	2.12	0.77	1.63	2.09	1.83	1.88	2.03	2.98	2.28
	Std. Dev.	1.30	0.78	0.58	0.63	0.74	0.83	1.34	1.02	1.71	1.23
	Median	1.32	2.06	0.57	1.53	2.01	1.68	1.44	1.77	2.74	1.84
	Max	5.14	3.99	2.68	3.60	3.46	3.85	5.89	4.55	7.78	5.52
	Min	0.38	1.13	0.09	0.84	1.06	1.00	0.46	0.65	0.46	0.44
Storm	Mean	1.17	1.23	0.89	0.99	1.16	1.11	1.29	1.21	1.35	1.25
	Std. Dev.	0.70	0.46	0.31	0.37	0.52	0.45	0.52	0.49	0.97	0.61
	Median	0.98	1.13	0.90	1.02	1.05	1.09	1.29	1.15	0.98	1.16
	Max	2.97	2.14	1.50	1.68	2.31	1.86	2.15	2.05	3.94	2.63
	Min	0.38	0.57	0.36	0.40	0.40	0.35	0.45	0.42	0.46	0.46

	pH	SC	TURB	DO	Temp	TP
SC	0.206					
TURB	-0.064	-0.164				
DO	0.200	0.235	0.161			
Temp	-0.057	-0.042	-0.096	***-0.768***		
TP	***-0.404***	***-0.886***	0.223	-0.302	0.145	
TN	-0.128	***0.498***	-0.245	***0.558***	***-0.522***	***-0.386***

Sample size (n) = 27

Significance : 95% = ±0.381   99% = ±0.487

Table 19. Pearson correlation matrix for all samples at site WC1. Significance at 95 % is indicated by **bold**, significance at 99 % is indicated by **bold.**

	pH	SC	TURB	DO	Temp	TP
SC	***0.555***					
TURB	0.423	0.347				
DO	0.135	0.064	0.128			
Temp	0.090	0.128	0.155	***-0.721***		
TP	-0.410	***-0.542***	-0.208	***-0.542***	***0.563***	
TN	-0.125	0.204	-0.217	***0.614***	***-0.731***	***-0.535***

Sample size (n) = 17

Significance : 95% = ±0.482   99% = ±0.606

Table 20. Pearson correlation matrix for base flow samples at site WC1. Significance at 95 % is indicated by **bold**, significance at 99 % is indicated by **bold**

	pH	SC	TURB	DO	Temp	TP
SC	***-0.747***					
TURB	-0.261	-0.084				
DO	0.192	-0.378	0.540			
Temp	-0.091	0.322	-0.601	***-0.933***		
TP	-0.369	0.152	0.117	0.001	-0.039	
TN	***-0.759***	***0.761***	0.017	0.019	-0.031	0.581

Sample size (n) = 10

Significance : 95% = ±0.632   99% = ±0.765

Table 21. Pearson correlation matrix for storm samples at site WC1. Significance at 95 % is indicated by **bold**, significance at 99 % is indicated by **bold**

Table 22. Pearson correlation for TN and Temp, and TN and Q for all sites at base flow.

	NB1	NB2	SB1	SB2	JC1	JC2	JC3	JC4	FC1	WC1
					TN and Temp					
All	0.252	-0.193	-0.362	-0.286	-0.341	-0.279	**-0.441**	-0.437	**-0.516**	**-0.522**
Base	0.150	**-0.652**	**-0.489**	**-0.594**	**-0.774**	**-0.627**	**-0.703**	**-0.734**	**-0.682**	**-0.731**
Storm	**0.792**	0.622	-0.060	0.479	0.515	0.519	0.354	0.251	-0.028	-0.031
					TN and Q					
All	-0.298	**-0.406**	0.101	**-0.449**	**-0.421**	**-0.400**	-0.163	-0.303	-0.267	-0.259
Base	-0.140	**0.504**	-0.072	0.413	0.220	**0.717**	-0.033	0.388	0.216	**0.719**
Storm	-0.413	-0.405	0.115	-0.554	-0.384	-0.396	0.054	-0.040	0.041	-0.007

	Significance	
	95%	**99%**
All	**± 0.381**	**± 0.487**
Base	**± 0.482**	**± 0.606**
Storm	**± 0.632**	**± 0.765**

Table 23. Flow Exceedance Probability Load Proportions for TN and TP.

					Nitrogen		Phosphorus	
Exceedance Range (avg daily Q)	**Midpoint %**	**$\log_{10}$ Q (cfs)**	**Actual Q (cfs)**	**Actual Q (m^3/s)**	**N Load (kg/day)**	**Load Proportion (load/20)**	**P load (kg/day)**	**Load Proportion (load/20)**
95 to 100	97.5	0.28	1.93	0.05	3.54	0.18	0.16	0.01
90 to 95	92.5	0.42	2.65	0.08	5.90	0.30	0.21	0.01
85 to 90	87.5	0.54	3.46	0.10	9.03	0.45	0.26	0.01
80 to 85	82.5	0.63	4.30	0.12	12.79	0.64	0.31	0.02
75 to 80	77.5	0.71	5.13	0.15	17.00	0.85	0.36	0.02
70 to 75	72.5	0.77	5.93	0.17	21.42	1.07	0.41	0.02
65 to 70	67.5	0.82	6.68	0.19	25.89	1.29	0.45	0.02
60 to 65	62.5	0.87	7.37	0.21	30.35	1.52	0.49	0.02
55 to 60	57.5	0.91	8.04	0.23	34.89	1.74	0.53	0.03
50 to 55	52.5	0.94	8.73	0.25	39.79	1.99	0.57	0.03
45 to 50	47.5	0.98	9.50	0.27	45.54	2.28	0.61	0.03
40 to 45	42.5	1.02	10.43	0.30	52.87	2.64	0.66	0.03
35 to 40	37.5	1.07	11.63	0.33	63.00	3.15	0.72	0.04
30 to 35	32.5	1.12	13.28	0.38	77.90	3.89	0.81	0.04
25 to 30	27.5	1.19	15.63	0.44	101.10	5.06	0.92	0.05
20 to 25	22.5	1.28	19.10	0.54	139.29	6.96	1.09	0.05
15 to 20	17.5	1.39	24.38	0.69	206.00	10.30	1.35	0.07
10 to 15	12.5	1.52	32.78	0.93	101.08	5.05	12.05	0.60
5 to 10	7.5	1.67	46.71	1.32	140.02	7.00	17.70	0.89
0 to 5	2.5	1.85	71.08	2.01	205.99	10.30	27.91	1.40
			Probable daily load (kg/d)			66.7		3.4
			Probable annual load (kg/y)			24,334		1,233
			Probable yield (kg/y - km^2)			484.7		24.6

Table 24. Annual load and yield estimates at site WC1 based on different methods for study period August 2004 to July 2005.

Method		Load (kg/y)		Yield[1] (kg/y-km^2)		Yield[2] (kg/y-ha)	
		TN	TP	TN	TP	TN	TP
Daily Average Flow		26,818	2,159	535	43	5.35	0.43
EPA	Min	10,728	2,585	214	51.5	2.14	0.51
	Median	20,693	3,355	412	66.8	4.12	0.67
	Max	30,471	4,049	607	80.7	6.07	0.81
Probable Annual		24,334	1,233	484.7	24.6	4.85	0.25

[1]Based on watershed area of 50.2 km^2
[2]Based on watershed area of 5016 ha

Table 25. James River TMDL sample site descriptions.

Watershed		Drainage Area (mi^2)	Land Use (%)			Obvious WWTP Influence
Site #	Location		Urban	Forest	Ag	
TMDL-2	James at Galena	987	6	30	64	(yes) SWWWTP
TMDL-3	Crane Cr	153	1	20	79	
TMDL-8	Finley Cr. at Green Bridge	178	1	60	39	
TMDL-9	James at Kinser	251	2	38	60	
TMDL-10	Pearson Cr	20	1	25	74	
TMDL-11	Panther Cr	36	1	43	56	
TMDL-12	James off B Hwy	92	1	42	57	

FIGURES

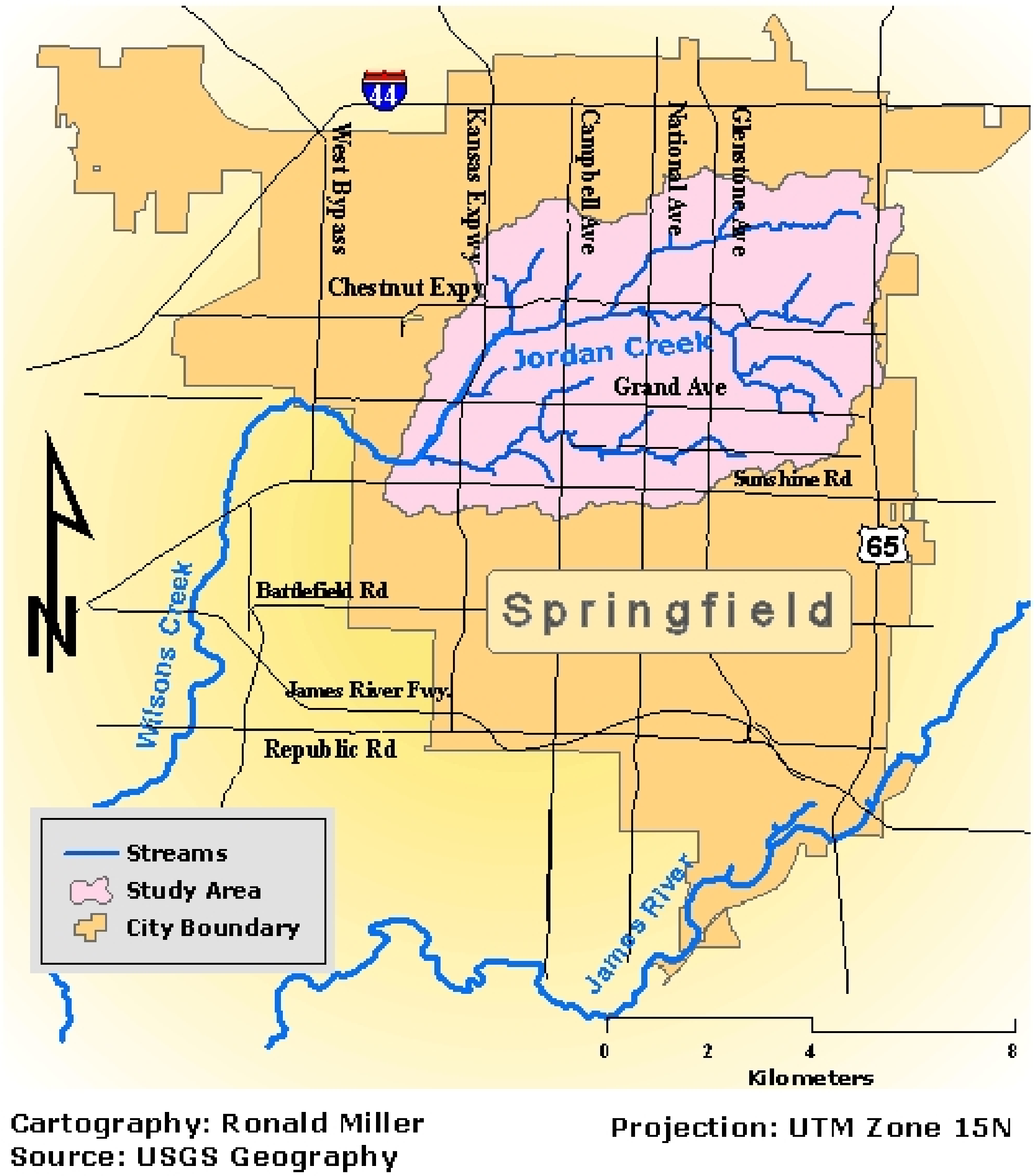

Figure 1. Location of study area watershed within Springfield, Missouri.

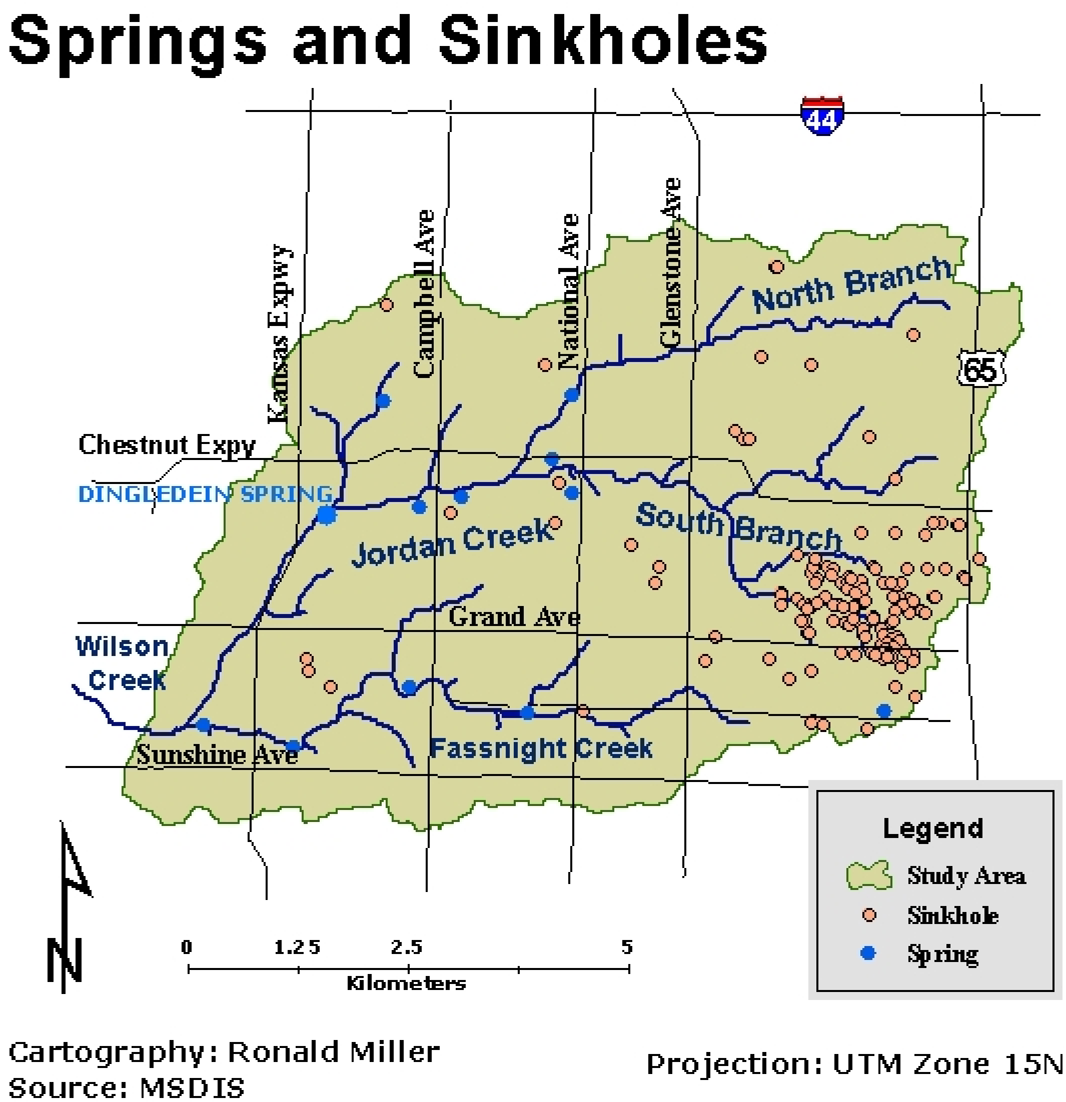

Figure 2. Springs and sinkholes locations within study area.

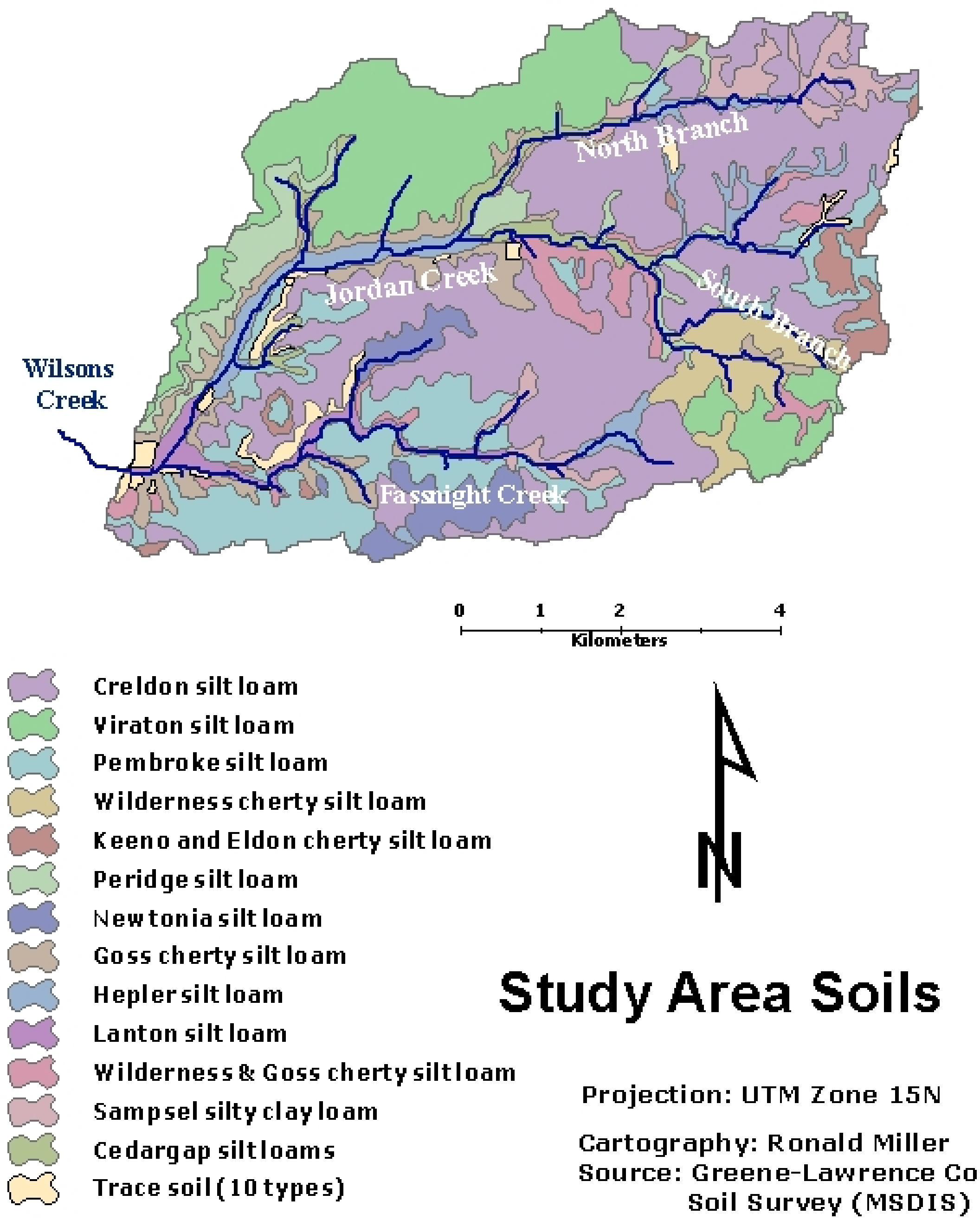

Figure 3. Soils within the study area.

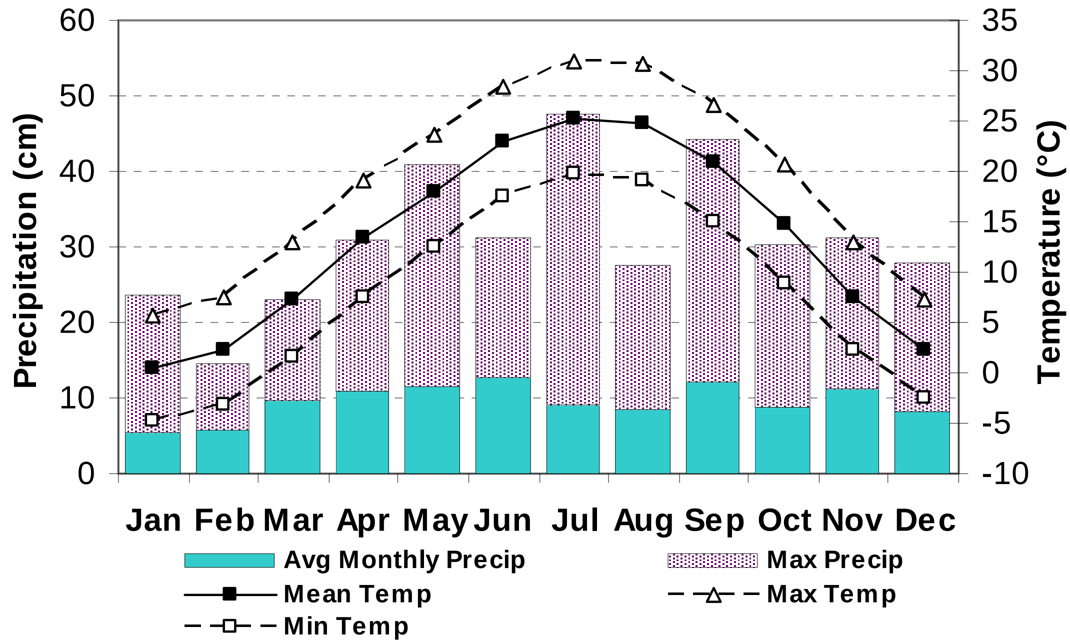

Figure 4. Springfield 30 - year precipitation and temperature data.

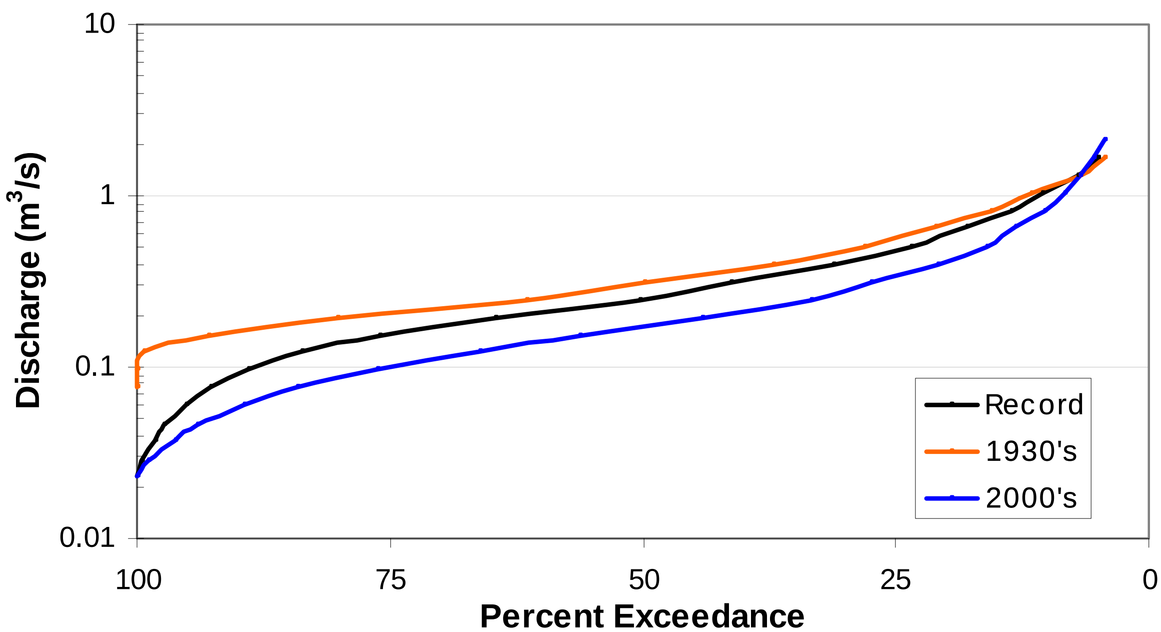

Figure 5. Comparison of flow duration graph for USGS Gage 07052000 to subsets of flows from the 1930's and 2000's (Wilson, 2005).

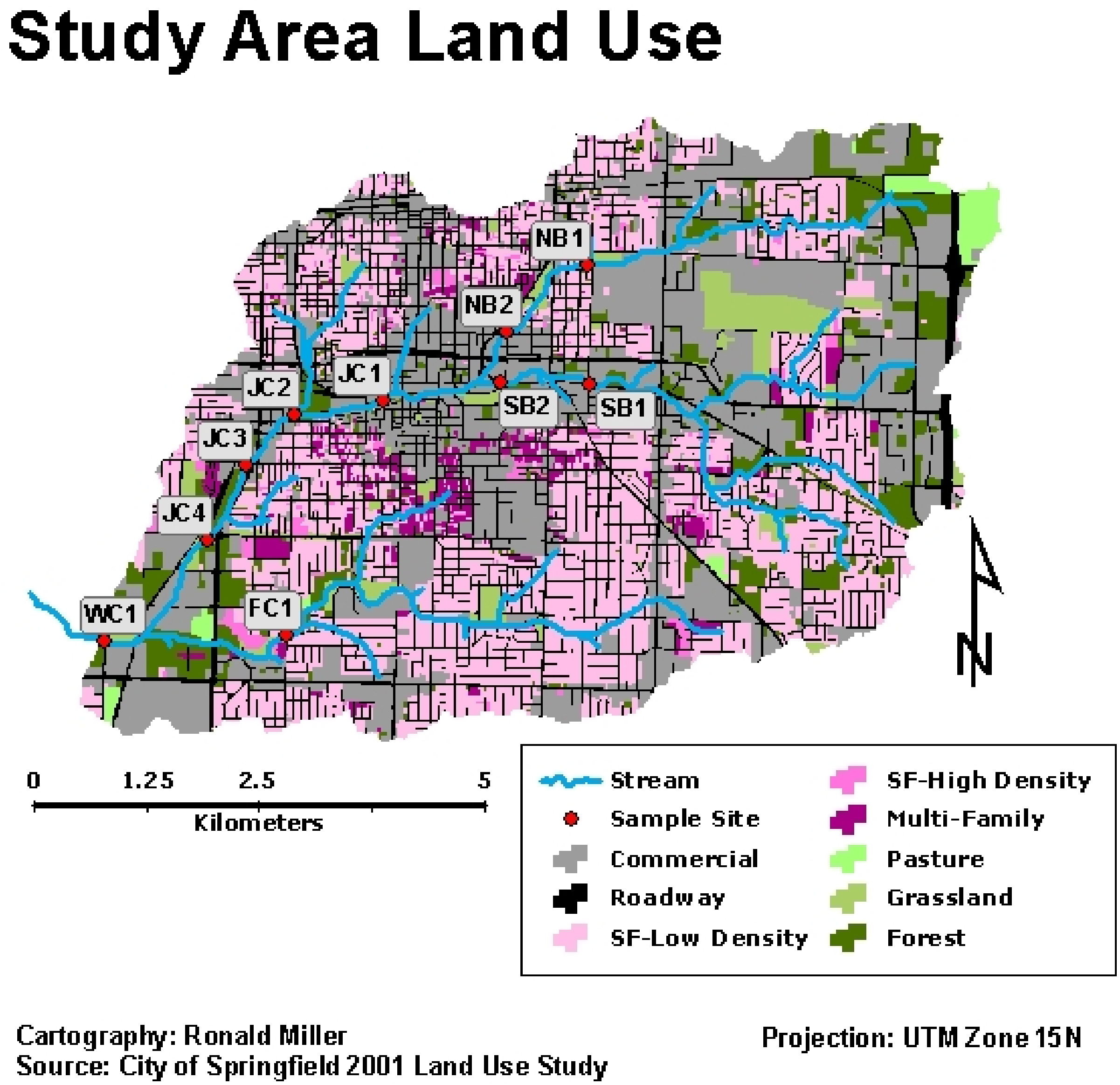

Figure 6. Study area land use.

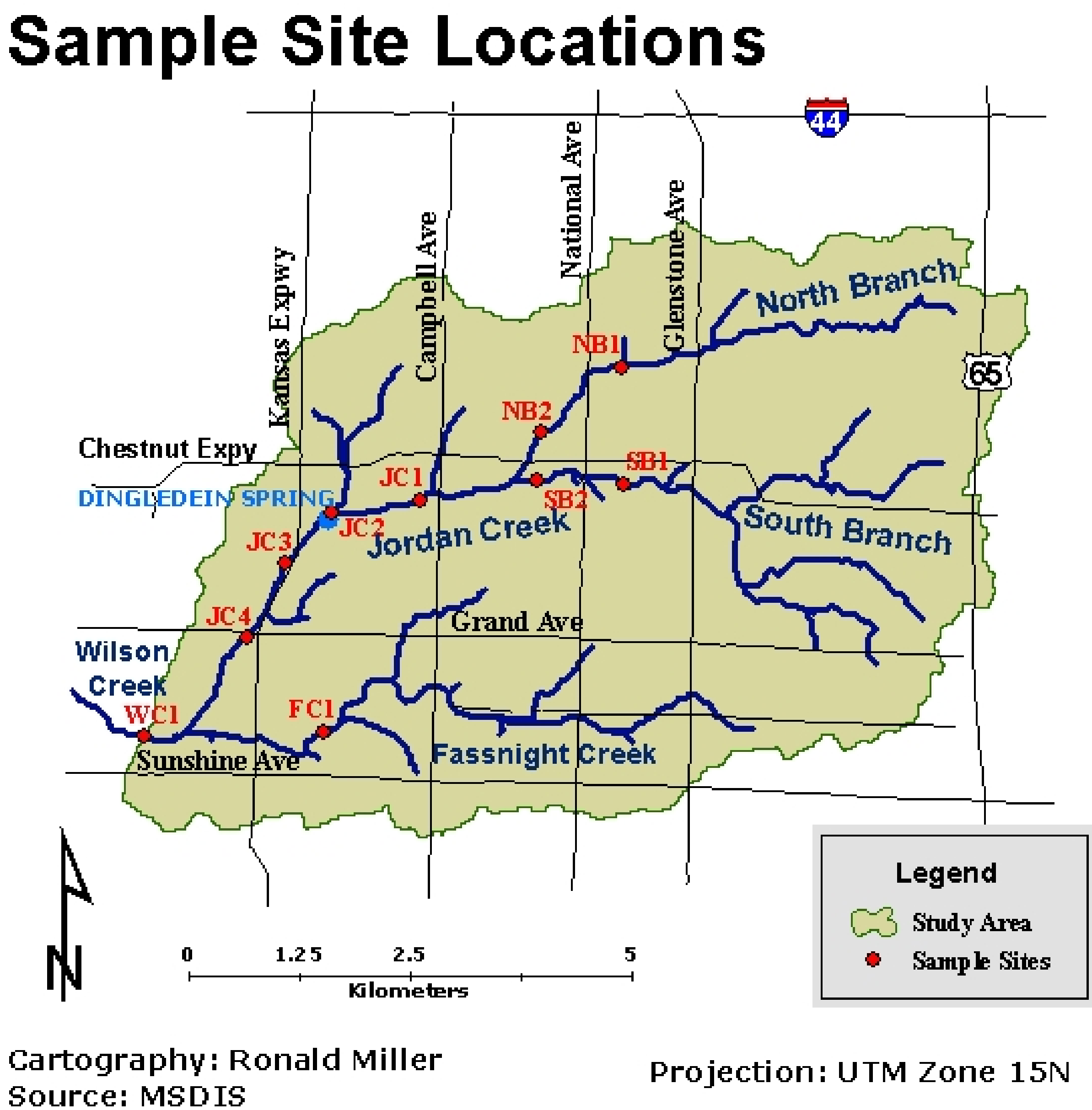

Figure 7. Sample site locations.

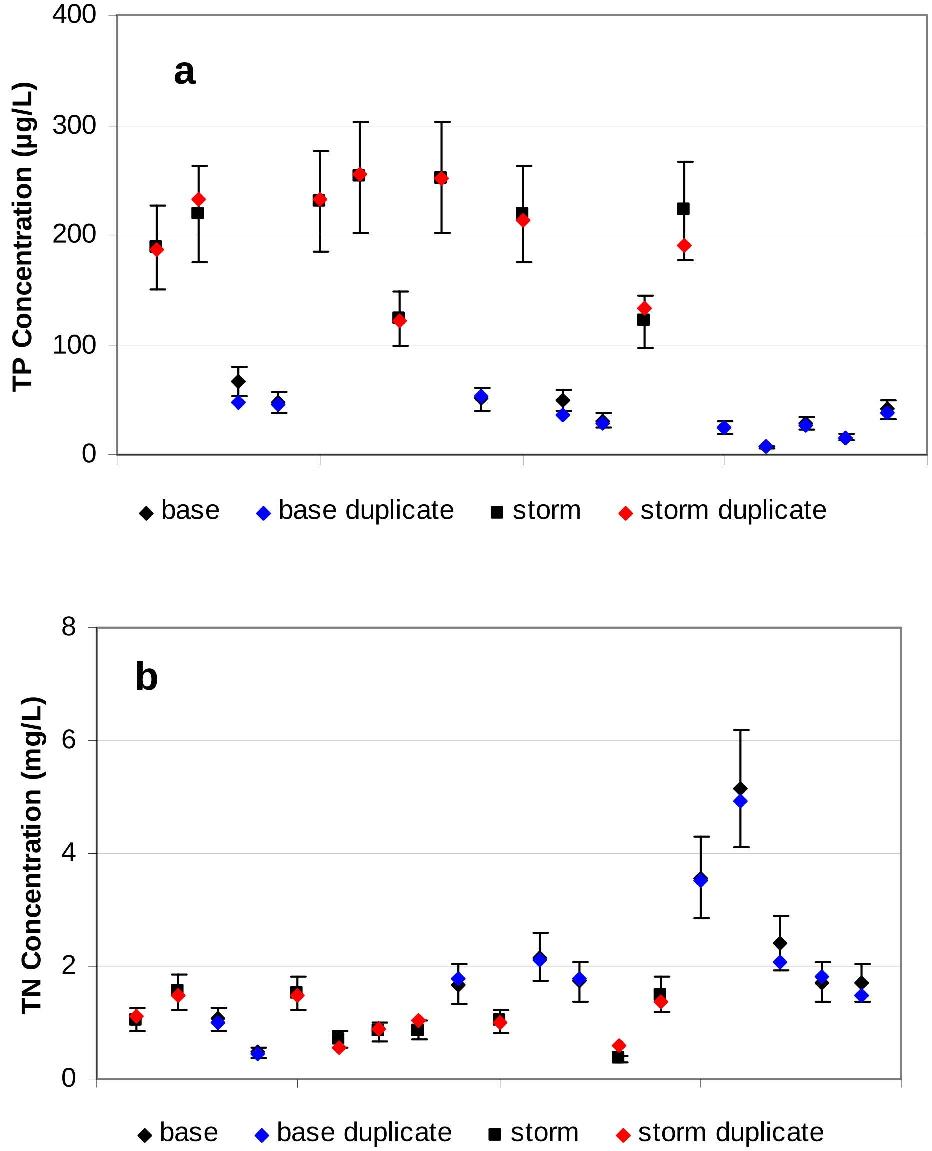

Figure 8. Field duplicate acceptance range (± 20%) for base flow and storm samples for TP (a) and TN (b).

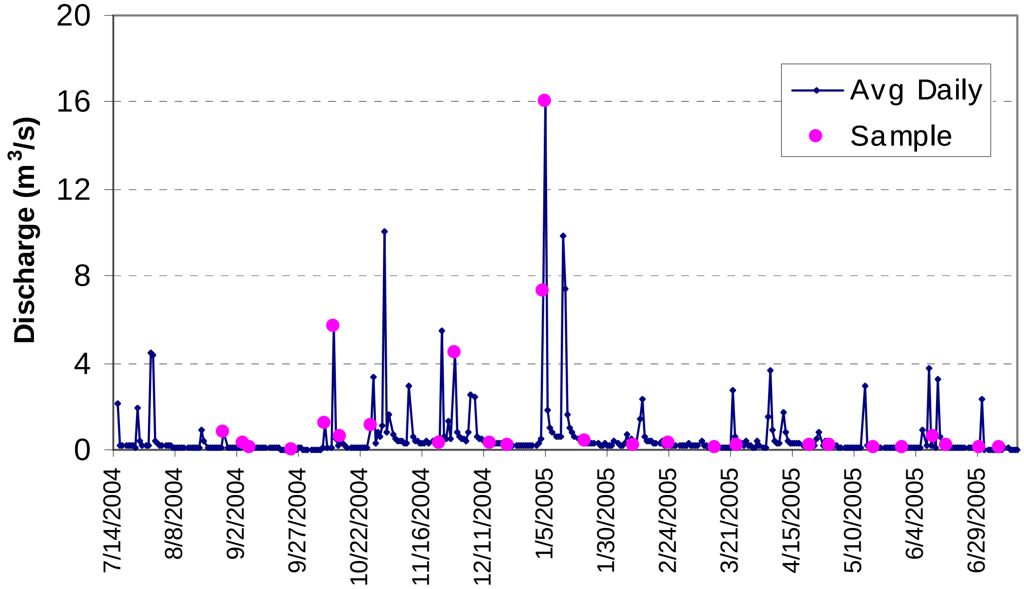

Figure 9. Average daily discharge for study period at site WC1 with sample dates.

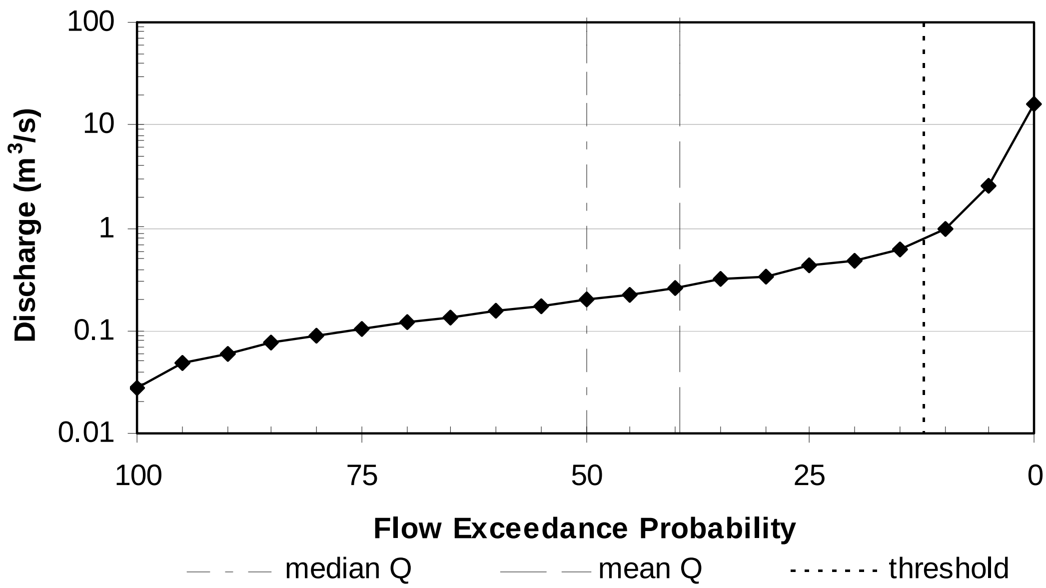

Figure 10. Flow exceedence graph for the study period at site WC1 based on average daily discharge recorded at USGS Gage 07052000.
Median and mean Q are calculated from flow record, "threshold" Q refers to separation between baseflow and storm runoff discharges observed in the study.

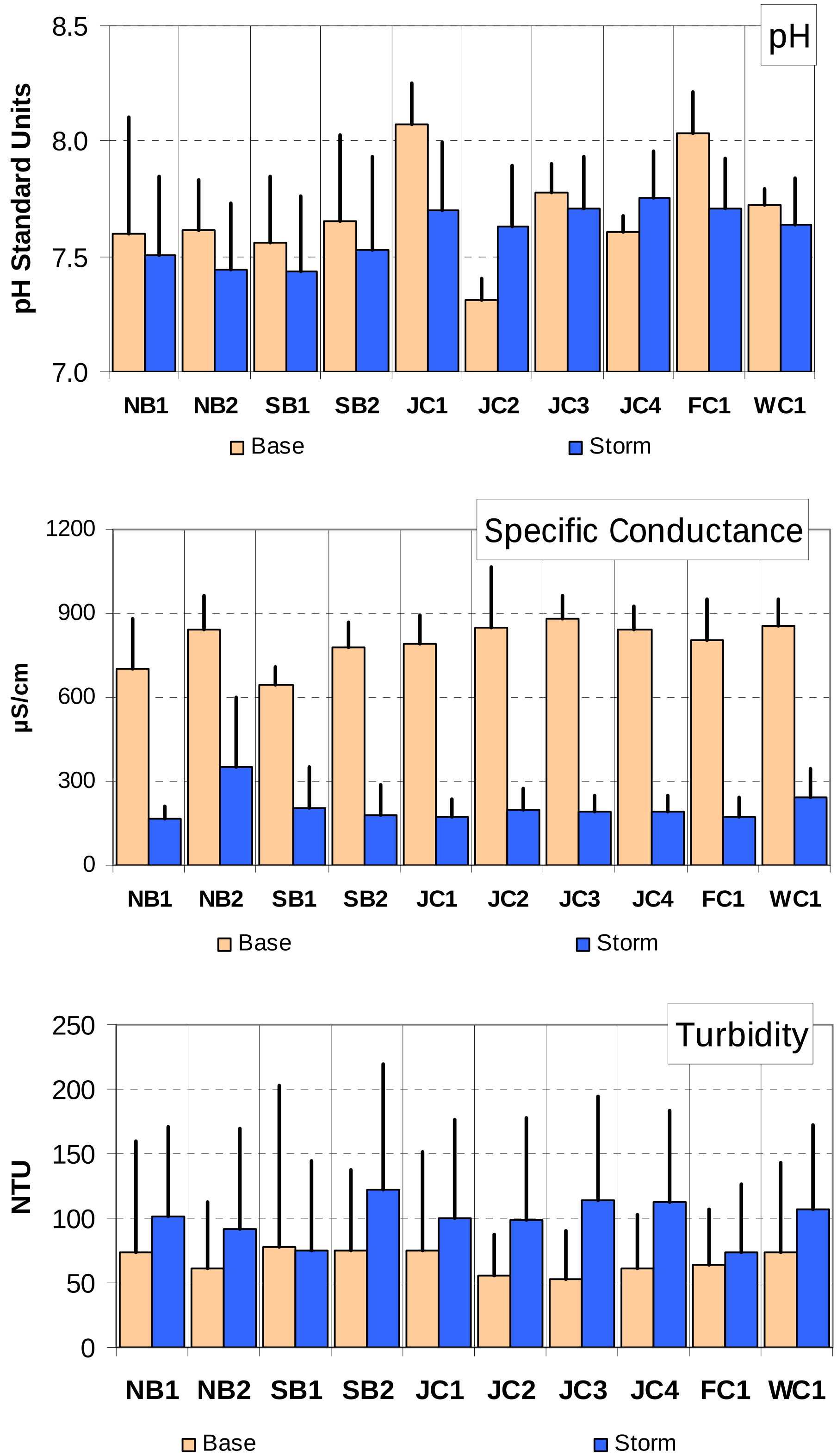

Figure 11. Mean water quality values and 1 standard deviation.

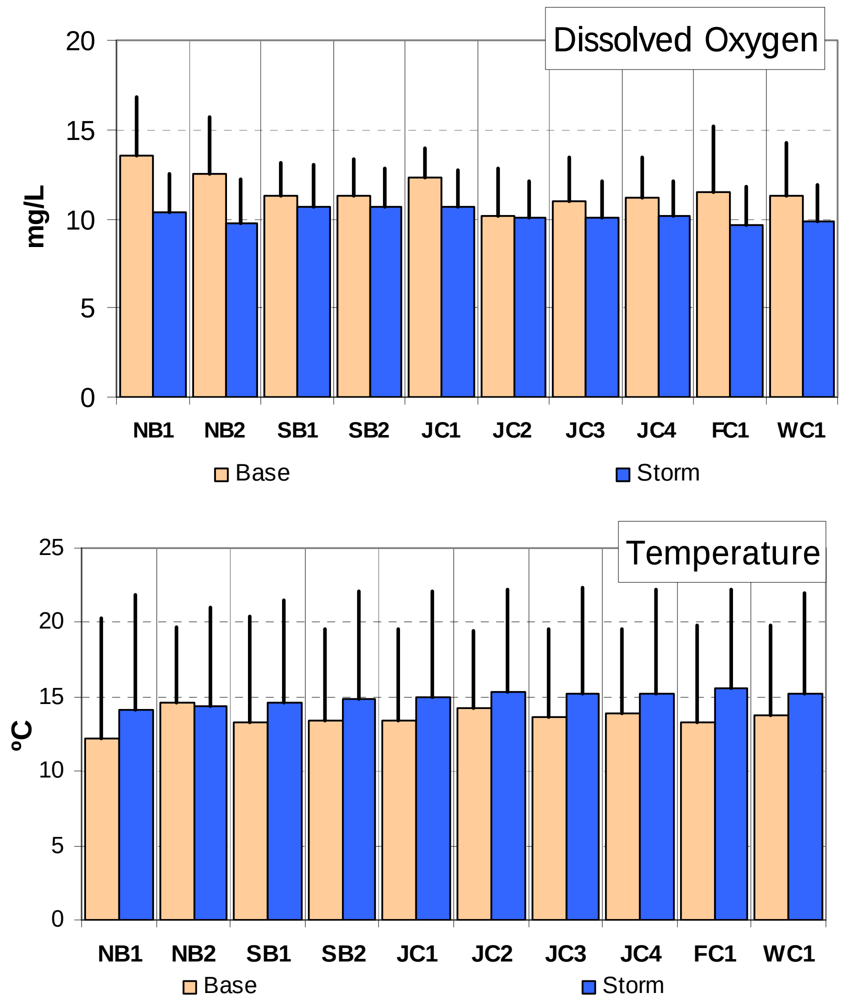

Figure 11. Mean water quality values and 1 standard deviation.

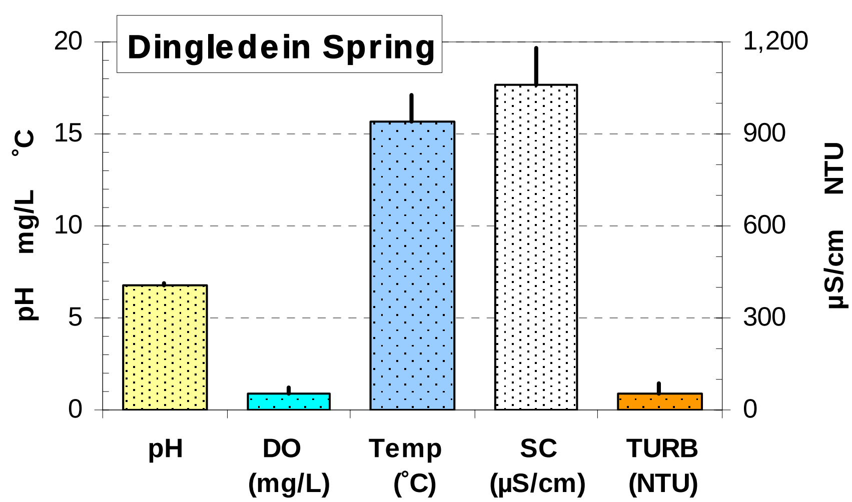

Figure 12. Dingledein Spring water quality parameters.

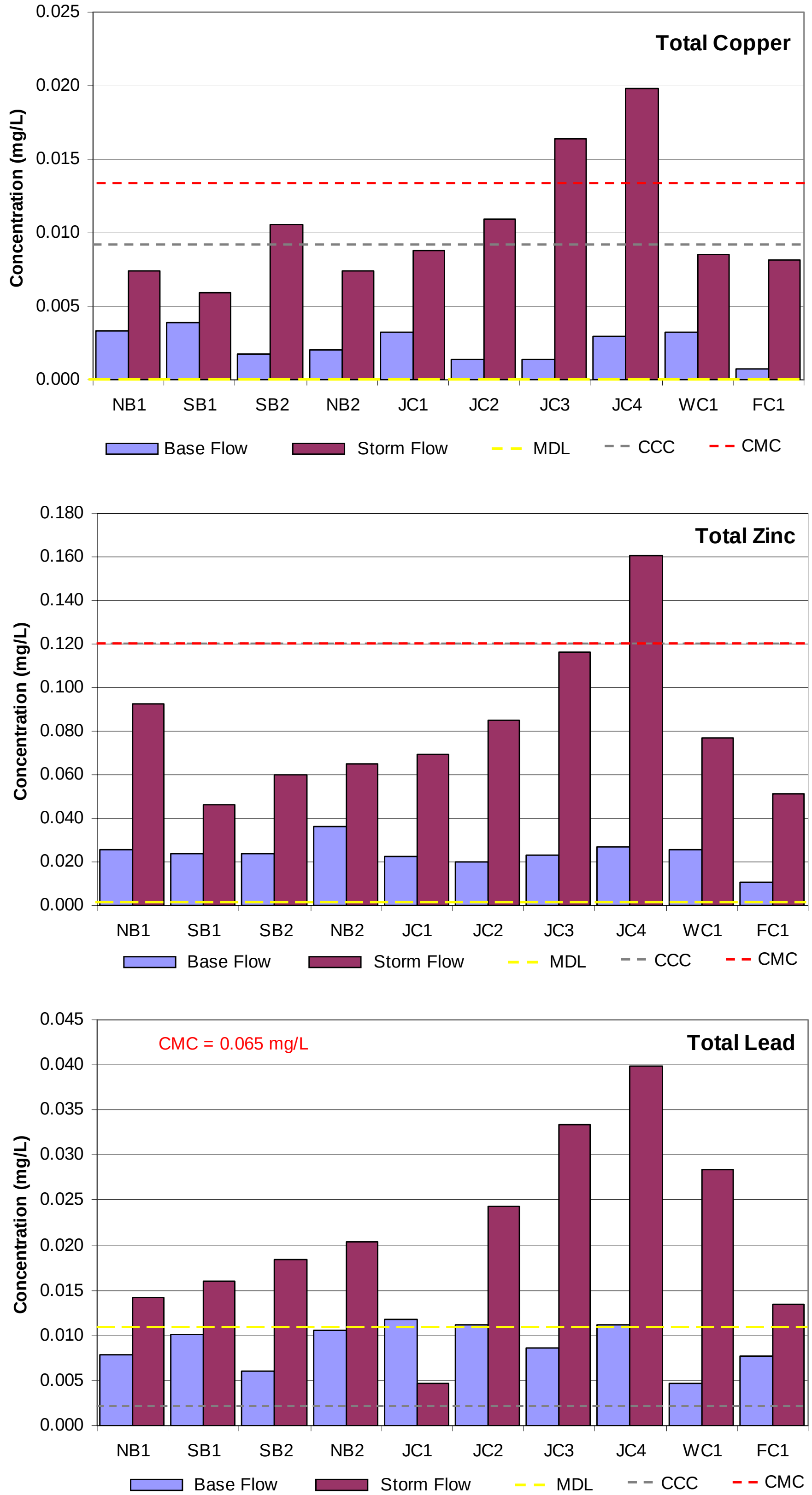

Figure 13. Metal concentration at base and storm flow with method detection limits (MDL), criteria continuous concentration (CCC), criteria maximum concentration (CMC). Each flow condition represents the average of two samples.

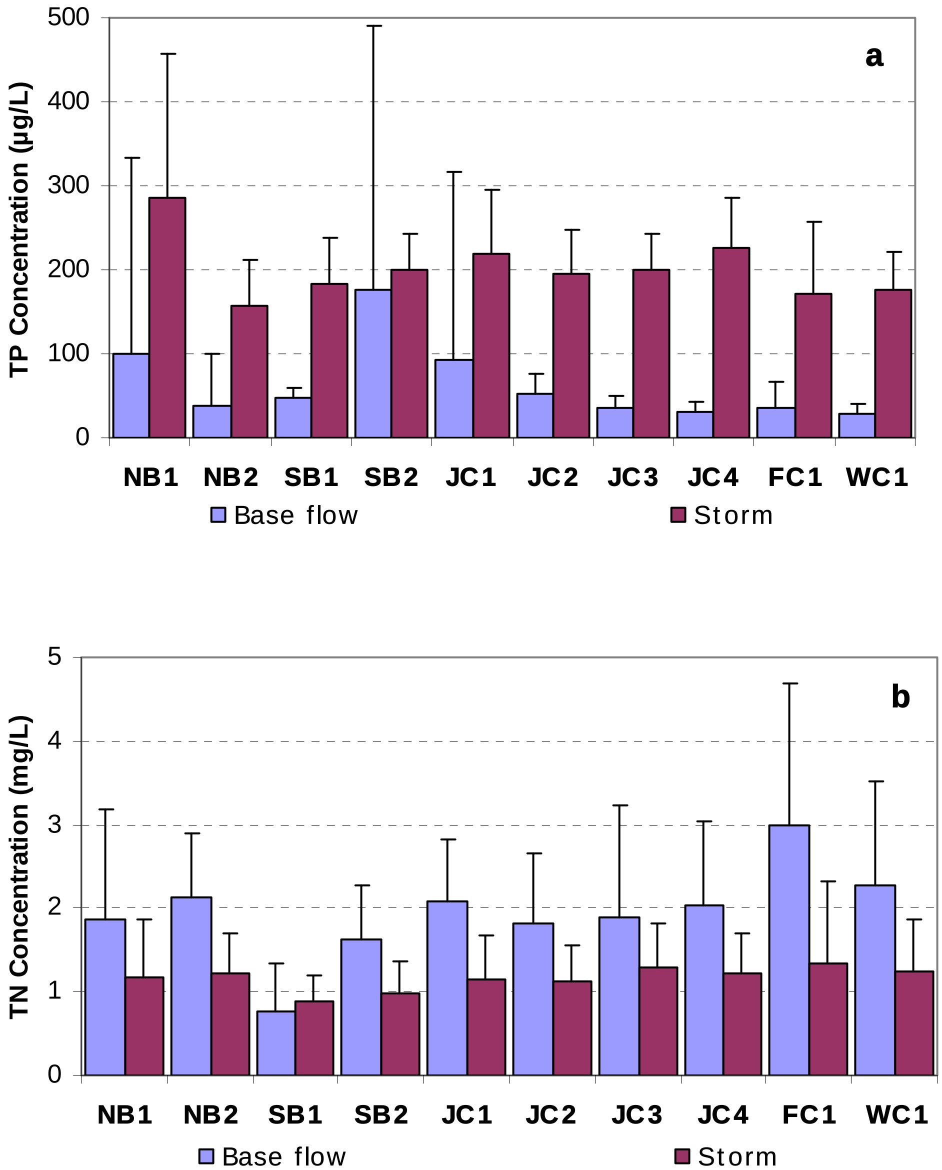

Figure14. Mean base flow and storm plus standard deviation for TP (a) and TN (b).

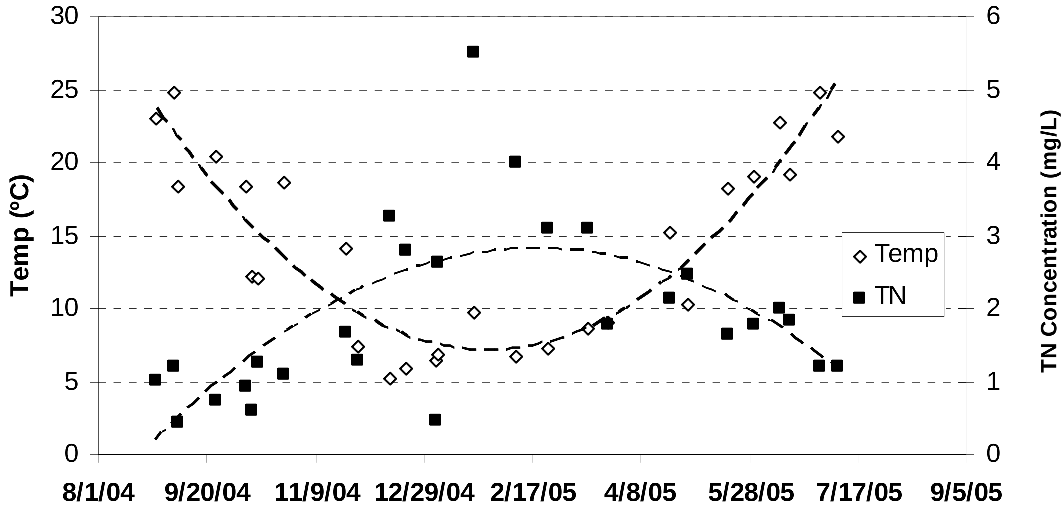

Figure15. Relationship between TN and water temperature showing seasonal trend.

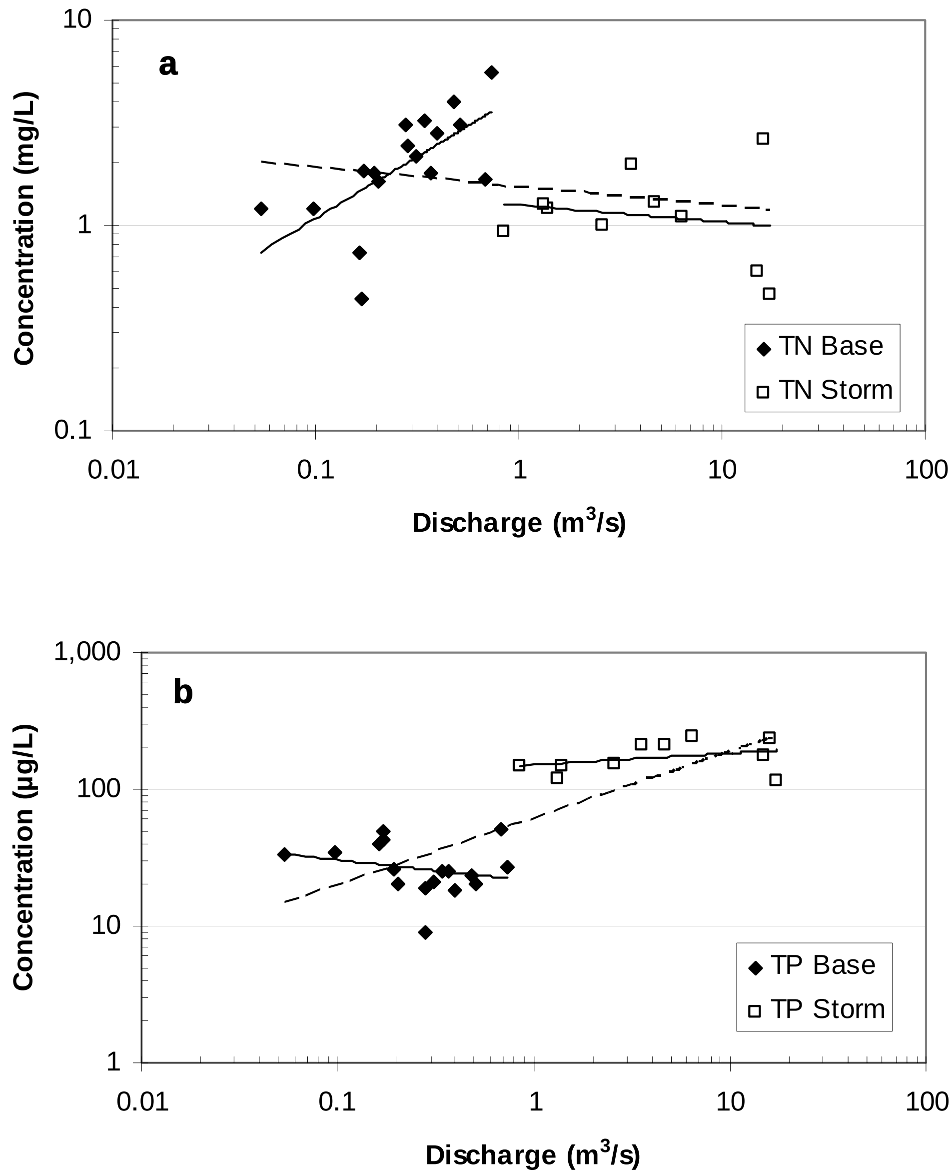

Figure16. Site WC1 concentration rating curves for TN (a) and TP (b).
Dashed line indicates the fitted regression curve for all samples considered together.

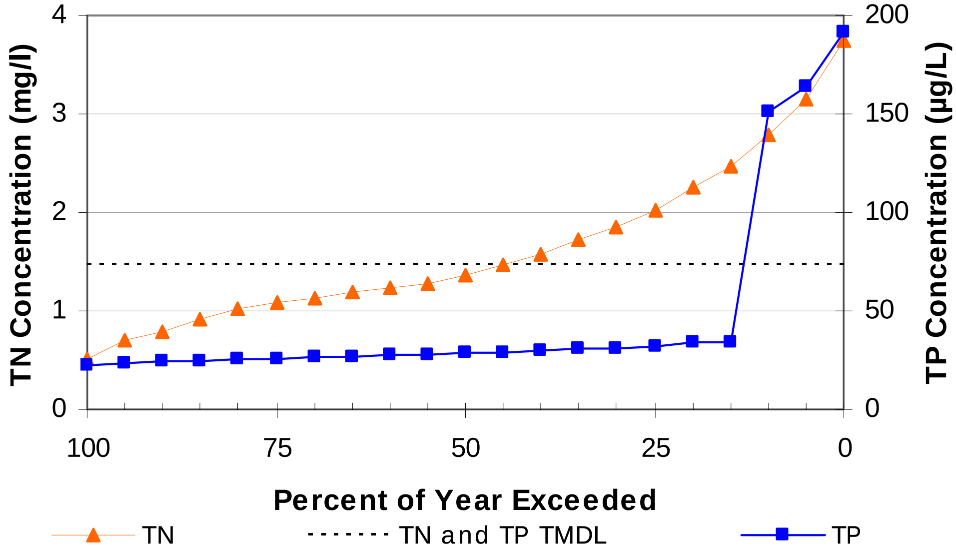

Figure17. Site WC1 TP and TN concentration exceedances.
Recommended James River TMDL limits: TN (1.5 mg/L), TP (75 µg/L).

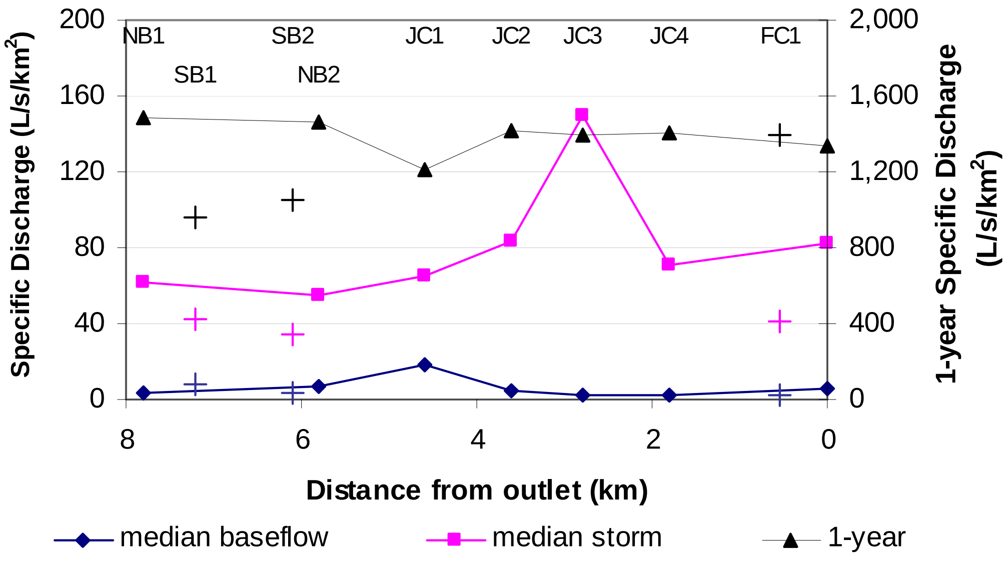

Figure18. Specific discharge by distance from watershed outlet on main stem of Jordan Creek and North Branch. Sample sites off of main stem are plotted as crosses by distance from watershed outlet.

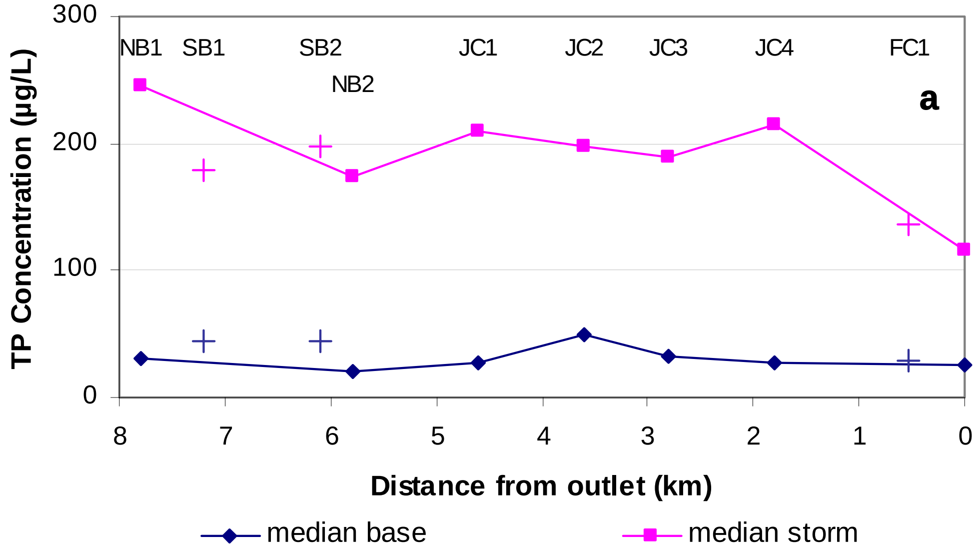

Figure19. Median TP concentrations for base flow and storm runoff arranged by distance from watershed outlet. Sample sites off of main stem are plotted as crosses by distance from watershed outlet.

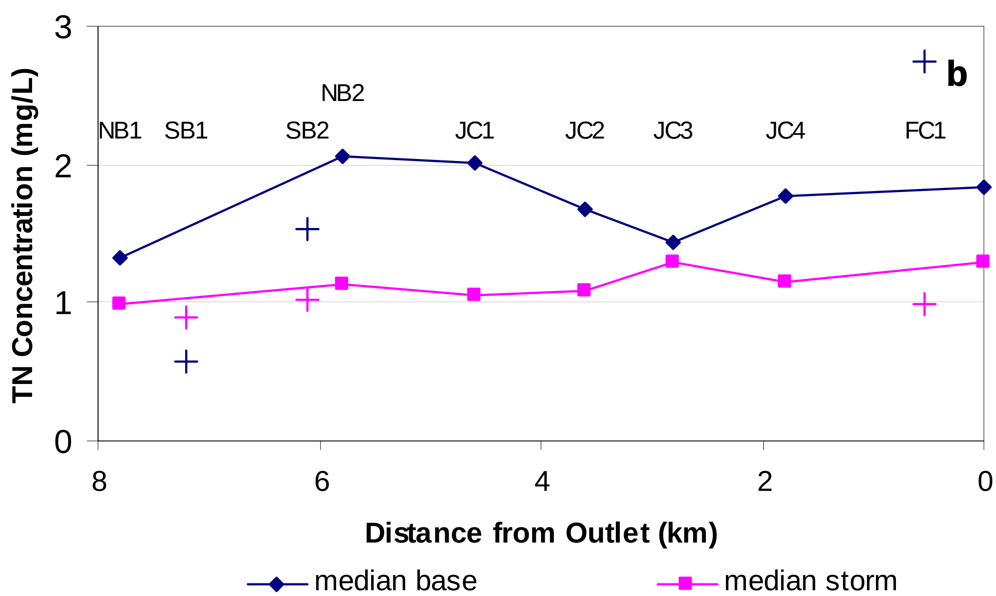

Figure 20. Median TN concentrations for base flow and storm runoff arranged by distance from watershed outlet. Sample sites off of main stem are plotted as crosses by distance from watershed outlet.

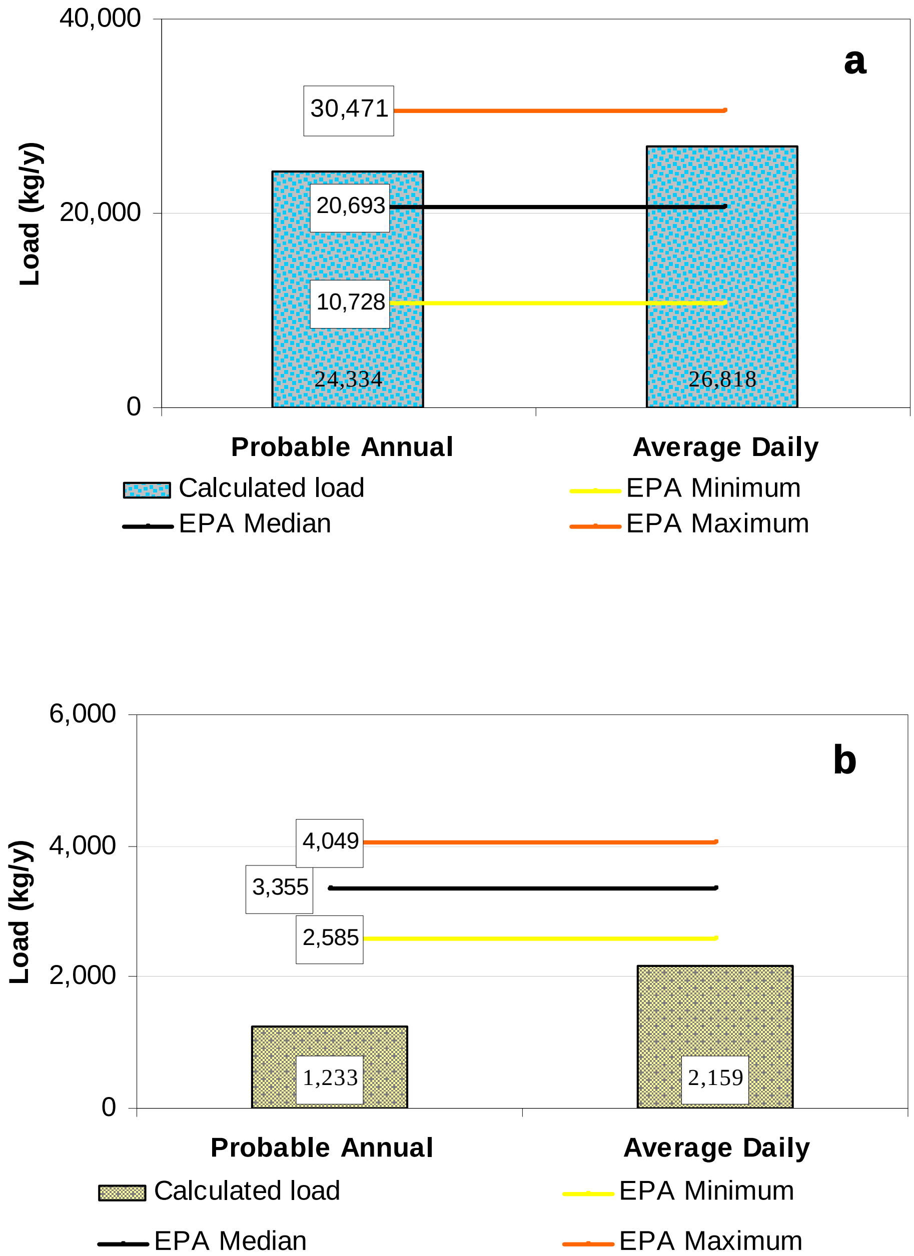

Figure 21. Comparison of TN (a) and TP (b) annual load estimates to lower Wilson Creek for study watershed.

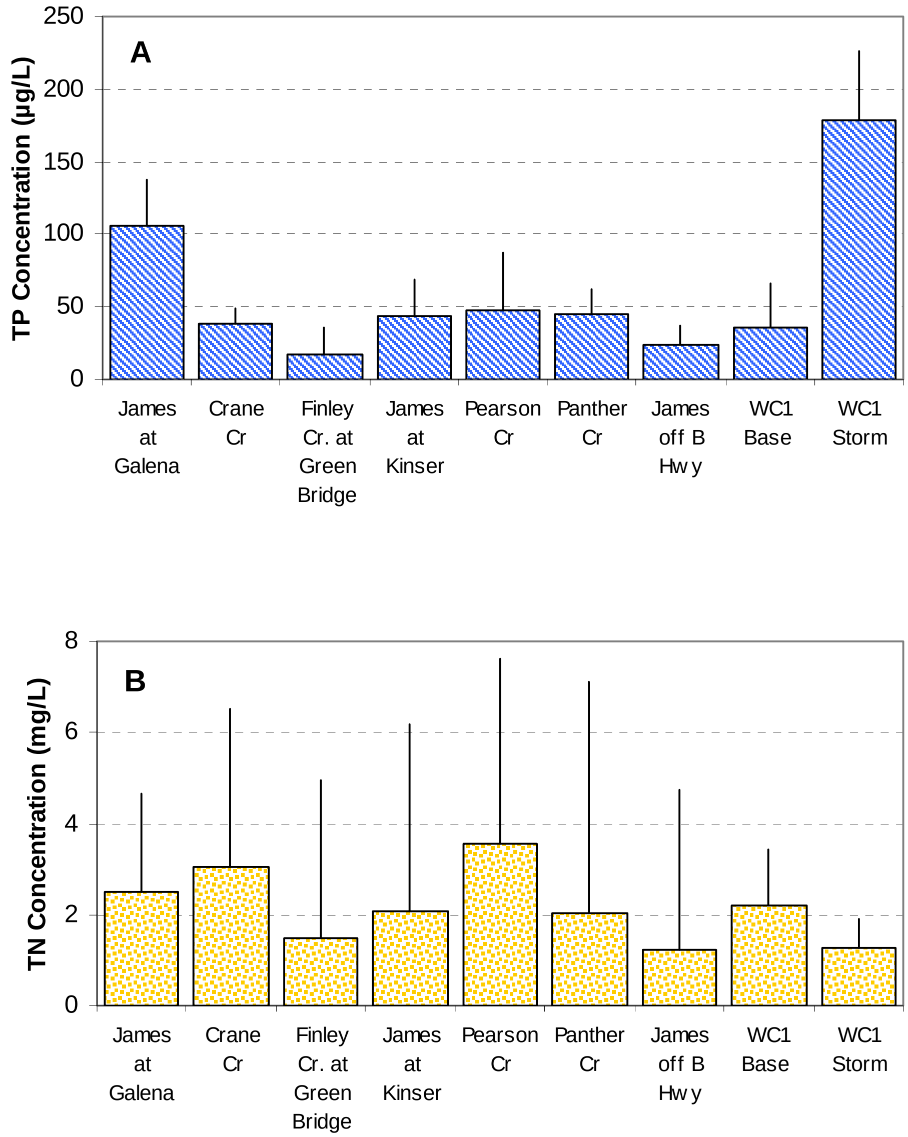

Figure 22. Comparison of concentration means and standard deviations between site WC1 and selected TMDL sites for TP (a) and TN (b).

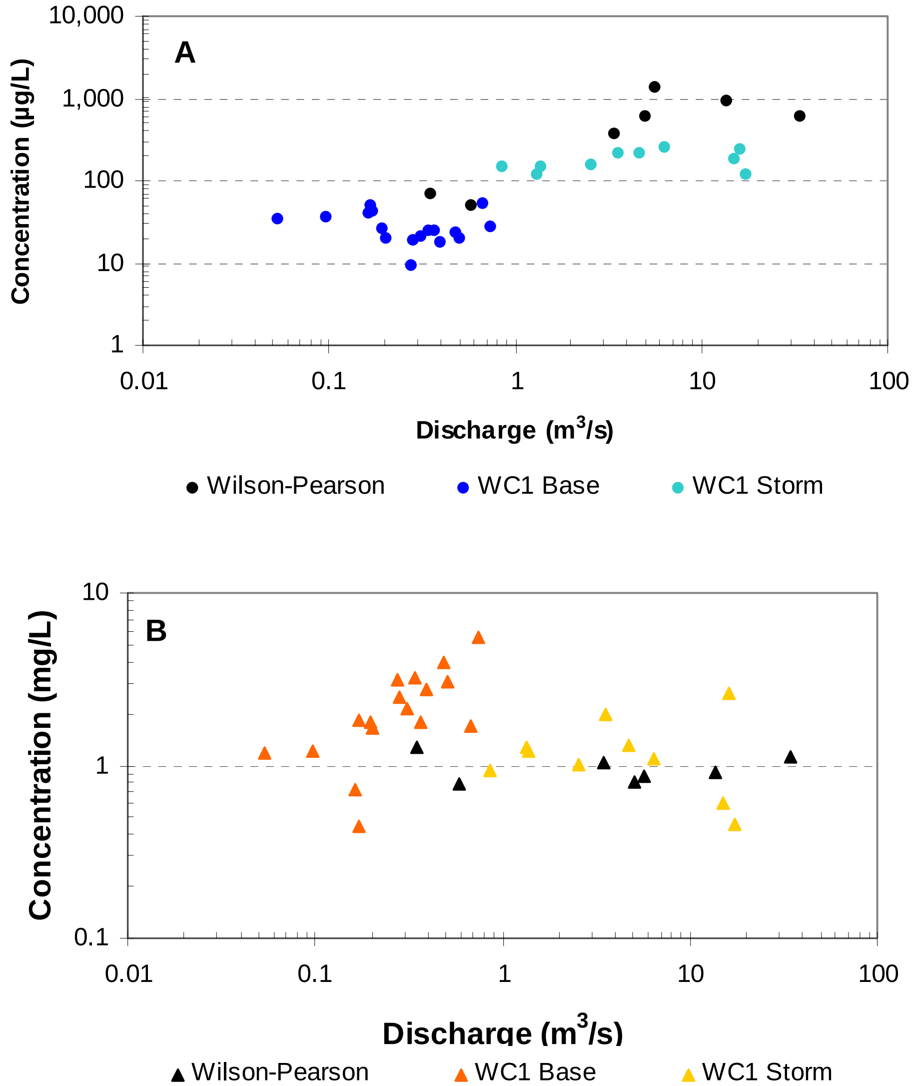

Figure 23. Comparison of Wilson-Pearson and WC1 nutrient concentrations and discharges for TP (a) and TN (b) (Richards and Johnson, 2002).

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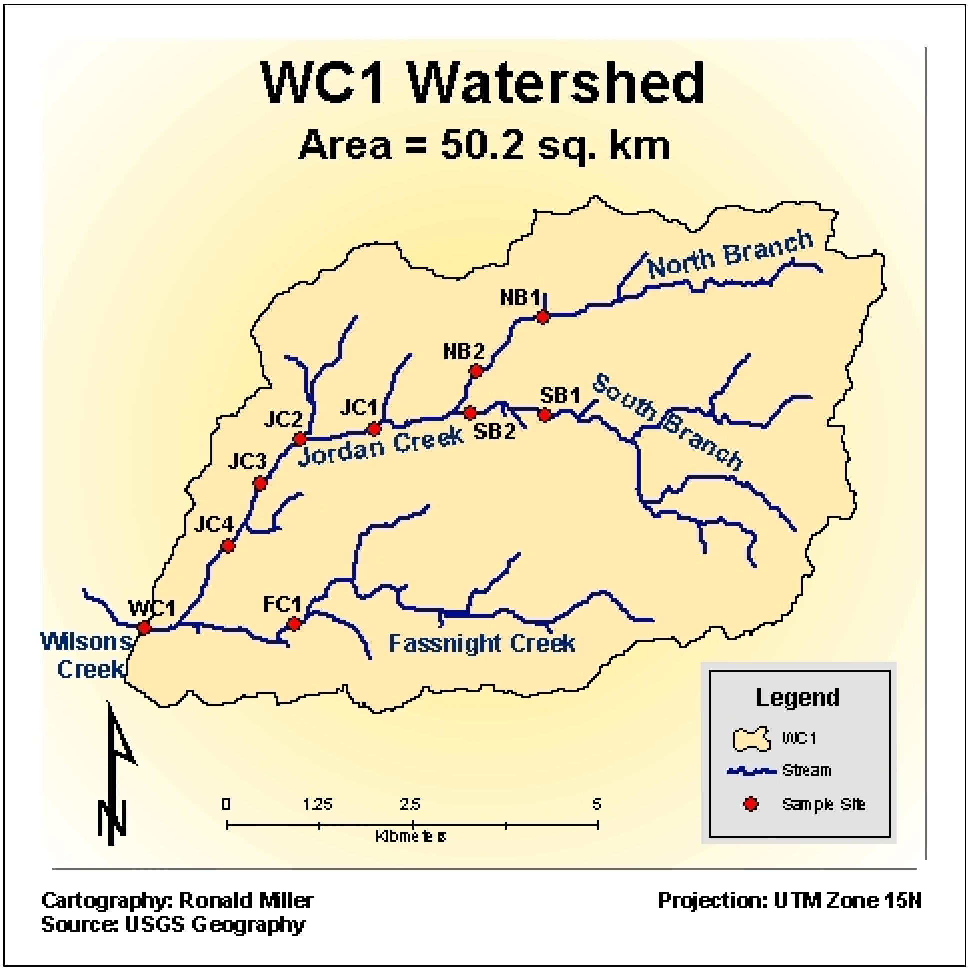
APPENDICES

APPENDIX A: Watershed Maps, Pictures of Sample Sites, Survey Cross – sections and Discharge Rating Curves



WC1 watershed area (same as entire study area)

APPENDIX A (continued)

Site NB1 (North Branch Jordan at Fremont Ave): Downstream view showing gage location, dry channel and karst seep

Site NB1: Upstream view showing dry channel and karst seep

Site NB2 (North Branch Jordan at Sherman Ave): Upstream view showing gage location and base flow

Site SB1 (South Branch Jordan at Fremont Ave): Downstream view showing gage location and base flow

Site SB2 (South Branch Jordan at Hammons Parkway): Downstream view showing gage location and base flow. Base flow stream gaging was done at channel center and event stages were reported as staff gage reading plus elevation difference between gage base and channel center.

APPENDIX A (continued)

Site JC1 (Main stem Jordan Creek at Main Ave): Upstream view showing gage location and base flow.

Site JC3 (Main stem Jordan Creek at Fort Avenue): Downstream view showing base flow (Staff gage is located on bridge base at right of picture).

APPENDIX A (continued)

Site JC3 (Main stem Jordan Creek at Mt Vernon Ave): Downstream view showing base flow and staff gage location.

Site JC4 (Main Stem Jordan Creek at Grand Ave): Upstream view showing gage location and baseflow.

Site FC1 (Fassnight Creek at Fort Avenue): Upstream view showing baseflow (Staff gage is located on near side of bridge support at right of picture)

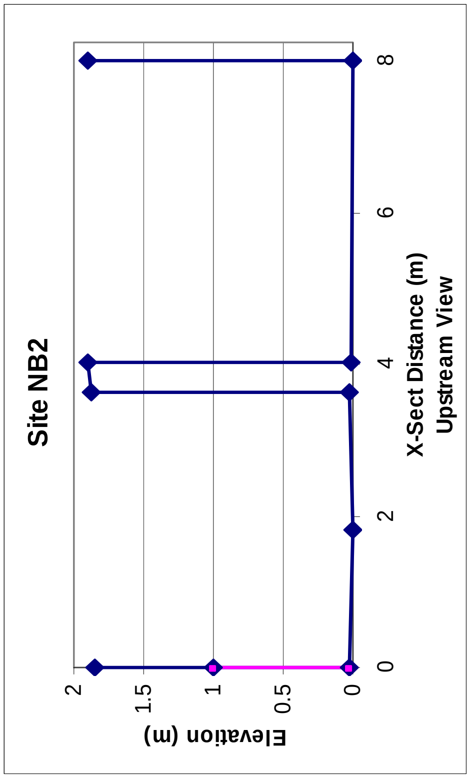
Site WC1 (Wilson Creek at Scenic Avenue): Upstream view showing baseflow. USGS gage is obscured by foliage at right of photo, gage sensor pipe on central bridge pier

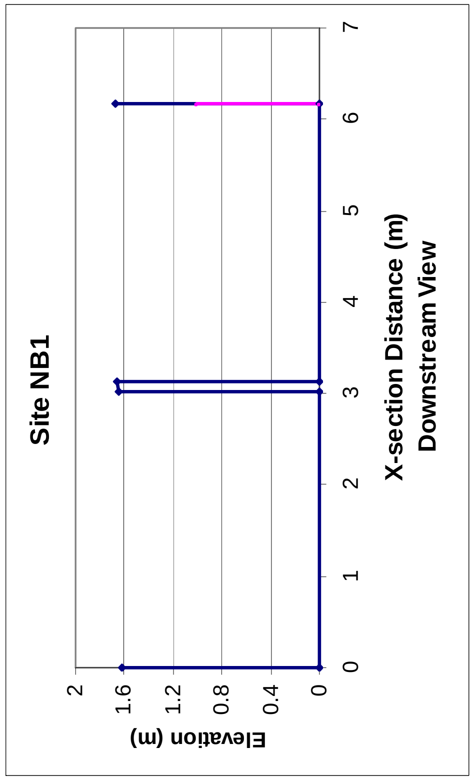
Concrete loading and truck wash station upstream of site SB2

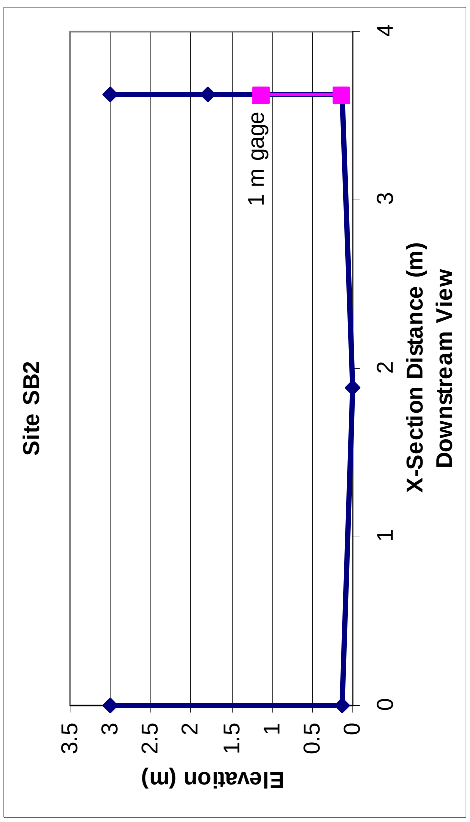
Upstream view of baseball stadium from site SB2.

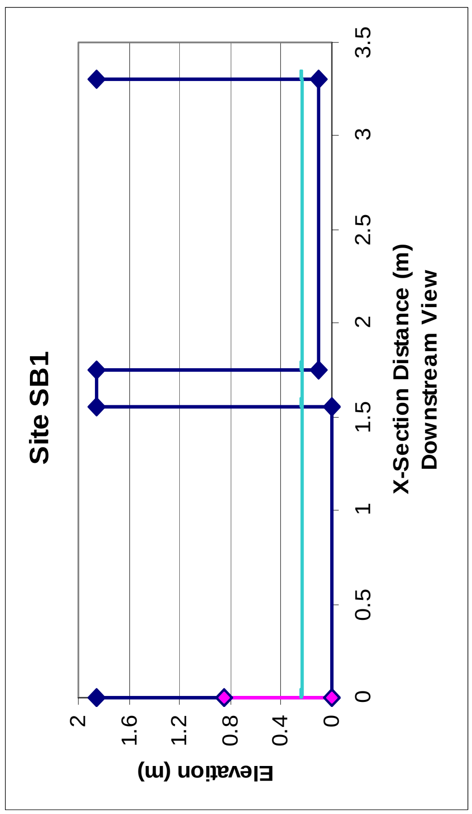
APPENDIX A (continued)

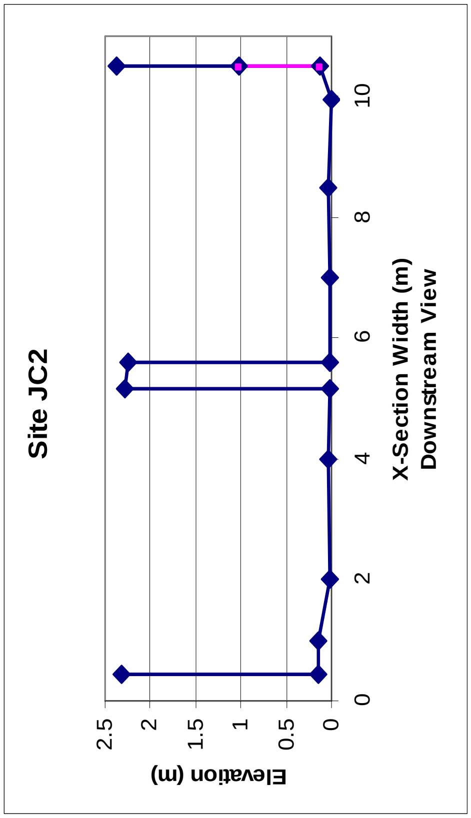
Site Surveys

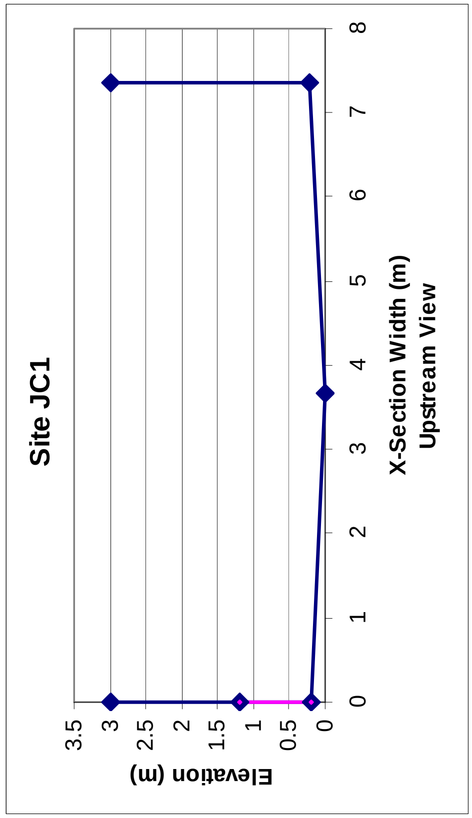


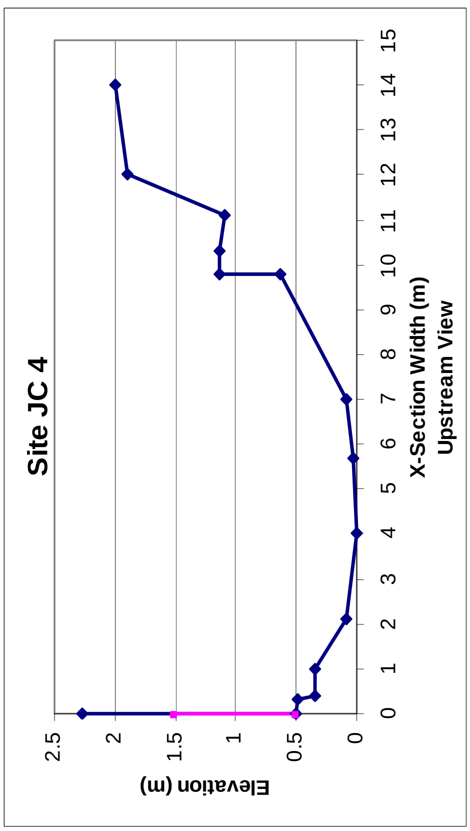


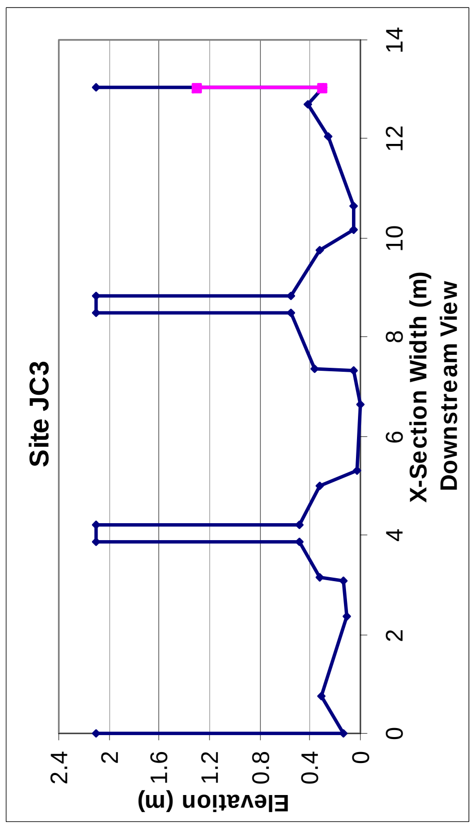


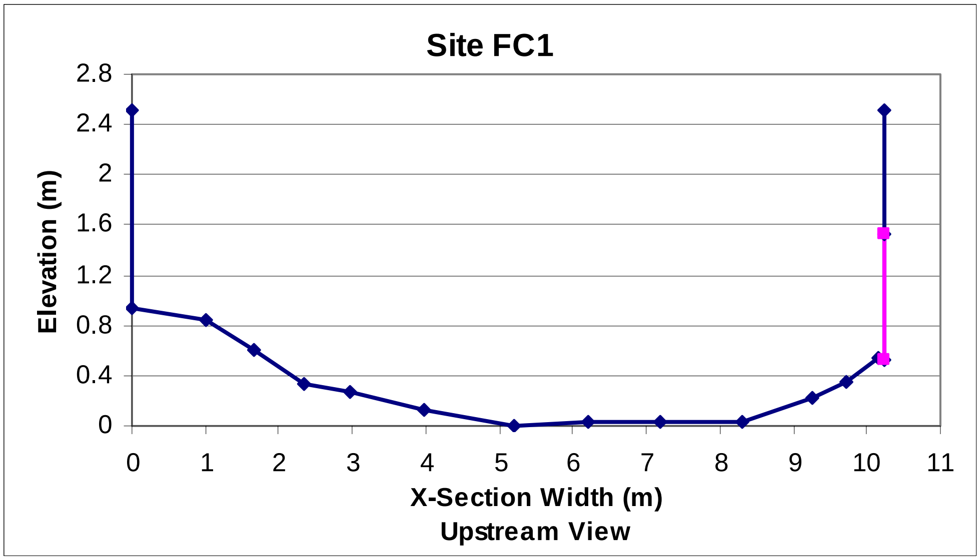



Site JC2
Elevation (m)
X-Section Width (m)
Downstream View
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10

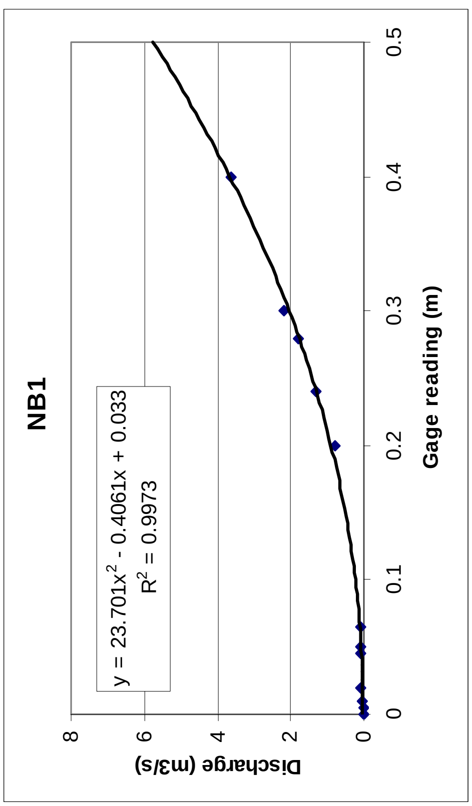

Site JC1
Elevation (m)
X-Section Width (m)
Upstream View
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8

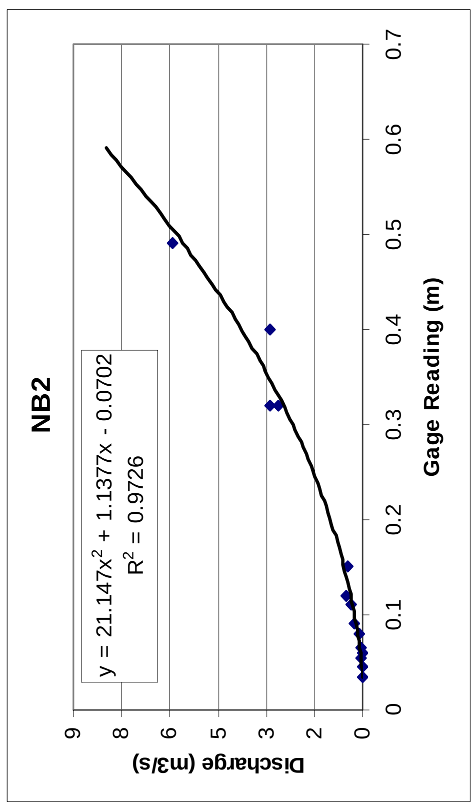

Site JC 4
Elevation (m)
X-Section Width (m)
Upstream View
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

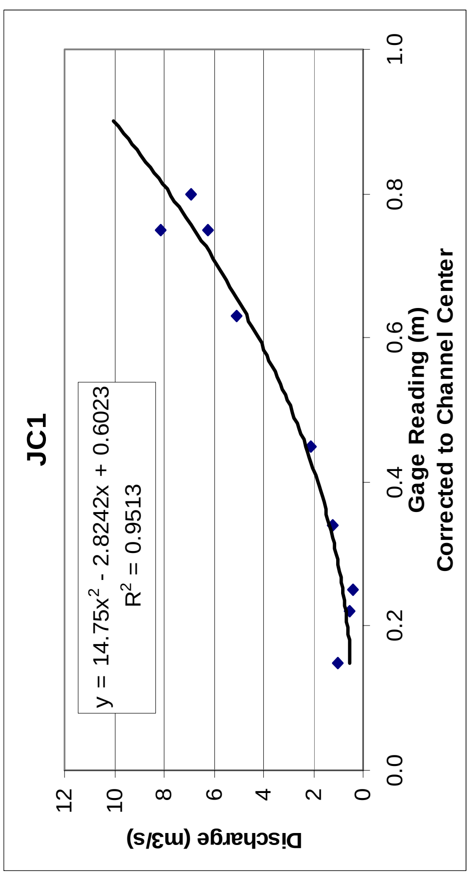

Site JC3
Elevation (m)
X-Section Width (m)
Downstream View
2.4
2
1.6
1.2
0.8
0.4
0
0
2
4
6
8
10
12
14

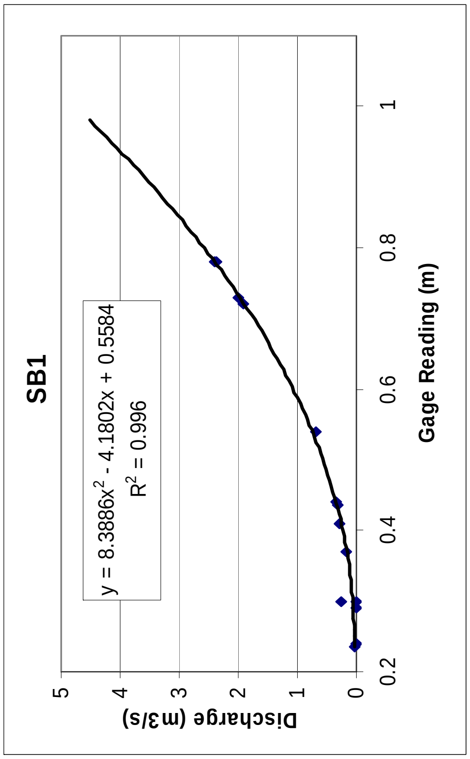


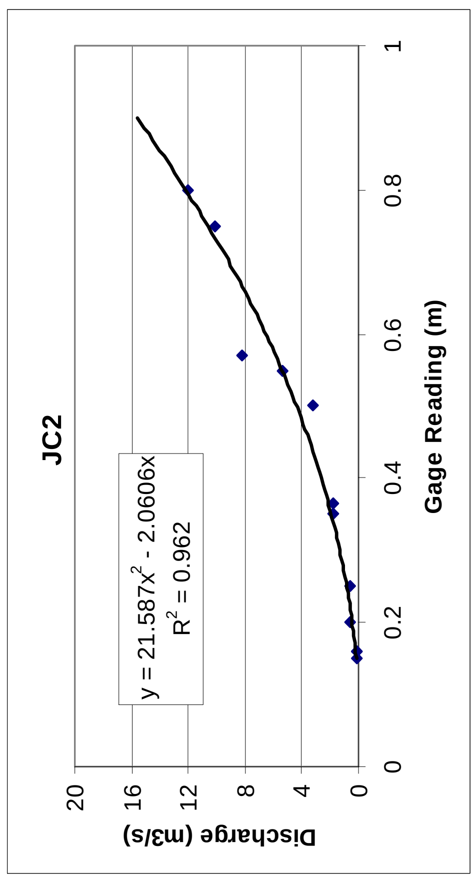
Site Discharge Rating Curves

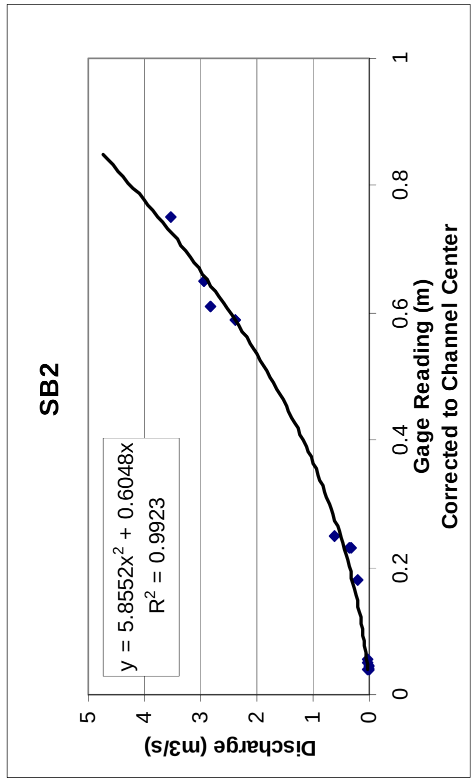


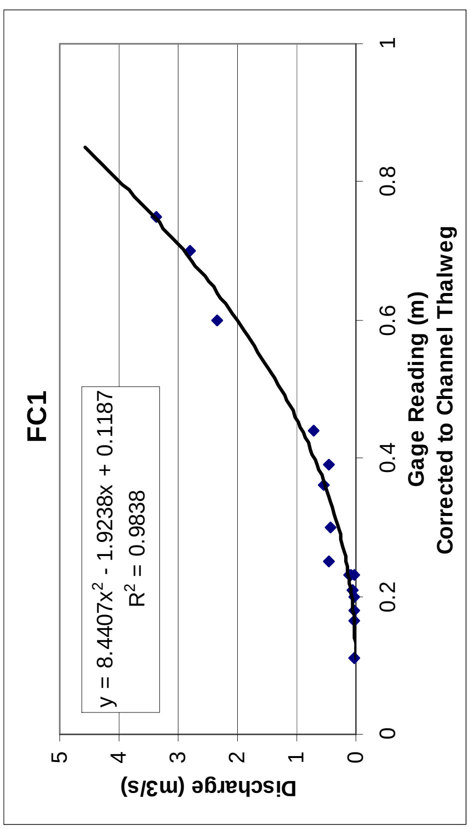


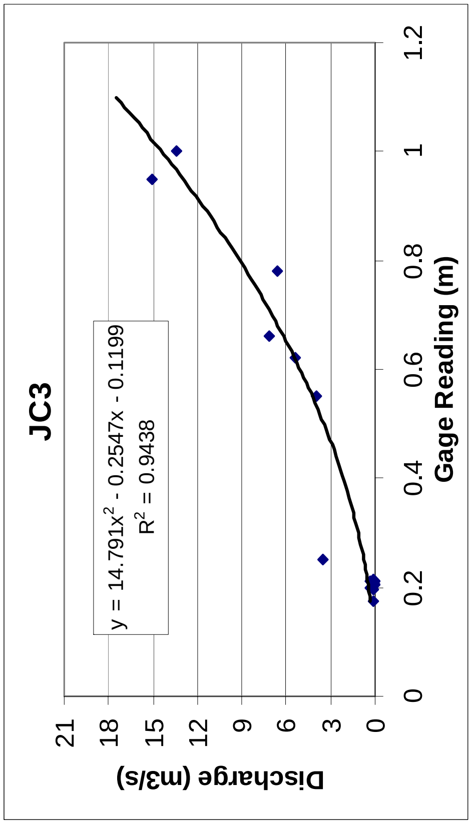

JC1
y = 14.75x2 - 2.8242x + 0.6023
R2 = 0.9513
Discharge (m3/s)
12
10
8
6
4
2
0
0.0
0.2
0.4
0.6
0.8
1.0
Gage Reading (m)
Corrected to Channel Center

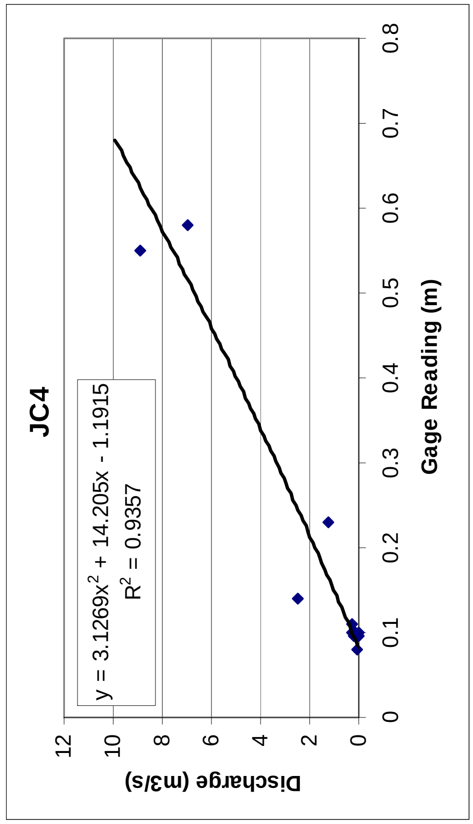

SB1
y = 8.3886x2 - 4.1802x + 0.5584
R2 = 0.996
Discharge (m3/s)
5
4
3
2
1
0
0.2
0.4
0.6
0.8
1
Gage Reading (m)


JC2
y = 21.587x2 - 2.0606x
R2 = 0.962
Discharge (m3/s)
20
16
12
8
4
0
0
0.2
0.4
0.6
0.8
1
Gage Reading (m)


SB2
y = 5.8552x2 + 0.6048x
R2 = 0.9923
Discharge (m3/s)
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
Gage Reading (m)
Corrected to Channel Center


FC1
y = 8.4407x2 - 1.9238x + 0.1187
R2 = 0.9838
Discharge (m3/s)
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
Gage Reading (m)
Corrected to Channel Thalweg


JC3
y = 14.791x2 - 0.2547x - 0.1199
R2 = 0.9438
Discharge (m3/s)
21
18
15
12
9
6
3
0
0
0.2
0.4
0.6
0.8
1
1.2
Gage Reading (m)


JC4
y = 3.1269x2 + 14.205x - 1.1915
R2 = 0.9357
Discharge (m3/s)
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Gage Reading (m)

APPENDIX B: Concentrations and Discharge by Date and Site

Site NB1

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004										293.8	0.85
Storm	9/5/2004	16:09:56	0.02	7.7	0.144	3.1	8.12	27.71	0.094	89	780.5	2.97
Base	9/7/2004		0								N/A	N/A
Base	9/24/2004		0								N/A	N/A
Storm	10/8/2004	8:15:16	0.045	7.79	0.198	0	7.68	18.08	0.129	196	284.0	1.52
Storm	10/11/2004	11:12:22	0.3	8.08	0.099	109	11.08	11.84	0.064	264	172.0	0.59
Storm	10/14/2004	10:07:56	0.065	7.24	0.166	124	10.86	10.77	0.108	252	167.0	1.10
Storm	10/26/2004	9:52:16	0.05	7.02	0.145	162	8.04	18.6	0.095	102	252.0	0.86
Base	11/23/2004	12:27:52	0.01	8.48	0.46	63.2	16.41	13.82	0.299	201	54.0	0.38
Storm	11/29/2004	11:26:30	0.28	7.85	0.17	173	13.21	6.01	0.11	240	238.0	0.73
Base	12/14/2004	10:22:02	0.005	7.24	0.61	4	12.59	0.81	0.39	202	18.0	1.03
Base	12/21/2004	10:27:42	TRACE	6.98	0.818	33.1	7.65	4.8	0.523	117	21.0	2.01
Storm	1/4/2005	11:03:04	0.24	7.2	0.154	201	12.77	6.3	0.1	239	289.0	0.38
Storm	1/5/2005	10:23:44	0.4	7.16	0.202	101	13.07	4.88	0.131	199	174.0	1.12
Base	1/21/2005	10:48:34	0.007	8.04	0.562	23.8	15.36	5.62	0.36	280	21.0	1.31
Base	2/10/2005	11:32:24	0.02	7.86	0.778	29.4	16.07	5.41	0.498	137	145.0	5.14
Base	2/24/2005	9:13:06	0.015	8.14	0.623	66.3	16.14	3.82	0.399	150	33.0	0.95
Base	3/15/2005	9:56:08	0.005	7.75	0.669	188	15.9	7.35	0.428	239	21.0	1.32
Base	3/24/2005	14:00:24	0.015	8.65	0.539	319	13.67	7.56	0.345	117	55.0	0.94
Base	4/22/2005	8:56:02	T	7.26	0.837	111	10.51	15.21	0.535	193	30.0	1.68
Base	4/30/2005	6:48:26	0.005	7.21	0.654	121	12.28	7.68	0.419	87	29.0	1.18
Base	5/18/2005	10:02:16	0	7.42	0.974	14.9	17.32	19.85	0.624	126	18.0	2.23
Base	5/30/2005	9:55:40	0	7.08	0.9	0	8.61	18.91	0.47	126	22.0	2.30
Storm	6/11/2005	12:14:26	0.02	7.48	0.244	41.1	8.36	23.16	0.158	249	213.0	1.57
Base	6/16/2005	9:15:38	0	7.4	0.337	122	7.94	20.7	0.22	113	966.0	4.75
Base	6/30/2005	11:10:42	0	7.19	0.887	0	15.85	27.79	0.568	107	52.0	1.64
Base	7/8/2005	9:05:48	0	7.25	0.9	24.8	16.92	24.02	0.42		31.0	1.21

Note: Flowing water not always present.

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site NB2

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	14:57:24	0.12	7.71	0.211	22.3	8.36	22.57	0.137	142	182.3	1.18
Storm	9/5/2004	16:51:08	0.08	7.73	0.801	26.6	8.93	23.71	0.512	135	92.7	1.79
Base	9/7/2004	12:04:30	0.045	7.82	0.953	14	8.9	17.18	0.61	247	32.5	1.13
Base	9/24/2004	13:24:26	0.035	7.79	0.988	81.8	11.18	20.86	0.632	171	29.0	1.14
Storm	10/8/2004	8:53:42	0.09	7.62	0.268	0	6.53	18.01	0.174	205	230.0	1.51
Storm	10/11/2004	12:02:22	0.4	7.84	0.109	118	11.46	11.95	0.071	181	191.0	0.67
Storm	10/14/2004	11:01:42	0.15	7.3	0.349	121	9.61	11.56	0.227	226	107.0	1.06
Storm	10/26/2004	10:52:30	0.11	7.34	0.3	87.4	6.59	18	0.195	198	202.0	1.07
Base	11/23/2004	13:16:08	0.055	7.51	0.645	114	13.41	14.81	0.413	130	49.0	1.65
Storm	11/29/2004	12:19:18	0.32	7.28	0.19	160	12.76	6.41	0.124	216	210.0	0.95
Base	12/14/2004	11:16:54	0.065	7.44	0.728	60.3	12	7.51	0.466	149	11.0	2.79
Base	12/21/2004	11:36:40	0.06	7.45	0.744	31.2	13.72	9.97	0.476	167	11.0	2.58
Storm	1/4/2005	12:05:48	0.32	7.2	0.157	255	12.93	6.38	0.102	169	130.0	0.57
Storm	1/5/2005	11:11:06	0.49	6.87	0.238	126	12.87	5.42	0.154	225	167.0	1.35
Base	1/21/2005	11:33:58	0.065	7.53	0.668	34	15.43	11.2	0.427	178	25.0	3.59
Base	2/10/2005	12:08:28	0.07	7.24	0.783	35.7	16.41	9.91	0.501	235	50.0	3.99
Base	2/24/2005	9:50:34	0.075	7.57	0.756	45.2	15.07	8.03	0.484	162	19.0	2.12
Base	3/15/2005	10:32:48	0.07	7.75	0.898	98.7	17.69	10.41	0.575	162	19.0	2.06
Base	3/24/2005	14:09:20	0.07	7.76	0.718	196	13.89	10.87	0.459	255	16.0	1.75
Base	4/22/2005	9:07:04	0.075	7.72	0.906	97.1	12.68	14.85	0.58	105	286.0	2.16
Base	4/30/2005	7:02:30	0.07	7.15	0.856	122	9.73	10.63	0.548	198	16.0	2.45
Base	5/18/2005	10:16:08	0.055	8.04	0.953	30.1	17.34	18.67	0.61	67	6.0	1.66
Base	5/30/2005	10:05:40	0.05	7.82	0.999	2	11.27	19.88	0.639	112	13.0	1.65
Storm	6/11/2005	12:25:08	0.065	7.57	0.861	4.1	7.55	20.19	0.551	127	55.0	2.14
Base	6/16/2005	9:24:56	0.055	7.51	0.714	5.8	7.91	17.49	0.46	255	21.0	2.51
Base	6/30/2005	11:21:04	0.05	7.69	0.999	-10	7.01	24.93	0.662	88	23.0	1.43
Base	7/8/2005	9:16:08	0.045	7.67	0.999	71.7	8.21	20.48	0.665	94	20.0	1.40

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site SB1

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	14:12:00	0.54	7.65	0.094	72.2	9.14	22.73	0.061	118	232	1.12975
Storm	9/5/2004	16:26:30	0.37	7.63	0.404	26.3	7.78	23.42	0.262	120	174	0.92322
Base	9/7/2004	11:38:48	0.24	7.78	0.618	0	10.27	21.1	0.396	252	63	0.48657
Base	9/24/2004	12:56:16	0.235	7.76	0.547	25.3	10.36	21.51	0.35	183	50	0.56863
Storm	10/8/2004	8:28:30	0.44	7.62	0.146	0	7.31	18.47	0.095	209	287	1.009
Storm	10/11/2004	11:21:22	0.78	7.97	0.067	73	11.68	11.65	0.044	198	184	0.603
Storm	10/14/2004	10:23:18	0.435	7.39	0.167	81.2	9.83	11.45	0.109	240	101	0.869
Storm	10/26/2004	10:11:12	0.41	7.08	0.157	63.7	13.99	18.81	0.102	287	142	0.659
Base	11/23/2004	12:41:48	0.3	7.36	0.562	67.7	11.79	14.15	0.359	117	50	0.08941
Storm	11/29/2004	11:45:50	0.73	7.28	0.131	128	12.8	6.61	0.085	209	227	1.11125
Base	12/14/2004	10:38:20	0.3	7.01	0.682	29.9	10.42	2.3	0.436	104	39	1.472
Base	12/21/2004	11:04:14	0.29	6.88	0.672	35.9	11.58	4.29	0.43	108	37	0.513
Storm	1/4/2005	11:19:58	0.72	7.04	0.074	246	13.31	6.09	0.048	155	141	0.36
Storm	1/5/2005	10:41:42	0.78	6.91	0.207	71.8	12.75	5.49	0.134	229	222	1.498
Base	1/21/2005	11:02:38	0.36	7.6	0.714	34.1	12.92	7.52	0.457	135	56	2.67645
Base	2/10/2005	11:46:46	0.36	7.37	0.632	35.8	14.48	5.66	0.405	239	39	1.05597
Base	2/24/2005	9:22:50	0.37	7.64	0.671	64.1	12.09	5.7	0.429	152	40	1.01608
Base	3/15/2005	10:06:42	0.34	7.82	0.595	103	15.63	8.37	0.381	150	24	0.483
Base	3/24/2005	13:48:28	0.36	7.53	0.662	135	11.02	8.58	0.424	263	43	0.603
Base	4/22/2005	8:44:12	0.435	7.75	0.778	65.9	11.84	14.47	0.498	96	42	0.431
Base	4/30/2005	6:34:24	0.335	7.15	0.699	123	9.56	9.22	0.447	166	47	1.132
Base	5/18/2005	9:43:56	0.32	7.76	0.711	28.9	12.33	17.43	0.455	73	44	0.356
Base	5/30/2005	9:42:06	0.22	7.87	0.657	0	9.92	19.08	0.42	180	43	0.6855
Storm	6/11/2005	12:05:26	0.335	7.76	0.567	0	8.4	21.89	0.363	126	126	0.739
Base	6/16/2005	9:02:26	0.365	7.67	0.528	10.2	7.41	19.74	0.34	253	83	0.648
Base	6/30/2005	11:01:24	0.32	7.77	0.569	554	10.55	25.76	0.364	84	48	0.545
Base	7/8/2005	8:56:08	0.32	7.76	0.639	11.3	9.1	21.03	0.409	88	48	0.267

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site SB2

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	2:36:56 PM	0.25	8.14	0.102	45.2	9.08	22.81	0.066	129	211	0.72
Storm	9/5/2004	4:35:54 PM	0.18	7.6	0.298	17.4	8.66	24.92	0.194	123	244	1.68
Base	9/7/2004	11:52:58	0.04	7.62	0.723	5.4	8.64	17.81	0.462	249	59	0.96
Base	9/24/2004	1:14:24 PM	0.04	7.93	0.697	256	8.57	20.2	0.446	148	47	1.11
Storm	10/8/2004	8:41:14 AM	0.045	7.66	0.154	0	8.15	18.46	0.1	211	233	1.13
Storm	10/11/2004	11:45:48 AM	0.62	7.68	0.068	93	11.98	11.67	0.044	201	184	0.53
Storm	10/14/2004	10:43:56 AM	0.1	7.69	0.16	250	12.65	11	0.104	214	157	0.92
Storm	10/26/2004	10:27:48 AM	0.1	7.91	0.147	313	8.43	18.95	0.096	189	269	0.85
Base	11/23/2004	1:00:16 PM	0.055	7.43	0.696	75.3	10.93	14.19	0.446	119	43	1.50
Storm	11/29/2004	12:07:08 PM	0.46	6.91	0.132	133	12.82	6.63	0.086	226	236	1.12
Base	12/14/2004	10:55:00	0.05	7.26	0.767	81.6	10.69	5.01	0.491	112	49	2.16
Base	12/21/2004	11:22:16 AM	0.04	7.17	0.804	32.9	11.66	6.11	0.514	100	31	1.73
Storm	1/4/2005	11:45:10 AM	0.52	7.22	0.074	190	13.43	6.04	0.048	175	128	0.40
Storm	1/5/2005	10:58:40 AM	0.48	6.78	0.199	89.2	12.96	5.41	0.13	227	172	1.13
Base	1/21/2005	11:17:02 AM	0.065	7.57	0.814	42.3	13.47	9.02	0.521	116	1097	3.60
Base	2/10/2005	11:57:36 AM	0.05	7.19	0.785	38.1	13.66	5.77	0.503	161	30	1.99
Base	2/24/2005	9:39:20 AM	0.05	7.47	0.673	58.2	11.96	6.87	0.431	155	43	2.02
Base	3/15/2005	10:22:06 AM	0.05	7.78	0.778	107	16.74	8.14	0.498	155	933	1.21
Base	3/24/2005	2:16:26 PM	0.055	7.56	0.847	176	11.76	9.21	0.542	259	45	1.72
Base	4/22/2005	9:18:46 AM	0.035	7.74	0.893	88.7	12.09	14.71	0.572	107	320	1.53
Base	4/30/2005	7:18:36 AM	0.045	7.37	0.864	98.3	9.79	10.45	0.553	132	25	1.85
Base	5/18/2005	10:31:02 AM	0.047	7.83	0.914	50.1	11.76	16.78	0.585	70	32	1.20
Base	5/30/2005	10:19:00 AM	0.065	7.99	0.859	22.2	11.05	19.25	0.55	103	34	1.22
Storm	6/11/2005	12:33:10 PM	0.045	7.66	0.444	104	8.64	22.72	0.289	114	170	1.41
Base	6/16/2005	9:32:38 AM	0.085	7.62	0.553	31.9	7.91	19.44	0.35	263	114	2.00
Base	6/30/2005	11:33:28 AM	0.05	7.69	0.741	0	9.3	24.07	0.474	86	49	0.84
Base	7/8/2005	9:24:32 AM	0.05	8.83	0.804	117	11.7	21.52	0.515	45	41	1.11

Site JC1

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	15:21:40	0.14	8	0.132	10.1	8.96	22.77	0.086	148	269	1.05
Storm	9/5/2004	17:07:24	0.02	7.81	0.264	12.5	8.49	24.94	0.171	121	216	1.64
Base	9/7/2004	12:21:46	L .07 R .1	8.33	0.76	13.8	11.04	18.88	0.487	209	66	1.06
Base	9/24/2004	13:48:10	L 0.08 R .105	8.29	0.831	67.2	9.85	20.25	0.532	169	76	1.41
Storm	10/8/2004	9:14:38	0.05	7.81	0.207	-10	8.1	18.31	0.135	201	221	1.19
Storm	10/11/2004	12:25:52	0.6	8.04	0.081	91.2	11.79	11.85	0.053	172	253	0.70
Storm	10/14/2004	11:20:52	0.15	7.78	0.174	200	11.44	10.92	0.113	196	141	0.86
Storm	10/26/2004	11:13:00	0.25	7.65	0.123	208	9.16	18.95	0.08	192	404	0.85
Base	11/23/2004	13:41:48	L 0.11 R 0.185	8.03	0.67	76.3	13.47	13.57	0.429	146	41	1.71
Storm	11/29/2004	12:42:36	0.43	7.44	0.16	146	12.82	6.69	0.104	205	203	1.06
Base	12/14/2004	11:38:56	L .105 R.16	7.99	0.757	55.7	12.42	5.32	0.485	160	17	2.92
Base	12/21/2004	11:53:50	L .11 R .14	8	0.778	31.7	12.97	6.57	0.498	185	17	2.55
Storm	1/4/2005	12:31:00	0.55	7.68	0.091	175	13.53	6.08	0.059	164	115	0.40
Storm	1/5/2005	11:26:00	0.55	6.97	0.235	96.5	13.24	5.63	0.153	183	197	1.52
Base	1/21/2005	11:54:52	0.14	7.91	0.744	37.6	14.06	8.7	0.476	199	23	3.35
Base	2/10/2005	12:20:28	0.15	7.9	0.804	37.1	15.21	5.53	0.515	237	19	3.46
Base	2/24/2005	10:08:44	0.145	7.81	0.73	40	13.72	6.92	0.467	159	28	2.42
Base	3/15/2005	10:47:16	0.15	7.99	0.846	106	15.07	8.14	0.541	160	22	1.65
Base	3/24/2005	14:32:32	0.17	7.75	0.783	213	12.41	8.93	0.501	233	983	3.00
Base	4/22/2005	9:39:34	0.12	8.21	0.855	70.6	12.9	14.62	0.547	99	16	2.01
Base	4/30/2005	7:46:10	0.095	8.07	0.729	28.8	11.53	11.01	0.47	229	21	2.04
Base	5/18/2005	11:05:34	0.11	8.33	0.953	34.1	12.22	16.11	0.61	57	29	1.52
Base	5/30/2005	10:29:52	0.05	8.26	0.894	319	10.72	18.58	0.572	99	14	1.56
Storm	6/11/2005	12:46:56	0.07	7.85	0.266	73.5	8.98	23.18	0.173	102	177	2.31
Base	6/16/2005	9:44:22	0.09	7.96	0.53	48.9	9.44	20.31	0.34	263	109	2.30
Base	6/30/2005	11:47:30	0.07	8.17	0.903	-10	10.28	23.63	0.578	68	42	1.35
Base	7/8/2005	9:37:22	0.065	8.22	0.93	95.3	11.06	21.72	0.595	69	44	1.18

Note: Some early stages were gaged at upstream site with two parallel channels

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site JC2

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	15:35:18	0.35	7.89	0.161	25.2	8.83	22.74	0.105	129	188	1.05
Storm	9/5/2004	17:28:36	0.2	7.42	0.229	21.3	7.25	25.20	0.149	134	219	1.55
Base	9/7/2004	12:35:46	---------	7.23	0.881	27.9	6.56	19.32	0.564	76	67	1.00
Base	9/24/2004	13:59:12	---------	7.18	0.901	71.2	7.69	20.31	0.577	108	115	1.10
Storm	10/8/2004	9:48:58	0.25	7.57	0.227	0	7.72	18.36	0.148	201	206	1.15
Storm	10/11/2004	12:57:06	0.8	8.06	0.097	83.7	11.61	12.31	0.063	139	164	0.58
Storm	10/14/2004	11:42:14	0.365	7.81	0.189	168	11.2	11.40	0.123	173	142	0.80
Storm	10/26/2004	11:36:30	0.5	7.78	0.114	260	8.37	19.03	0.074	169	311	1.13
Base	11/23/2004	14:03:00	0.16	7.34	0.787	71.3	12.04	14.85	0.503	35	49	1.68
Storm	11/29/2004	13:10:40	0.55	7.46	0.273	129	11.74	8.30	0.178	173	219	1.03
Base	12/14/2004	12:01:08	0.16	7.38	0.871	41.8	10.48	7.04	0.558	33	28	2.66
Base	12/21/2004	12:11:42	0.15	7.32	0.862	30.3	11.61	8.66	0.552	17	51	2.22
Storm	1/4/2005	13:07:28	0.57	7.57	0.104	174	13.03	6.32	0.068	151	121	0.35
Storm	1/5/2005	11:43:30	0.75	7.07	0.335	84	12.65	6.86	0.218	138	226	1.64
Base	1/21/2005	12:10:34	0.16	7.20	0.886	44.3	10.88	10.41	0.567	63	34	3.85
Base	2/10/2005	12:29:42	0.16	7.41	0.95	38.4	14.25	8.63	0.608	92	38	3.48
Base	2/24/2005	10:23:18	0.165	7.19	0.881	34.6	12.84	8.41	0.564	75	40	2.05
Base	3/15/2005	11:01:16	0.14	7.17	0.997	100	15.35	9.70	0.638	75	47	1.31
Base	3/24/2005	14:44:46	0.15	7.24	0.88	119	11.68	9.65	0.563	80	29	1.57
Base	4/22/2005	10:17:38	0.14	7.45	0.979	80	12.14	15.18	0.626	7	50	1.82
Base	4/30/2005	7:56:42	0.13	7.32	0.844	6.1	8.13	11.04	0.540	62	25	1.68
Base	5/18/2005	11:21:46	0.12	7.39	0.9	53.7	10.22	17.13	0.480	3	32	1.12
Base	5/30/2005	10:42:14	0.13	7.37	0.9495	16.6	8.375	18.31	0.592	40	55	1.29
Storm	6/11/2005	12:56:54	0.32	7.68	0.261	56.1	8.25	23.33	0.169	111	166	1.86
Base	6/16/2005	9:52:50	0.175	7.39	0.016	19.5	7.93	19.83	0.010	148	102	2.24
Base	6/30/2005	11:59:06	0.11	7.45	0.999	72.3	6.12	23.16	0.647	75	59	1.02
Base	7/8/2005	9:49:58	0.105	7.28	0.9	110	6.93	20.61	0.480	73	67	1.03

Note: Some stage readings not taken with discharge measurement

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site JC3

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	16:04:22	0.55	7.78	0.186	27.3	8.7	22.88	0.121	151	201	1.41
Storm	9/5/2004	17:50:24	0.38	7.70	0.244	37.4	7.41	25.15	0.159	140	183	1.60
Base	9/7/2004	12:46:30	0.18	7.74	0.830	19.9	8.11	17.94	0.531	154	49	0.67
Base	9/24/2004	14:24:02	0.19	7.94	0.880	83.2	10.62	20.63	0.563	64	74	0.83
Storm	10/8/2004	10:03:50	0.36	7.63	0.233	0.0	7.6	18.35	0.151	202	171	0.97
Storm	10/11/2004	13:12:48	0.25	8.19	0.092	90.2	11.44	12.15	0.059	158	193	0.55
Storm	10/14/2004	12:01:42	0.62	7.76	0.221	167.0	10.8	11.12	0.144	156	146	1.09
Storm	10/26/2004	11:57:04	0.78	7.67	0.145	219.0	7.97	18.95	0.094	171	308	1.69
Base	11/23/2004	14:16:42	0.18	7.70	0.711	75.6	12.63	14.5	0.455	116	49	1.44
Storm	11/29/2004	13:39:34	0.66	7.57	0.205	166.0	12.16	7.2	0.133	88	236	1.16
Base	12/14/2004	12:17:34	0.18	7.99	0.884	31.8	10.96	4.99	0.565	78	23	2.37
Base	12/21/2004	12:25:18	0.165	7.76	0.883	38.5	12.12	6.35	0.565	102	25	5.89
Storm	1/4/2005	13:28:34	1	7.74	0.104	248.0	12.96	6.28	0.068	152	165	0.45
Storm	1/5/2005	12:00:44	0.95	7.22	0.283	127.0	12.6	6.22	0.184	128	212	2.15
Base	1/21/2005	12:47:10	0.21	7.70	0.886	25.3	12.47	9.53	0.567	132	29	3.56
Base	2/10/2005	12:55:52	0.2	7.71	0.933	23.2	14.75	7.22	0.597	103	41	3.48
Base	2/24/2005	10:43:36	0.21	7.63	0.838	37.8	12.53	7.26	0.537	128	33	2.03
Base	3/15/2005	11:16:20	0.175	7.83	0.985	117.0	15.89	8.24	0.631	68	26	1.21
Base	3/24/2005	14:56:18	0.195	7.69	0.863	129.0	12.45	9.33	0.553	136	41	1.69
Base	4/22/2005	10:32:40	0.21	7.86	0.900	84.5	10.64	14.75	0.48	60	23	1.42
Base	4/30/2005	8:10:32	0.215	7.54	0.771	7.3	8.26	10.07	0.49	128	18	2.47
Base	5/18/2005	11:35:52	0.205	7.97	0.999	58.7	10.65	17.27	0.697	51	31	1.21
Base	5/30/2005	11:02:24	0.195	7.91	0.950	18.8	7.295	18.495	0.545	40.5	25	0.80
Storm	6/11/2005	13:09:14	0.42	7.79	0.172	60.8	8.68	23.63	0.112	102	186	1.85
Base	6/16/2005	10:02:48	0.245	7.66	0.724	18.7	6.79	19.3	0.46	215	47	1.69
Base	6/30/2005	12:10:02	0.185	7.83	0.995	27.9	10.42	24.84	0.637	62	34	0.46
Base	7/8/2005	10:00:10	0.178	7.78	0.900	99.4	10.77	20.91	0.48	69	46	0.82

APPENDIX B: Concentrations and Discharge by Date and Site (Cont'd)

Site JC4

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	16:26:56	0.23	7.82	0.209	34	8.7	22.8	0.136	155	194	1.20
Storm	9/5/2004	17:59:02	0.21	7.78	0.213	36.2	7.68	25.21	0.138	142	205	1.42
Base	9/7/2004	12:55:44	0.1	7.55	0.733	31	7.98	18.96	0.469	175	50	1.11
Base	9/24/2004	14:41:34	0.08	7.53	0.716	97.8	9.43	20.27	0.458	104	63	0.65
Storm	10/8/2004	10:15:42	0.16	7.70	0.227	0	7.85	18.31	0.147	198	168	1.11
Storm	10/11/2004	13:43:10	0.4	8.20	0.096	85.5	11.21	12.24	0.062	160	204	0.70
Storm	10/14/2004	12:17:30	0.1	7.79	0.237	175	10.8	11.15	0.154	175	161	1.26
Storm	10/26/2004	12:07:54	0.16	7.72	0.136	238	8.41	18.96	0.088	186	225	0.88
Base	11/23/2004	14:33:56	0.095	7.58	0.778	78.9	12.68	14.19	0.498	157	37	1.71
Storm	11/29/2004	13:51:26	0.36	7.61	0.206	136	12.18	7.25	0.134	146	229	1.10
Base	12/14/2004	12:34:28	0.1	7.66	0.822	51.4	10.84	6.06	0.526	101	24	3.01
Base	12/21/2004	12:43:38	0.09	7.56	0.818	41.1	11.89	7.18	0.523	114	20	2.56
Storm	1/4/2005	13:40:06	0.58	7.73	0.106	172	12.99	6.33	0.069	155	382	0.42
Storm	1/5/2005	12:22:24	0.55	7.33	0.287	121	12.84	6.31	0.187	152	263	2.05
Base	1/21/2005	13:03:20	0.1	7.58	0.893	28.5	12.75	9.62	0.571	166	27	4.55
Base	2/10/2005	13:09:10	0.1	7.55	0.901	31.2	15.15	7.71	0.577	121	28	3.95
Base	2/24/2005	10:59:24	0.1	7.52	0.832	37.6	13.33	7.58	0.532	154	26	2.91
Base	3/15/2005	11:26:38	0.08	7.61	0.912	123	15.43	9.12	0.584	124	16	1.71
Base	3/24/2005	15:14:16	0.095	7.59	0.852	126	12.33	9.31	0.545	179	25	1.81
Base	4/22/2005	10:45:06	0.095	7.69	0.956	76	12.02	15.14	0.612	81	18	1.77
Base	4/30/2005	8:17:36	0.095	7.58	0.756	7.5	9.88	10.79	0.48	157	25	1.77
Base	5/18/2005	12:00:36	0.095	7.73	0.995	126	11.54	17.58	0.637	68	19	1.84
Base	5/30/2005	11:12:14	0.07	7.73	0.912	26.8	7.69	18.34	0.584	66	29	1.19
Storm	6/11/2005	13:17:46	0.235	7.86	0.198	132	8.62	23.34	0.129	98	238	2.00
Base	6/16/2005	10:10:24	0.09	7.59	0.736	4.3	8.48	18.73	0.47	236	34	1.67
Base	6/30/2005	12:18:10	0.065	7.52	0.886	28.6	10.17	23.46	0.567	82	31	1.22
Base	7/8/2005	10:07:58	0.065	7.71	0.872	123	8.96	22.04	0.558	77	46	1.12

Site FC1

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	17:35:50	0.39	7.88	0.154	57	9.02	22.95	0.100	161	135	1.05
Storm	9/5/2004	18:28:42	0.25	7.58	0.201	16.7	6.44	24.91	0.131	146	225	1.79
Base	9/7/2004	13:24:02	0.165	7.63	0.431	35.5	5.04	18.97	0.280	190	69	0.56
Base	9/24/2004	15:17:18	0.11	7.94	0.757	99.7	8.81	20.09	0.484	129	48	0.46
Storm	10/8/2004	10:41:18	0.23	7.70	0.174	-10	6.81	18.52	0.113	188	118	0.91
Storm	10/11/2004	14:21:52	0.7	8.16	0.09	62.4	10.93	12.95	0.058	152	120	0.60
Storm	10/14/2004	12:46:18	0.3	7.86	0.148	154	10.89	11.13	0.096	168	124	0.84
Storm	10/26/2004	12:33:42	0.44	7.53	0.113	117	8.16	18.96	0.073	170	188	0.92
Base	11/23/2004	15:07:56	0.21	8.01	0.723	72.9	12.38	13.02	0.462	169	35	2.52
Storm	11/29/2004	14:20:08	0.36	7.65	0.195	101	11.97	7.85	0.127	177	137	1.13
Base	12/14/2004	13:07:24	0.11	8.28	0.803	39.5	12.31	2.90	0.514	101	11	4.24
Base	12/21/2004	13:10:54	0.18	8.19	0.813	53.9	14.27	4.57	0.520	144	18	3.95
Storm	1/4/2005	14:30:12	0.75	7.73	0.101	149	12.68	6.83	0.065	157	82	0.46
Storm	1/5/2005	12:59:16	0.6	7.29	0.358	53.9	11.88	8.32	0.233	155	390	3.94
Base	1/21/2005	13:45:52	0.23	8.19	0.835	42.7	14.5	9.00	0.535	189	15	7.78
Base	2/10/2005	13:31:30	0.21	8.25	0.838	33.4	18.37	5.86	0.536	199	7	5.15
Base	2/24/2005	11:28:50	0.23	8.06	0.756	39.3	15.53	6.47	0.484	156	15	4.06
Base	3/15/2005	12:03:38	0.2	8.21	0.901	123	17.64	8.23	0.576	137	5	2.92
Base	3/24/2005	15:39:20	0.25	8.03	0.797	175	12.71	8.44	0.510	196	29	2.74
Base	4/22/2005	11:26:10	0.195	8.06	0.916	95.7	11.67	15.28	0.586	93	13	2.71
Base	4/30/2005	8:43:48	0.019	7.99	0.775	6	10.6	9.95	0.500	155	18	3.00
Base	5/18/2005	12:41:50	0.16	8.13	0.957	71.9	9.55	17.24	0.612	56	34	2.08
Base	5/30/2005	11:49:32	0.145	8.15	0.985	36.1	7.53	18.68	0.631	62	55	2.79
Storm	6/11/2005	13:42:48	0.3	7.66	0.182	38.4	7.53	23.32	0.118	103	206	1.88
Base	6/16/2005	10:32:44	0.245	7.69	0.497	19.1	6.22	20.20	0.320	243	127	2.69
Base	6/30/2005	12:46:38	0.125	7.84	0.945	28.2	9.5	24.84	0.605	71	62	1.79
Base	7/8/2005	10:37:36	0.14	7.92	0.937	113	9.31	21.60	0.600	74	50	1.20

Site WC1

EVENT	DATE	TIME	STADIA (m)	pH	COND (mS/cm)	TURB (NTU)	DO (mg/L)	Temp (ºC)	TDS (mg/L)	ORP	TP (µg/L)	TN (mg/L)
Storm	8/28/2004	16:40:06		7.75	0.187	51.7	8.66	22.96	0.121	158	154	1.00
Storm	9/5/2004	18:15:06		7.54	0.326	61.9	7.79	24.79	0.212	158	146	1.22
Base	9/7/2004	13:04:42		7.69	0.700	47.3	8.03	18.39	0.448	188	50	0.44
Base	9/24/2004	14:52:36		7.73	0.803	105.0	9.01	20.37	0.514	115	40	0.73
Storm	10/8/2004	10:25:12		7.68	0.223	0	7.54	18.33	0.145	204	149	0.94
Storm	10/11/2004	13:56:50		8.12	0.098	81.1	11.27	12.25	0.064	169	178	0.60
Storm	10/14/2004	12:27:46		7.55	0.355	188.0	9.98	12.09	0.231	193	118	1.26
Storm	10/26/2004	12:19:18		7.48	0.200	191.0	8.06	18.64	0.13	195	246	1.11
Base	11/23/2004	14:48:36		7.65	0.726	78.0	13.12	14.05	0.465	161	51	1.68
Storm	11/29/2004	14:03:28		7.67	0.213	133.0	11.98	7.33	0.139	167	214	1.30
Base	12/14/2004	12:48:24		7.78	0.853	42.1	11.14	5.23	0.546	75	25	3.26
Base	12/21/2004	12:53:56		7.78	0.864	45.2	13.74	5.85	0.553	91	18	2.80
Storm	1/4/2005	14:00:16		7.75	0.115	179.0	12.79	6.42	0.075	155	116	0.46
Storm	1/5/2005	12:30:56		7.33	0.326	140.0	12.49	6.84	0.212	163	234	2.63
Base	1/21/2005	13:18:12		7.64	0.904	42.5	12.41	9.67	0.579	161	27	5.52
Base	2/10/2005	13:20:16		7.70	0.901	35.2	15.89	6.69	0.577	182	23	4.01
Base	2/24/2005	11:12:26		7.62	0.801	51.3	13.83	7.25	0.513	159	20	3.09
Base	3/15/2005	11:46:26		7.82	0.937	120.0	16.4	8.58	0.599	138	9	3.11
Base	3/24/2005	15:23:52		7.67	0.785	125.0	12.13	9.07	0.503	189	25	1.79
Base	4/22/2005	11:08:24		7.85	0.942	86.5	12.67	15.23	0.603	93	21	2.15
Base	4/30/2005	8:33:28		7.65	0.754	6.5	10.2	10.24	0.48	159	19	2.47
Base	5/18/2005	12:27:50		7.83	0.968	315.0	11.76	18.24	0.619	64	20	1.64
Base	5/30/2005	11:32:22	.	7.80	0.978	26.0	8.56	19.06	0.626	68	26	1.78
Storm	6/11/2005	13:27:26		7.51	0.411	55.2	7.67	22.7	0.267	117	211	1.99
Base	6/16/2005	10:19:44		7.70	0.688	5.6	8.52	19.11	0.44	248	42	1.84
Base	6/30/2005	12:31:04		7.71	0.929	41.2	10.21	24.8	0.594	75	35	1.21
Base	7/8/2005	10:20:42		7.69	0.999	87.7	4.88	21.78	0.667	79	33	1.20

Note: Stage and discharge from real-time USGS data (Appendix D)

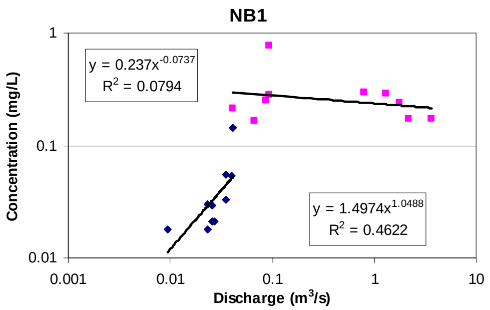
APPENDIX C: Concentration and Load Rating Curves for Sites

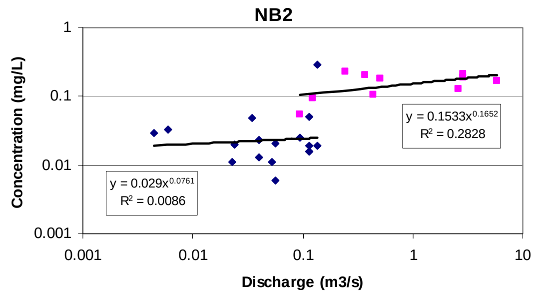
Site Total Phosphorus Concentration Rating Curves.

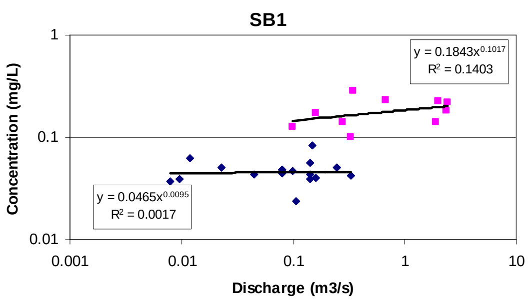
Legend

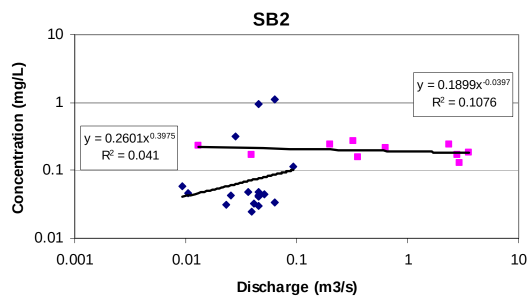
Base

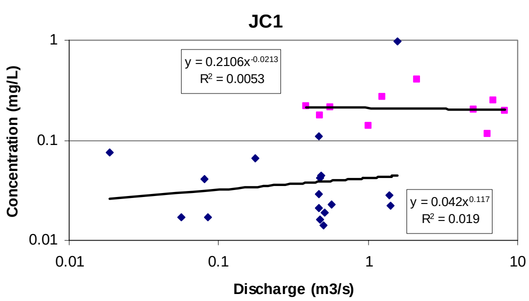
Storm

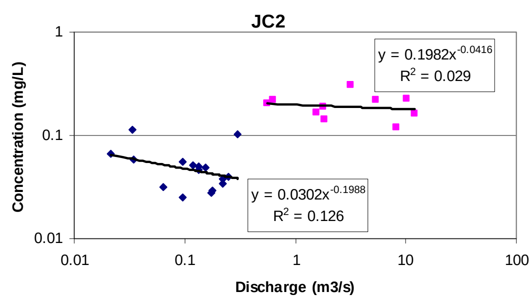










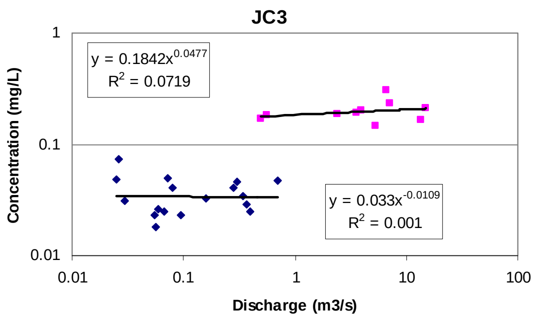


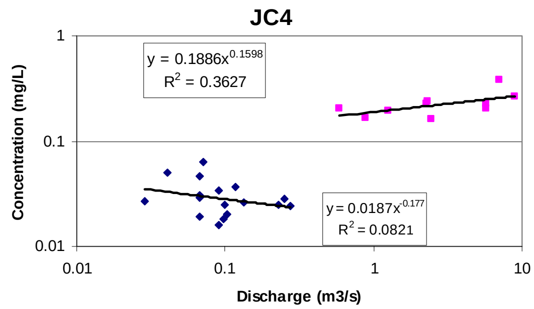
Site Total Phosphorus Concentration Rating Curves (Cont'd).

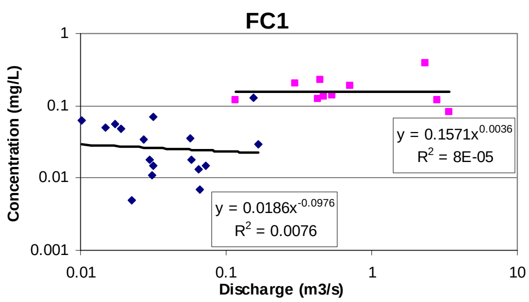
Legend

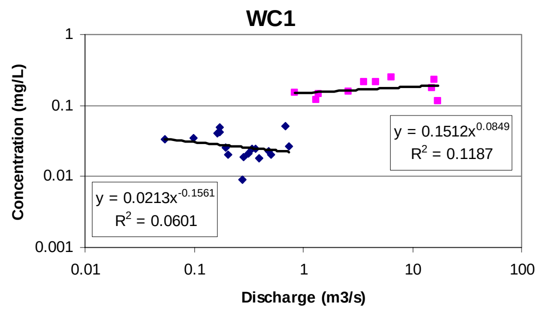
Base

Storm







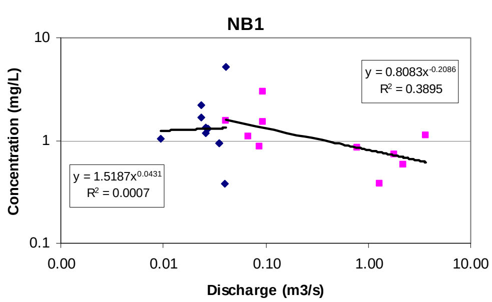


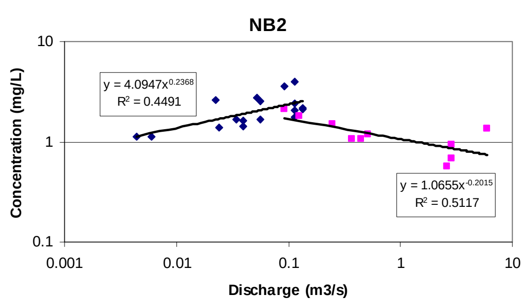
Site Total Nitrogen Concentration Rating Curves.

Legend

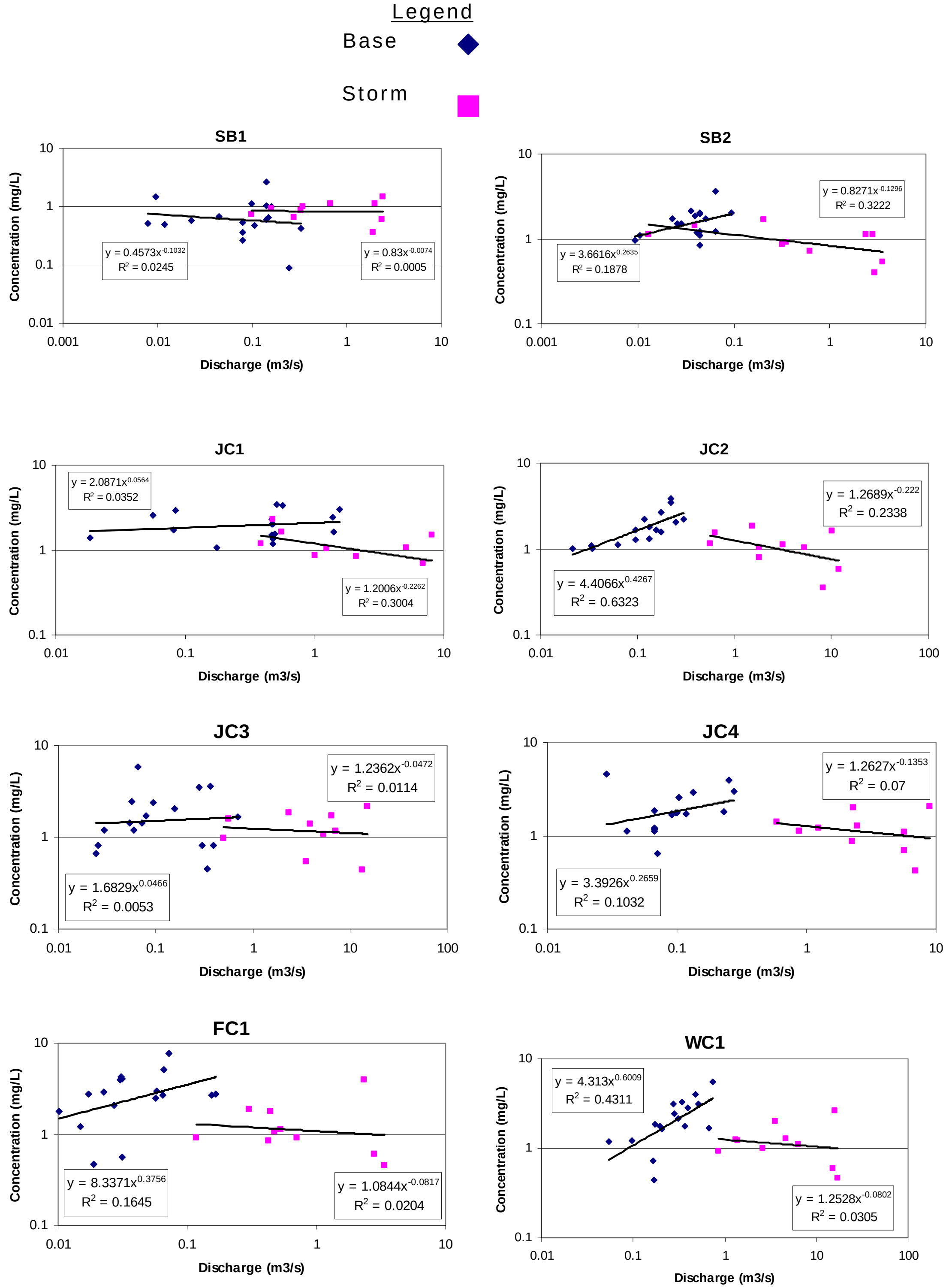
Base

Storm



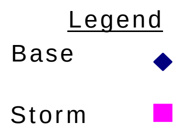


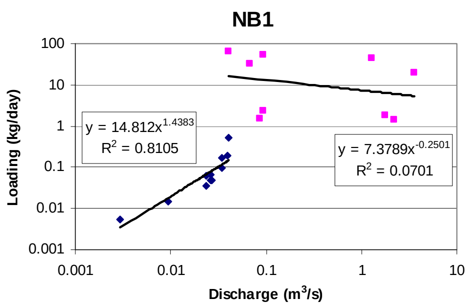
Site Total Nitrogen Concentration Rating Curves (cont'd).

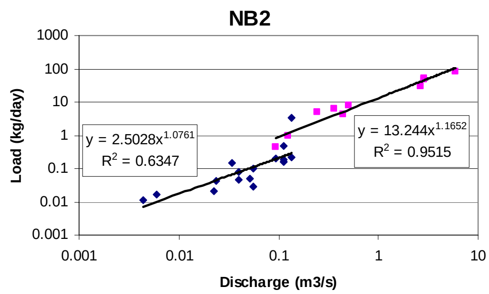


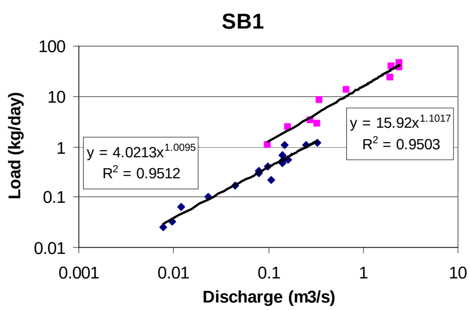
APPENDIX C (Continued)

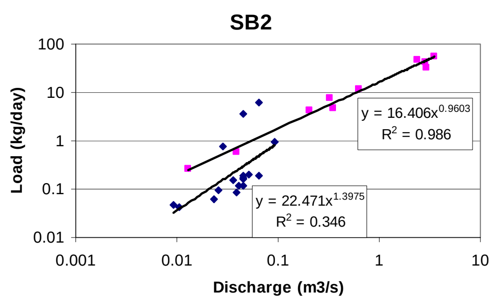
Site Total Phosphorus Load Curves.

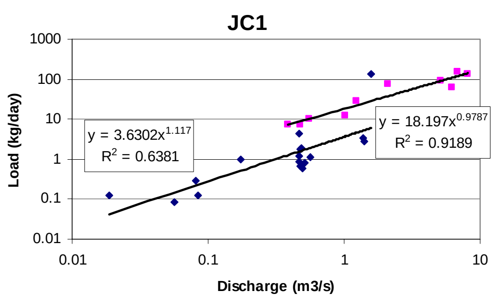


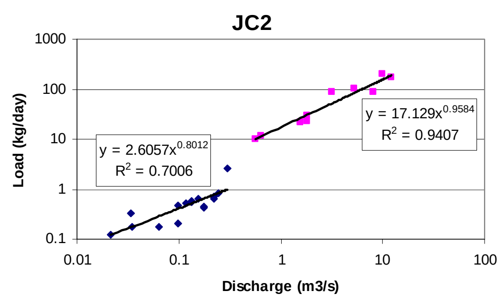


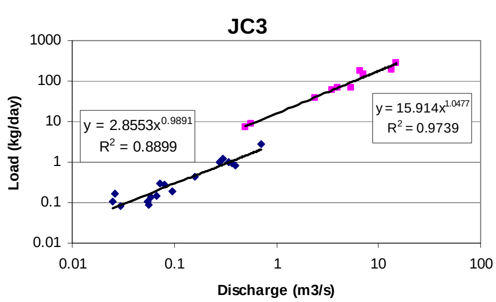


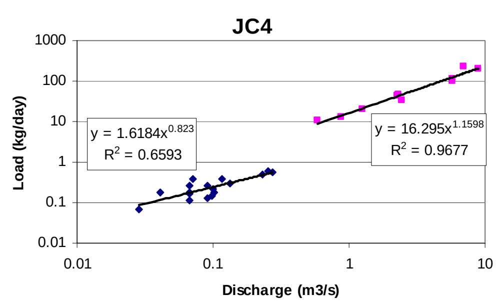








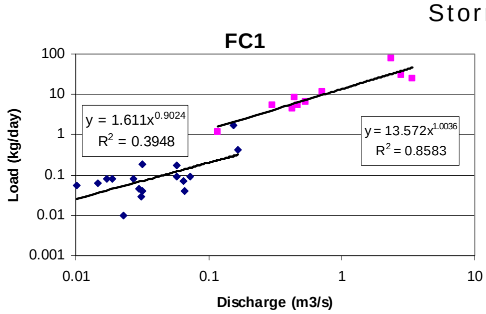


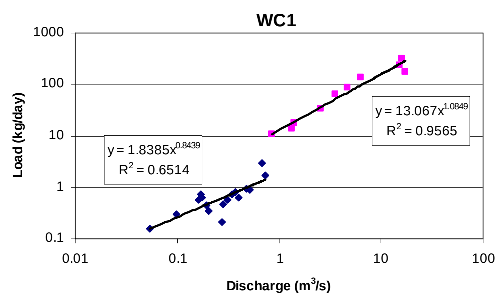


APPENDIX C (Continued)

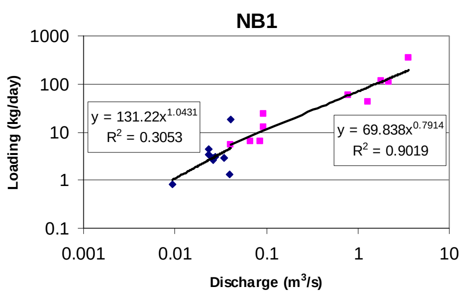
Site Total Phosphorus Load Curves.

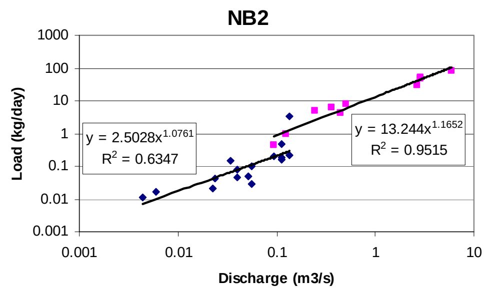
Legend
Base
Storm

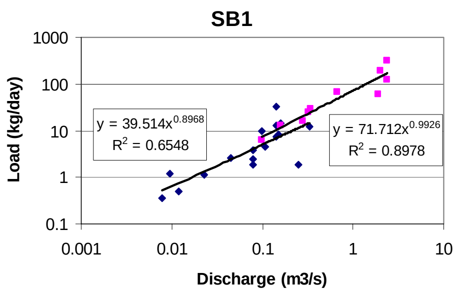


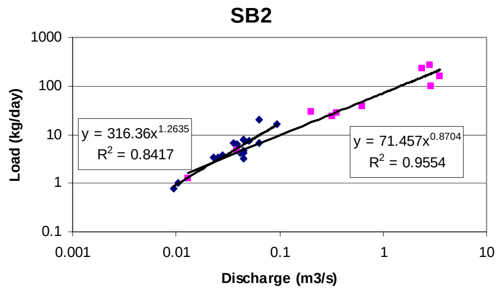


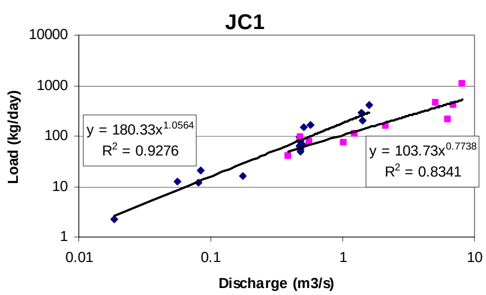
Site Total Nitrogen Load Curves.

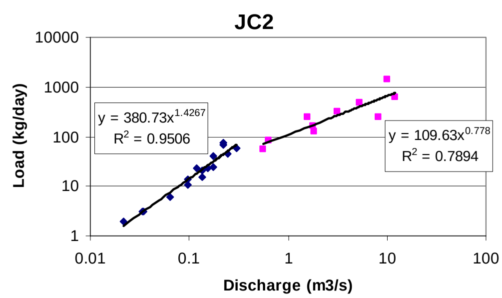






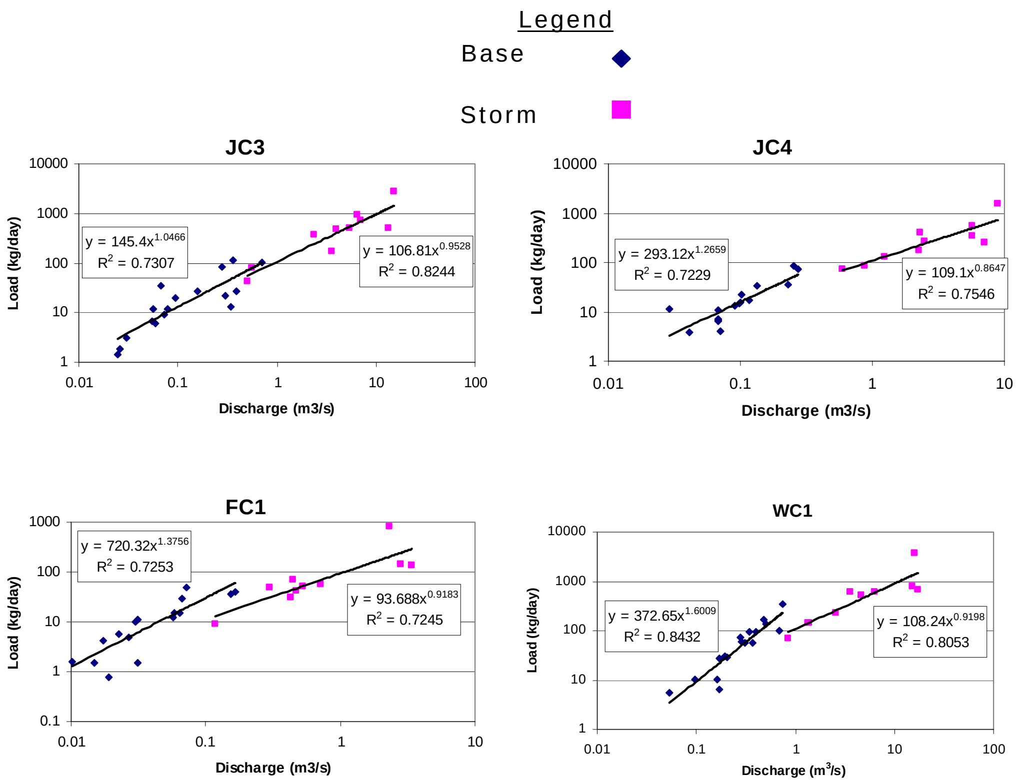






APPENDIX C (Continued)

Site Total Nitrogen Load Curves.

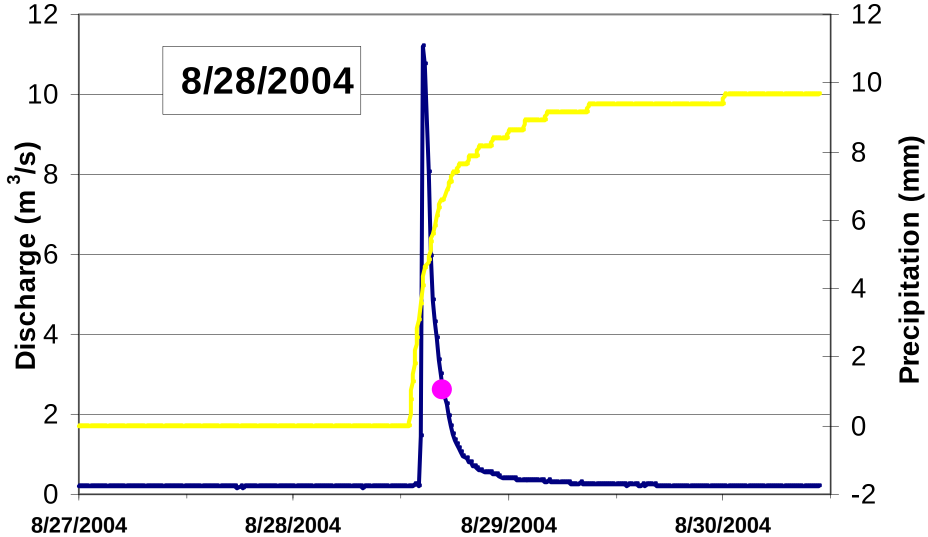


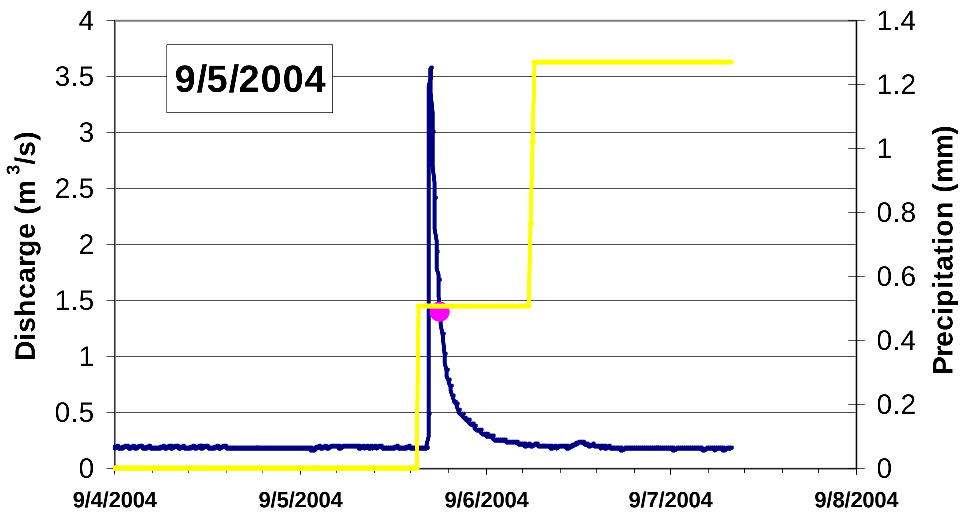
APPENDIX D: Storm Hydrographs, Average Daily Discharge, Peak Daily Discharge

Storm Hydrographs.

Legend

- Hydrograph
- Precipitation
- Sample





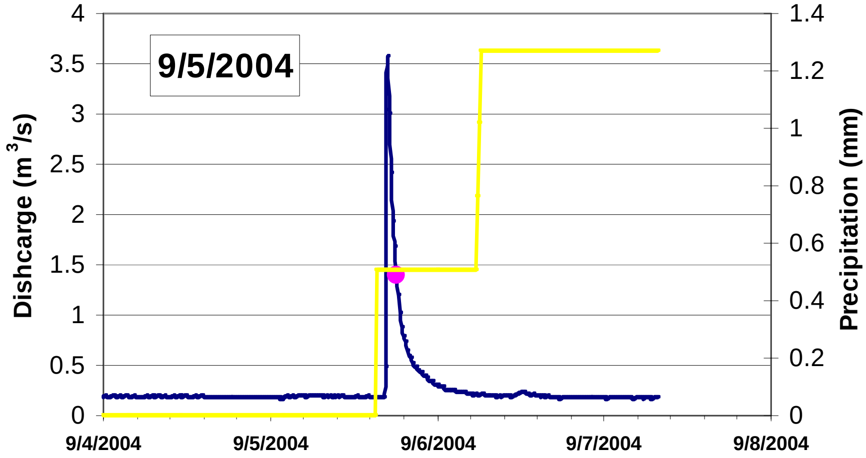
APPENDIX D: Storm Hydrographs (continued)

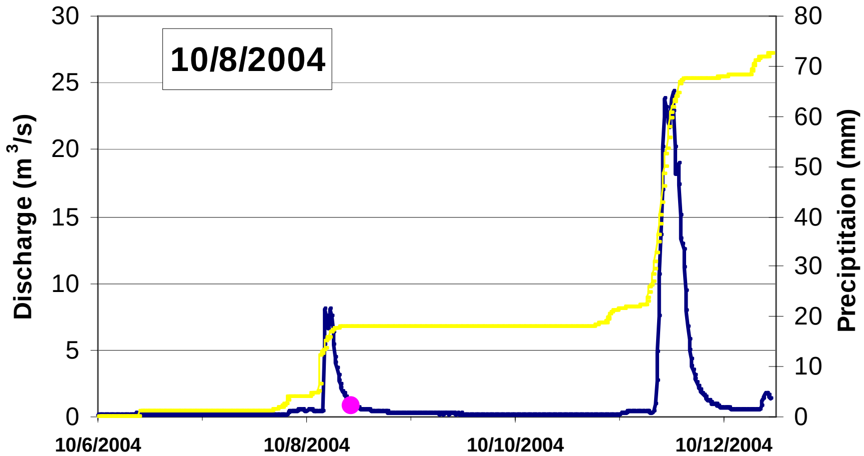
Legend

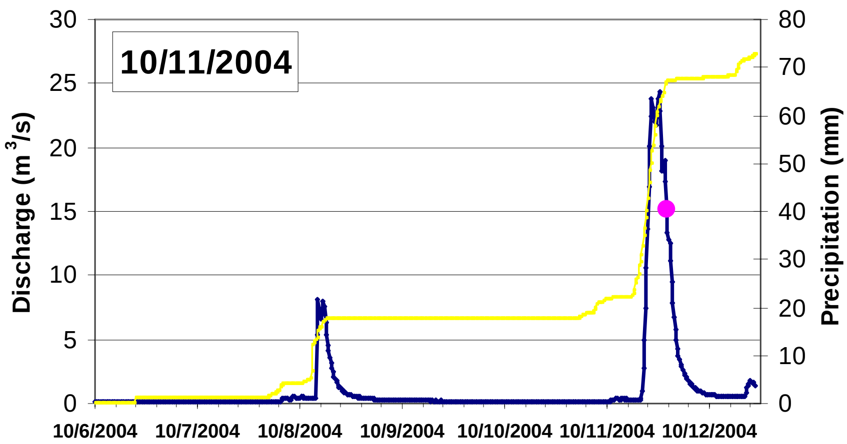
Hydrograph

Precipitation

Sample

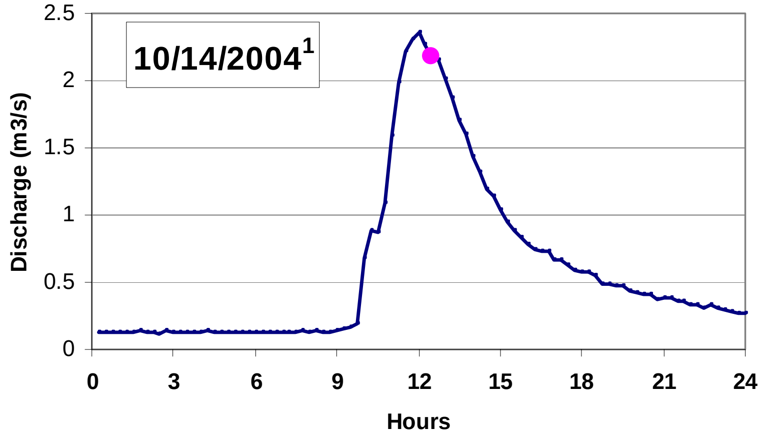


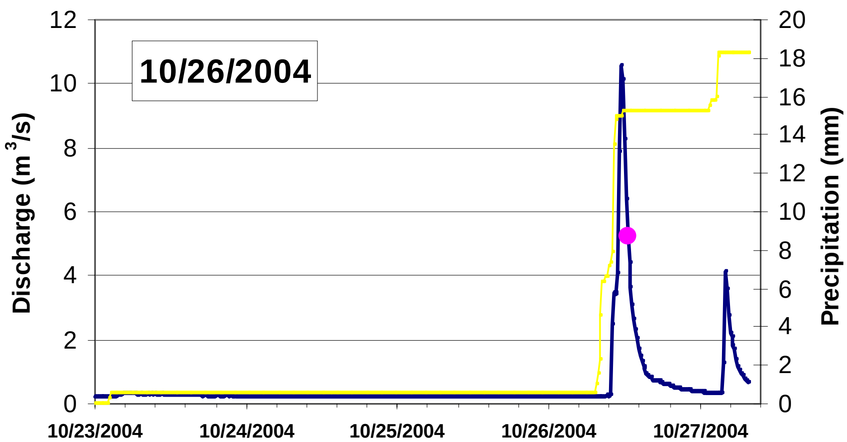


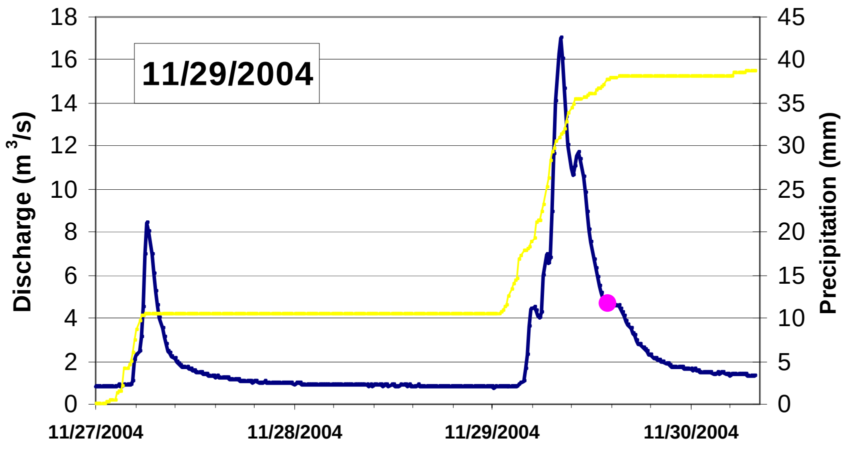


Legend

Hydrograph
Precipitation
Sample





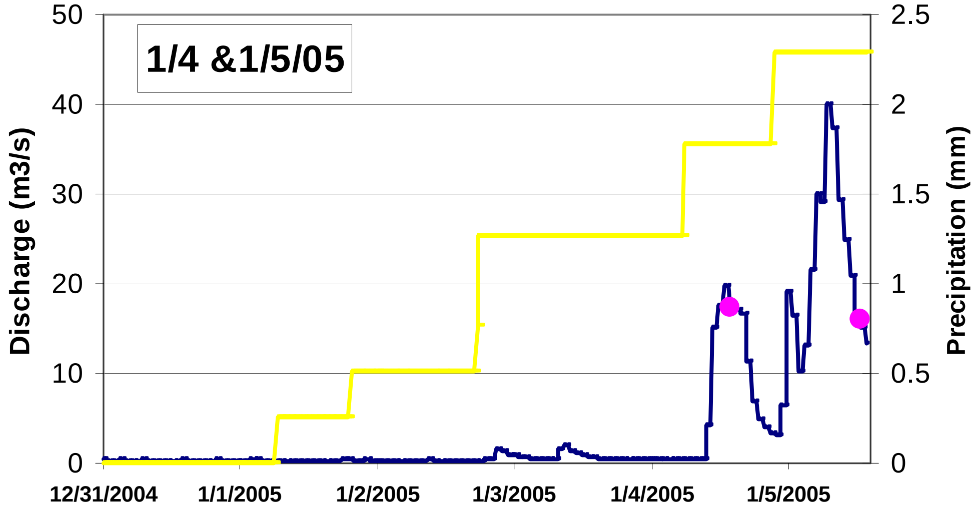


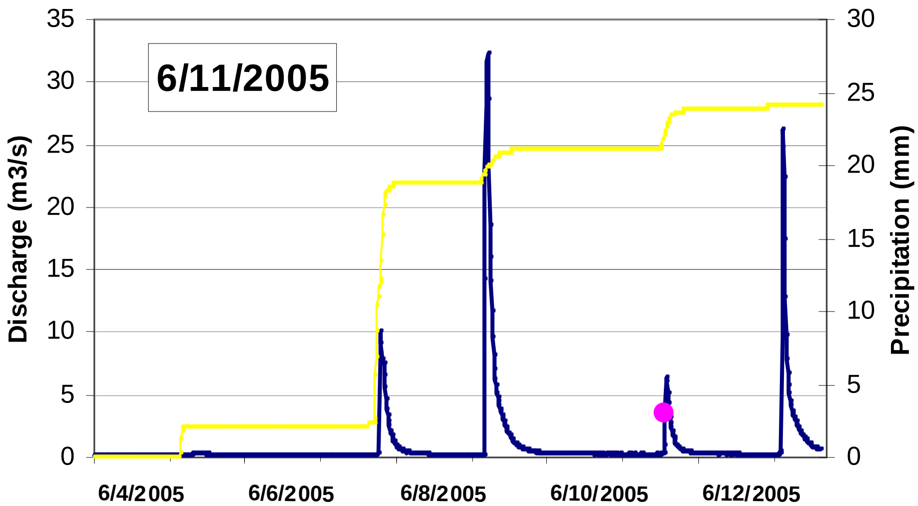
[1]Precipitation not available for this date.

APPENDIX D: Storm Hydrographs (continued)

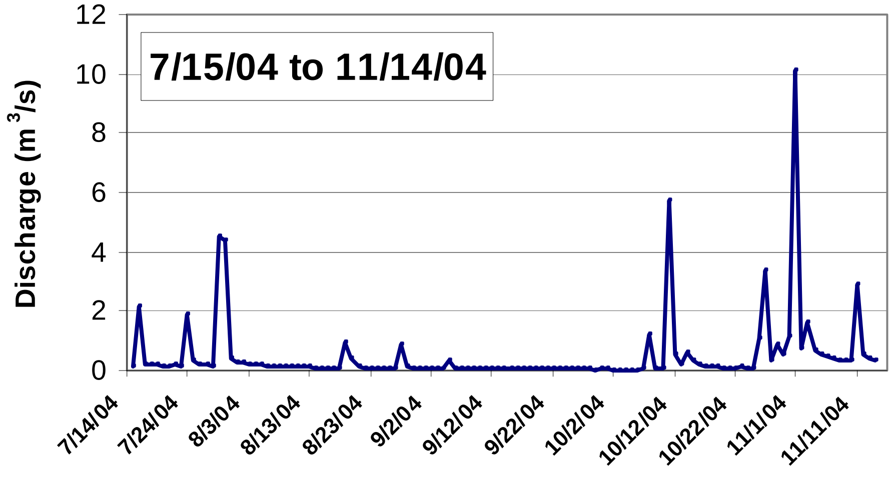
Legend

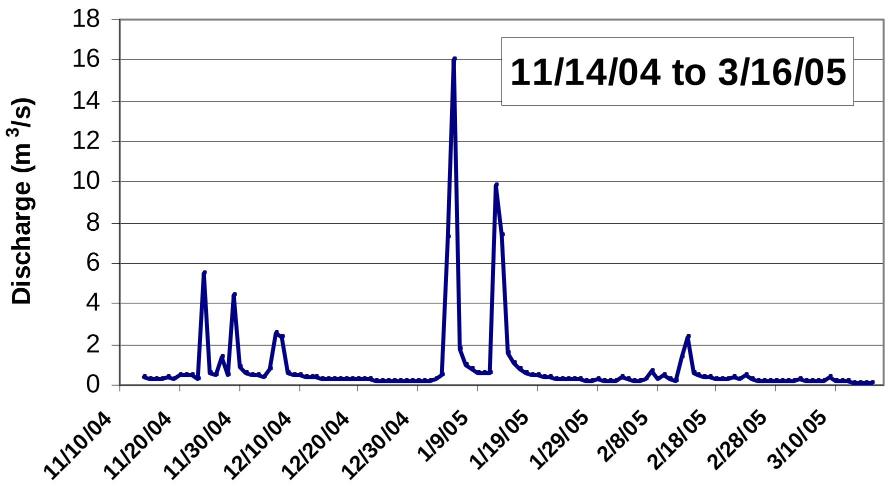
Hydrograph
Precipitation
Sample

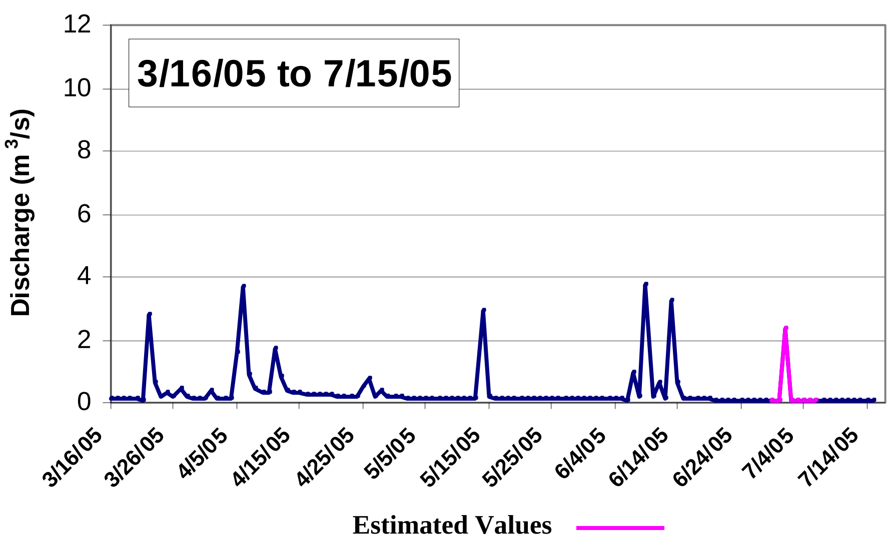




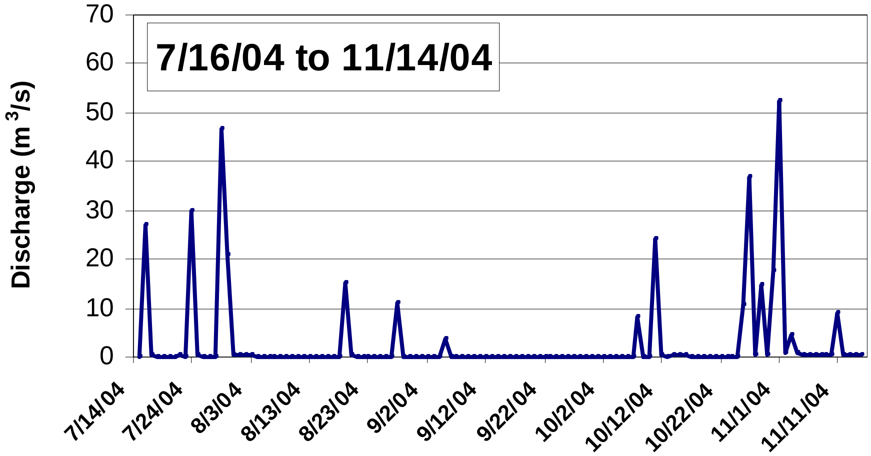
APPENDIX D: Average Daily Discharge (continued)

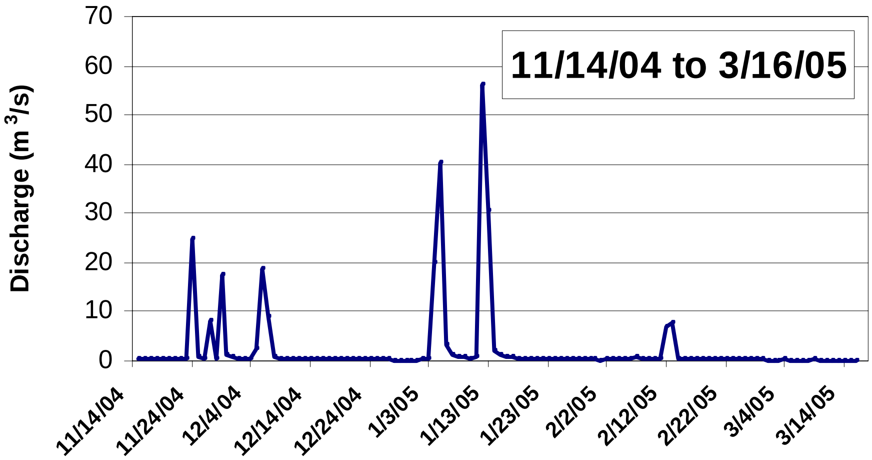


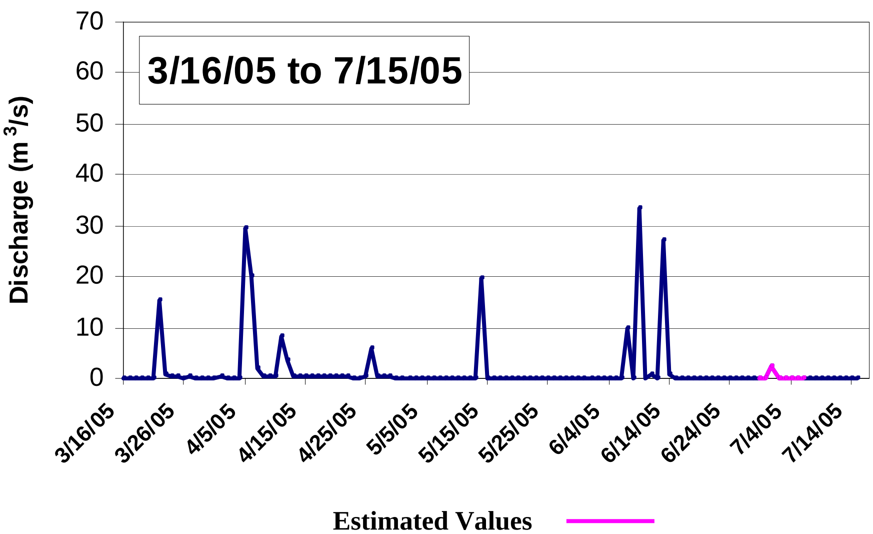




APPENDIX D: Peak Daily Discharge (continued)







APPENDIX E: Landuse Area Tables for Subwatersheds

Cell values are: area in hectares (percent total area)

	NB1	NB2	SB1	SB2	JC1
Roadway	88.9 (12.4)	128.2 (14.9)	187 (15.5)	239.3 (16.7)	434.3 (17.0)
Commercial	297 (41.5)	318.9 (37.1)	403.7 (33.6)	492.1 (34.3)	957.5 (37.5)
Multi-family Res	0.5 (0.1)	6.5 (0.8)	21.7 (1.8)	38.8 (2.7)	54.5 (2.1)
SF High-Density	6.9 (1.0)	10.8 (1.3)	14.7 (1.2)	19.7 (1.4)	37.6 (1.5)
SF Low-Density	158.7 (22.2)	217.9 (25.4)	352.3 (29.3)	409.7 (28.6)	646.4 (25.3)
Forest	107.4 (15.0)	110.7 (12.9)	130.6 (10.9)	139.6 (9.7)	258.9 (10.1)
Grass	13.7 (1.9)	23.6 (2.7)	91.7 (7.6)	92.4 (6.5)	123.6 (4.8)
Pasture	42.1 (5.9)	42.1 (4.9)	1.2 (0.1)	1.2 (0.1)	43.3 (1.7)
Total Area (ha)	715.1	858.8	1202.8	1432.9	2556.2
Total Area (km^2)	7.2	8.6	12.0	14.3	25.6

	JC2	JC3	JC4	FC1	WC1
Roadway	554.9 (18.6)	585 (18.9)	640.4 (19.0)	218.8 (18.0)	721.7 (14.4)
Commercial	1082.1 (36.3)	1133.5 (36.6)	1162.7 (34.5)	313.4 (25.8)	1858.8 (37.1)
Multi-family Res	62.2 (2.1)	62.6 (2.0)	86.8 (2.6)	53.2 (4.4)	145 (2.9)
SF High-Density	46 (1.5)	47.4 (1.5)	60.7 (1.8)	17.9 (1.5)	66.3 (1.3)
SF Low-Density	784 (26.3)	813.3 (26.2)	934.5 (27.7)	532.1 (43.7)	1544.1 (30.8)
Forest	281.8 (9.4)	284.5 (9.2)	305.2 (9.0)	44.3 (3.6)	424.6 (8.5)
Grass	130.1 (4.4)	130.1 (4.2)	140.7 (4.2)	30.9 (2.5)	193.9 (3.9)
Pasture	43.3 (1.4)	43.3 (1.4)	43.3 (1.3)	6.3 (0.5)	61.6 (1.2)
Total Area (ha)	2984.4	3099.7	3374.4	1216.9	5015.9
Total Area (km^2)	29.8	31.0	33.7	12.2	50.2

APPENDIX F: City Modeled Flood Discharges

Notes: 1) All discharges in cubic feet per second (cfs)
2) Top box indicates period of rainfall accumulation
3) Column headers indicates frequency of rainfall event
(i.e. "1" indicates a 1-year recurrence event)

Study Site	City Point Code	2 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	332	472	615	691	827	1070
SB1	SJ37	301	432	584	672	833	1115
SB2	SJ44B	511	691	862	951	1108	1485
NB2	NB57	399	568	744	841	1004	1291
JC1	LJ31	948	1297	1686	1918	2357	3104
JC2	HCLJ15	1437	2005	2553	2854	3375	4389
JC3	HCLJ16	1459	2045	2611	2921	3455	4464
JC4	HCLJ19	1540	2208	2863	3229	3855	4961
FC1	COMB9	900	1223	1511	1653	1912	2346
WC1	COMB13	2313	3183	4057	4568	5408	6874

Study Site	City Point Code	3 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	312	444	584	660	801	1035
SB1	SJ37	266	432	605	693	842	1106
SB2	SJ44B	446	594	799	917	1116	1453
NB2	NB57	375	538	705	792	955	1232
JC1	LJ31	865	1238	1686	1921	2319	2996
JC2	HCLJ15	1309	1803	2365	2677	3215	4155
JC3	HCLJ16	1335	1840	2415	2734	3282	4235
JC4	HCLJ19	1427	2007	2661	3022	3642	4710
FC1	COMB9	822	1095	1348	1477	1696	2067
WC1	COMB13	0	0	0	0	0	0

APPENDIX F CONTINUED

Study Site	City Point Code	6 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	265	383	498	559	668	848
SB1	SJ37	262	401	541	611	734	957
SB2	SJ44B	344	525	714	810	978	1261
NB2	NB57	317	461	598	671	799	1023
JC1	LJ31	743	1116	1479	1670	1998	2562
JC2	HCLJ15	1049	1527	2020	2283	2744	3492
JC3	HCLJ16	1071	1555	2059	2327	2797	3560
JC4	HCLJ19	1161	1704	2263	2560	3085	3939
FC1	COMB9	647	849	1031	1137	1307	1586
WC1	COMB13	0	0	0	0	0	0

Study Site	City Point Code	12 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	260	373	470	519	602	742
SB1	SJ37	270	409	529	593	707	899
SB2	SJ44B	355	534	704	791	934	1180
NB2	NB57	310	444	561	622	726	900
JC1	LJ31	750	1096	1423	1587	1863	2330
JC2	HCLJ15	1021	1491	1932	2152	2518	3127
JC3	HCLJ16	1042	1521	1970	2195	2567	3188
JC4	HCLJ19	1145	1676	2173	2425	2840	3531
FC1	COMB9	447	597	780	881	1060	1354
WC1	COMB13	0	0	0	0	0	0

Study Site	City Point Code	18 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	258	359	446	489	561	682
SB1	SJ37	277	407	519	581	684	892
SB2	SJ44B	358	539	687	762	895	1128
NB2	NB57	307	427	534	587	676	823
JC1	LJ31	744	1078	1362	1506	1751	2164
JC2	HCLJ15	1022	1455	1833	2019	2341	2863
JC3	HCLJ16	1042	1482	1868	2057	2385	2916
JC4	HCLJ19	1148	1633	2062	2273	2637	3225
FC1	COMB9	422	607	785	874	1024	1272
WC1	COMB13	0	0	0	0	0	0

APPENDIX F CONTINUED

Study Site	City Point Code	24 Hour Peak Flows					
		0.5	1	1.5	2	3	5
NB1	HCNB27	227	313	387	423	483	582
SB1	SJ37	240	359	454	504	588	795
SB2	SJ44B	309	472	594	657	765	1015
NB2	NB57	269	372	463	507	580	699
JC1	LJ31	654	942	1180	1297	1498	1893
JC2	HCLJ15	892	1261	1571	1724	1987	2470
JC3	HCLJ16	910	1284	1600	1757	2024	2514
JC4	HCLJ19	1000	1412	1765	1940	2239	2771
FC1	COMB9	367	527	669	741	863	1062
WC1	COMB13	0	0	0	0	0	0

APPENDIX G: USGS Gage 07052000 Flow Frequency Data

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Water Year									**# Days In Class**						
1933-1933							1	14	7	2	30	49	48	63	44
1934-1934									26	91	86	59	40	25	15
1935-1935								1	35	35	35	18	57	41	28
1936-1936							1	12	79	87	98	35	26	11	4
1937-1937									1	1	7	42	75	57	38
1938-1938										47	88	34	41	24	36
1939-1939										18	95	65	43	38	32
1999-1999			12	7	15	20	24	15	31	45	40	29	27	22	19
2000-2000		3	21	24	38	30	40	34	35	18	20	9	15	21	10
2001-2001			7	5	17	14	34	71	47	42	35	13	19	7	9
2002-2002		14	5	5	23	15	21	39	40	42	33	27	22	21	11
2003-2003		8	11	2	2	11	31	41	36	53	46	26	23	20	9
2004-2004			1	3	10	23	26	19	31	61	63	29	36	14	7
ClassSum	0	25	57	46	105	113	178	246	368	542	676	435	472	364	262
RunSum	0	25	82	128	233	346	524	770	1138	1680	2356	2791	3263	3627	3889
ClassValue	0.00	0.81	1.00	1.30	1.60	2.10	2.70	3.40	4.30	5.40	6.90	8.70	11.00	14.00	18.00
Percentage	100.00	99.47	98.27	97.30	95.09	92.71	88.96	83.78	76.03	64.62	50.38	41.22	31.28	23.61	18.09
Accum	4748	4748	4723	4666	4620	4515	4402	4224	3978	3610	3068	2392	1957	1485	1121
Value (cfs)	0	0.81	1	1.3	1.6	2.1	2.7	3.4	4.3	5.4	6.9	8.7	11	14	18

Class	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Water Year									**# Days In Class**							
1933-1933	30	18	19	12	10	4	4	5	2		2	1				
1934-1934	11	5	4	3												
1935-1935	22	22	18	16	16	3	5	3	3	1	2	1	3			
1936-1936	8	2	1	1	1											
1937-1937	35	23	28	20	15	8	5	5	1	1	2		1			
1938-1938	29	22	21	8	5	3	1	2	3		1					
1939-1939	17	14	32	6	2	2	1									
1999-1999	16	12	7	6	3	2	5	4		1	1	1	1			
2000-2000	9	8	4	4	2	6	2	2	6	3	1					
2001-2001	9	6	9	6	4	3	3	2	2					1		
2002-2002	9	4	7	4	5	5	5			5	2					1
2003-2003	9	8	4	4	3	9	2	3	3			1				
2004-2004	9	6	5	4	5	5	2	1	4	2						
ClassSum	213	150	159	94	71	50	35	27	24	13	11	4	5	1	0	1
RunSum	4102	4252	4411	4505	4576	4626	4661	4688	4712	4725	4736	4740	4745	4746	4746	4747
ClassValu	23.00	29.00	36.00	46.00	58.00	74.00	94.00	119.00	151.00	191.00	243.00	308.00	390.00	495.00	628.00	796.00
Percentag	13.61	10.45	7.10	5.12	3.62	2.57	1.83	1.26	0.76	0.48	0.25	0.17	0.06	0.04	0.04	0.02
Accum	859	646	496	337	243	172	122	87	60	36	23	12	8	3	2	2
Value (cfs	23	29	36	46	58	74	94	119	151	191	243	308	390	495	628	796

APPENDIX G (continued)

Class	32	33	34	35	Total Days
Water Year	**# Days In Class**				
1933-1933					365
1934-1934					365
1935-1935					365
1936-1936					366
1937-1937					365
1938-1938					365
1939-1939					365
1999-1999					365
2000-2000			1		366
2001-2001					365
2002-2002					365
2003-2003					365
2004-2004					366
ClassSum	0	0	1	0	4748
RunSum	4747	4747	4748	4748	
ClassValu	1010.0	1280.0	1620.0	2060.0	
Percentag	0.02	0.02	0.00	0.00	
Accum	1	1	1	0	
Value (cfs	1010	1280	1620	2060	