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CHARACTERIZATION AND POLLUTANT LOADING ESTIMATION FOR HIGHWAY RUNOFF IN OMAHA, NEBRASKA

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Stormwater from roadways could have negative effects on the environment. Typical highway runoff pollutants include heavy metals, petroleum hydrocarbons, gasoline constituents, PAHs (polyaromatic hydrocarbons), oxygen demanding compounds measured as COD (chemical oxygen demand) and BOD (biochemical oxygen demand), and road salts.

The objectives of this research were: characterize the pollutants in roadway runoff and determine the effectiveness of the existing stormwater BMPs at the study site. To accomplish these objectives, eleven rainfall events were sampled from November 2008 through November 2010.

First flush and composite highway runoff samples were analyzed for heavy metals, anions, nutrients, particulates, BOD, COD, VOCs, and SVOCs. In addition to the concentrations, event loads were calculated using the hydrologic information from the study site. The results were compared to the Nebraska standards for water quality to establish which contaminants could have a negative impact in the environment. Additionally, an assessment of the effectiveness of the existing detention basin was completed, using the pollutant loads from the different outlet pipes.

Heavy metals, especially copper and zinc, total suspended solids (TSS), total

dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD) were found to be the primary contaminants from the highway runoff. The current detention basin seems to be somewhat effective to reduce pollutant loads from small rainfall events. However, if pollutant reduction for all type of rainfall events is required, the basin should be modified into an extended detention basin which would provide better removal efficiency.

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Section 1. Introduction

History of Roadway Stormwater Pollution Regulation

Since the early 1970s, an increasing awareness about the environmental impact of storm runoff resulted in the creation of environmental laws, executive orders, and policies that protect water quality. The acts and regulations that include highway runoff are: the National Environmental Policy Act (NEPA), Clean Water Act (CWA), the National Pollution Discharge Elimination System (NPDES), the Nonpoint Source (NPS) Management Programs, The Department of Transportation (DOT) National Transportation Policy, the Federal Highway Administration (FHWA) Environmental Policy Statement (EPS), and the Coastal Zone Reauthorization Amendment (CZRA). For purposes of this study, the CWA and its amendments are more relevant. More information about the other laws and regulations can be found in Appendix A.

The Clean Water Act (CWA) was originally called the Federal Water Pollution Control Act (FWPCA) of 1948. This law consisted of a regulatory system of water quality standards applicable to navigable waters. In 1972, the FWPCA included a system of standards, permits, and goals for fishable and swimmable waters to be achieved by 1983, and the total elimination of pollutant discharges into navigable waters by 1985. With the 1977 amendments, the name was changed to the Clean Water Act. The general purpose of this act was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Clean Water Act, 1977a), declaring unlawful the unregulated discharge of pollutants into all waters of the United States.

The amended section 402 of the CWA created a permit system, the National Pollutant Discharge Elimination System (NPDES). These discharge permits could be granted by the

Environmental Protection Agency (EPA) or by EPA through approved state programs. These permits regulate discharges into navigable waters from point sources. According to the CWA, a point source is “any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or floating craft, from which pollutants are or may be discharged" (Clean Water Act, 1977b). The permits require that the permittee comply with discharge limits based on the use of “best technology” and with discharge and monitoring and reporting obligations.

The set of amendments passed in 1987 includes regulation of nonpoint source pollutants. According to these amendments, States are required to identify water bodies where water quality standards cannot be met without control of nonpoint source pollutants and to establish management programs for these water bodies. The plans need to include Best Management Practices (BMPs) for categories of sources, schedules of implementation milestones, and appropriate regulatory measures. Additionally, in Section 319 of the CWA, EPA is authorized to issue grants to States to help in the implementation of management programs that have been approved. Under these amendments, highway construction and operation was included as a source of pollution due to the accumulation of pollutants on the surface from oil, tires, dust, grease and other materials. These compounds may be washed into receiving waters during rain events. As a result, activities related with the construction, operation, and maintenance of roads and roadways need to be controlled and regulated by State regulations and programs related to nonpoint source pollution.

Section 319 of the Clean Water Act also established the Nonpoint Source (NPS) Program. Congress chose not to address nonpoint sources through a regulatory approach, instead under Section 319, a Federal grant program was created to provide money to States, Tribes and Territories for the development and implementation of NPS management programs.

Stormwater from roadways can contain several chemicals that could potentially have negative effects on the environment (FHWA and USGS, 2005). Therefore, several states have conducted studies to determine the contaminants and the potential impact that these pollutants may caused to the environment.

Section 2. Objectives and Scope

2.1 Objectives

The objectives of this project are to determine water quality of runoff from a selected Nebraska high-use roadway, evaluate the potential for existing stormwater BMPs to remove pollutants from stormwater from roadways, and improve the guidelines of roadside stormwater BMPs for pollutant removal. This thesis covers the first two objectives of the project, and the remaining objective will be undertaken in a second stage of the project.

2.2 Scope

In order to accomplish these objectives, stormwater samples were collected in an existing detention basin located next to a high-traffic roadway. This detention basin receives water from a construction debris lot, two outlet pipes, and a grass section next to the roadway shoulder, and discharges the water to a nearby stream through an outlet pipe at the east end of the basin.

Concentrations from the roadway outlet pipes were compared to the basin outlet pipe to determine if concentrations were reduced when the stormwater pass though the detention basin. Loads for all the sampling sites were calculated using the hydrologic information obtained from the HEC-HMS model created for the project. The total pollutant loads deposited into the stream by the roadway were determined by subtracting the construction debris lot loads from the basin outlet pipe. Additionally, concentrations and loads were compared against factors affecting highway runoff (e.g., total suspended solids concentrations, antecedent dry period, volume of runoff, and total rainfall) to determine if correlations exist.

This thesis is divided into seven sections and four appendices. Section 1 is an introduction to roadway stormwater pollution. Section 2 explains the purpose and scope of the project. Section 3 provides technical background on the topics covered in this thesis. Section 4 discusses the methods used in the project. Section 5 summarizes the results obtained. Section 6 contains the discussion of results. Section 7 contains the conclusions from this project.

Section 3. Literature Review

3.1 Typical Contaminants from Roadways

As part of the urbanization process, highways have become a potential source for an extensive variety of contaminants to surface and subsurface waters (Gupta et al., 1981, Barret et al., 1995; Chui et al., 1982; Mitton and Payne., 1997).

3.1.1 Roadway Contaminant Sources

Sources of highway runoff pollutants can be classified into three different categories: a) vehicle traffic, b) snowmelt and ice-melt containing deicing chemicals, and c) chemicals used to manage roadside vegetation (U.S Environmental Protection Agency [EPA], 2005). Young et al. (1995) reported the major sources of pollutants on highways are vehicles, dustfall, and precipitation. Table 3-1 shows the major highway pollutant constituents and their sources (Kobriger, 1984)

Table 3-1: Primary Contaminants and their Major Sources in Highway Runoff

Constituent	Primary Source
Particulates	Pavement wear, vehicles, atmosphere, maintenance, snow/ice abrasives, sediment disturbance.
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer use, sediments.
Lead	Leaded gasoline, tire wear, lubricating oil and grease, bearing wear, atmospheric fallout.
Zinc	Tire wear, motor oil, grease.
Iron	Auto body rust, steel highway structures, engine parts.
Copper	Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use.
Cadmium	Tire wear, insecticide application.
Chromium	Metal plating, engine parts, brake lining wear.
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving.
Manganese	Engine parts.
Bromide	Exhaust.
Cyanide	Anticake compound used to keep deicing salt granular.
Sodium, Calcium	Deicing salts, grease.
Chloride	Deicing salts.
Sulphate	Roadway beds, fuel, deicing salts.
Petroleum	Spills, leaks, blow-by-motor lubricants, antifreeze, hydraulic fluids, asphalt surface leachate.
PCBs, pesticides	Spraying of highway right of way, atmospheric deposition, PCB catalyst in synthetic tires.
Pathogenic bacteria	Soil litter, bird droppings, truck hauling livestock/stockyard waste.
Rubber	Tire wear
Asbestos*	Clutch and brake lining wear.

*No mineral asbestos has been identified in runoff; however, some break-down products of asbestos have been measured.

3.1.2 Factors Affecting Highway Pollutants

Authors of different studies agree that runoff characteristics and pollutant accumulation are site-specific and are affected by several variables. Some of the factors affecting the pollutant accumulation (Gupta et al. 1981; Thiem et al., 1998; East-West, 2000; Chui et al., 1982; Herrera, 2007; EPA, 2005; Barret et al., 1995) are:

- Traffic characteristics (volume, speed, braking);
- Climate conditions (intensity and form of precipitation, wind, temperature);

- Maintenance policies (sweeping, mowing, repair, deicing, herbicides);
- Surrounding land use (residential, commercial, industrial, rural);
- Percent pervious and impervious areas;
- Age and condition of vehicles;
- Anti-litter laws and regulations covering car emissions and delivery trucks;
- Use of special additives in vehicle operation;
- Vegetation types on the highway right-of-way; and
- Accidental spills.

The East-West Gateway Coordinating Council (2000) suggests that a stronger correlation of potential runoff impacts exists with storm characteristics such as the number of dry days preceding the storm event, the intensity of the storm, and the elapsed time of the total storm event. Of these three characteristics, the most critical is storm intensity because many of the pollutants attach themselves to particulate matter (or sediment). The more intense the storm, the greater the movement of particulate matter. Long-duration storms usually reduce the pollutant concentrations due to the increased volume; however, the overall loading of pollutants is greater with these storms than with shorter but more intense storms.

In a study of particulates generated by traffic in Cincinatti (average daily traffic load was 150,000 vehicles), Sansalone and Buchberger (1997) found that 44 to 49 percent of particulates originated from pavement wear, 28 to 31 percent from tire wear, and 15 percent from engine and brake pad wear. The authors also found that 6 percent of particulates were deposited from settleable exhaust and 3 percent from atmospheric deposition.

Several studies (e.g., Gupta et al., 1981; Barret et al., 1995) have found that traffic volume is a factor affecting levels of pollutants in highway runoff. However, Driscoll et al.

(1990) did not find any correlation between Total Suspended Solids (TSS), total solids, Biological Oxygen Demand (BOD), oil and grease, phosphorus, nitrate, Total Kjeldahl Nitrogen (TKN), or heavy metals with traffic density. Another study conducted by Kayhanian et al. (2003) at 83 highway sites in California, concluded that there is not an evident correlation between annual average daily traffic (AADT) and pollutant concentrations. This study found that a more consistent correlation emerged when mean and median concentrations were analyzed with medium and higher range of AADTs for urban highways. In another study, Kerri et al. (1985) also found that there was no statistically significant correlation between pollutant loads and the amount of traffic before the storm. Kerri et al. (1985) state that during dry periods there is a greater adherence of materials to the engine, undercarriage, and wheel walls of vehicles, while during a storm or wet period, there is more splashing and washing of materials from the vehicles. Therefore, they suggest that the number of vehicles during storm (VDS) may be a better predictor for constituent concentrations.

Hoffman et al. (1985) found that concentrations of various pollutants in highway runoff varied within the storm event. That is, suspended solids, petroleum hydrocarbons, lead, cadmium, copper, and iron concentrations were higher during the first flush. Additionally, during this period the most highway litter, such as styrofoam cups, cigarette butts, beverage cans, and fast food wrappers, were present in the runoff. Hoffman et al. (1985) concluded that in general, peaks in pollutant concentrations occur during high flow rates when transport of contaminants is more efficient. However, peak concentrations may occur during lower flow conditions, due to reduced dilution.

Higher concentrations of pollutants are often observed during the first runoff from a storm. This phenomenon is often described as “first-flush” (Barret et al., 1995). According to the Center for Watershed Protection (1994) the first flush contains around 90 percent of the annual stormwater pollutant load; therefore, to treat 90 percent of the annual load, it would be necessary to treat the first half inch of runoff. Recent studies conducted by Chang et al. (1990) reveal that even though the first flush concentration is significantly higher, in many cases the first half inch does not carry most of the storm pollutant load. This study found that for developments with large areas of impervious cover the first half inch of runoff cannot transport as much of the pollutant load that is produced during larger storms. For example, for a development with 90 percent impervious cover, the first half inch of runoff of larger storms removed only about 40 percent of the total storm pollutant load on average.

Season and weather conditions may have a large impact on highway pollutant concentrations. Sansalone (1995) found that urban highway snowbanks can be significant sinks for metal elements and solids generated by traffic and maintenance activities. They also found that metal element concentrations are significantly correlated to solids concentrations in snowmelt. In contrast, metal element concentrations in rainfall events varied depending on the degree to which the metal element was dissolved, the presence of solid fractions, and the hydrology of the event and site. It is believed that physical entrapment and long residence times of metals and suspended solids in close proximity to the snow matrix may be the reason for a stronger correlation for snow washoff events than rainfall-runoff events.

3.2 Sampling Methods for Roadway Pollutants

Studies done on highway runoff have used a variety of sampling methods. Some have used automatic samplers (Gupta et al., 1981; Granato and Smith, 1999; Horner et al., 1979; Desta et al., 2007; Kayhanian et al., 2003; Khan et al., 2006; Sansalone and Buchberger, 1997; Barrett et al., 1998; Wu et al., 1998). Others have used grab sampling methods (Horner et al., 1979; Kayhanian and Stenstrom, 2005; Khan et al., 2006; Hoffman et al., 1985; Shinya et al., 2000; Thiem et al., 1998; Little et al., 1983; Marsalek et al., 1997) and some have used a combination of two or more sampling techniques (Mitton and Payne, 1997; Wu et al., 1998).

Gupta et al. (1981) obtained data on traffic characteristics, highway maintenance, precipitation, air particulate fallout (dustfall), and runoff quantity and quality at numerous sites. The monitoring of storm events was conducted for a minimum 12 month period at each site. Instrument Speciality Company (ISCO) water quality samplers (models 1392 and 1680) were used to sample the storm events. Two ISCO samplers were installed at each site to collect samples at intervals of 5 and 15 minutes. The samplers were installed behind weirs and flumes where a maximum turbulence was experienced during the runoff events. Manual grab samples were required to analyze for oil and grease, pesticides/herbicides, and PCBs because plastic bottles used in the autosamplers may absorb some of these pollutants.

Gupta et al. (1981) recommend that during the first stages of the event, discrete samples should be collected at more frequent intervals. Drainage areas with a high proportion of paved area require sampling frequencies of 2 to 5 minutes during first flushes, and 15 to 30 minutes after that until runoff ends. Drainage areas with a high proportion of unpaved area require sampling frequencies of 5 to 15 minutes during first flushes and 15 to 60 minutes after that.

Granato and Smith (1999) used an automated sampler that took samples immediately downstream of the throat section of a Palmer-Bowles flume in order to take advantage of the mixing action of the flume throat. The automated sampler was triggered by changes in specific conductivity.

Desta et al. (2007) used a full-size portable automatic water quality sampler (ISCO

6712) with 24 glass bottles each with 350 mL capacity. The sampler was programmed to trigger during storm events and collect samples according to the volume of runoff passing the measuring section. The 24 bottles were divided into two parts: Part A (bottles 1-6) and Part B (bottles 7-24). Bottles in Part A were used to account for the first-flush effect sample, approximately 25 percent of the storm, and the last 18 were used in Part B for the rest of the event.

Barrett et al. (1998) used ISCO 3700 automatic samplers. The automatic samplers were programmed to sample based on the volume of runoff passing the sampler. At two sites, the sampler was programmed to draw samples at set volumes of flow. At a third location, the sampler was initially programmed to collect samples on a timed basis, but was later converted to collect flow-weighted composite samples.

Kayhanian and Stenstrom (2005) collected a series of grab samples during storm events. In the first year, five to six grab samples were collected during the first hour and a manually composited sample was collected over the following hours. In the second, third, and fourth years, five grab samples were collected in the first hour, followed by one grab sample per hour until the end of the 8th hour. If the storm lasted beyond the 8th hour, one or two additional grab samples were collected to characterize the tail of the runoff. Samples were collected in 4-L amber glass bottles.

Thiem et al. (1998) used glass and plastic (HDPE) bottles to collect runoff samples. Their major goal was to collect samples in the period immediately after the beginning of the storm. During this initial rainfall period (approximately 30 minutes in duration), samples were taken every five minutes. After this period, the sampling interval time was gradually increased to one sample every 30 minutes.

Shinya et al. (2000) collected runoff samples manually with a clean 20 L plastic bucket. Samples were collected during four different periods during a rainfall event. At the beginning of the storm, samples were collected every five minutes for the first fifteen minutes, and then every fifteen minutes until one hour had elapsed from the beginning of the storm. Then two samples every half an hour were taken. Finally, samples were taken every hour until the end of water runoff or six hours had elapsed from the beginning of the storm.

Hoffman et al. (1985) collected samples manually from the outfall with buckets. A metal bucket was used for hydrocarbons and solids, and a plastic bucket was used for heavy metals analysis. Sampling was started at the beginning of the rainfall event and ended when the drain flow subsided following the end of the storm. Samples were usually collected every 30 minutes or more frequently (every 10 to 15 min) when flow rates were high or rapidly changing.

Little et al. (1983) used the composite sampling system and procedures developed by Clark et al. (1981). This system consisted of a calibrated flow-splitter and collection tanks. The flow-splitters were designed for each sampling site to capture a set proportion of the design storm flow, typically 1 to 2 percent.

Marsalek et al. (1997) used custom-made fluidic devices in the form of a stainless steel flow splitter, formed by a cylinder with closed bottom and 16 openings (D = 12 mm) in the side wall, just above the bottom. Each of the openings conveyed 1/16 of the inflow. Outflow from one of the openings was then directed to a second stage splitter of similar design. Outflows from the remaining 15 openings were discarded.

Wu et al. (1998) used ISCO or American Sigma automatic samplers to collect discrete samples from two of the three study sites. For site III, an elliptical flow divider was installed at the end of the drain pipe to collect composite samples. The divider provides accurate diversion for a fixed fraction of runoff, proportional to the flow rate. Water coming out the divider was collected in a holding of 48 X 47 X 36 in. capacity. The automatic samplers were programmed depending of the runoff event. Each automatic sampler was programmed to collect discrete samples at a preset time increment to ensure the collection of at least 6 to 8 samples. Composite sampling was done by taking a fixed amount of sample at equal flow intervals during a storm.

Khan et al. (2006) collect both grab and composite samples. Grab samples, 4-L each, were collected at 15 minutes intervals during the first hour of runoff and at 1 hour intervals over the next 7 hours. For storms lasting more than 7 hours, additional grab samples were collected to capture the end of the storm. Grab samples were collected by bailing from a freefall of runoff exiting a discharge pipe. An American Sigma model 950 automatic sampler was used for flow-weighted composite samples. The automatic sampler was allowed to run until the end of runoff.

Horner et al. (1979) took three different types of samples where discrete sampling was the most common. For the discrete samples, one-liter portions of highway runoff were collected in plastic bottles. These samples were typically collected every 5-10 minutes during the first hour of a storm, every 15-20 minutes during the second and third hours and every 30-60 minutes thereafter. Composite samples were taken directly from drums after the contents were thoroughly mixed with a stick. Composite sampling was used at the beginning of the storms when runoff began to collect before the technician reached the monitoring station. The third set of samples was collected using an ISCO Model 1680 and a Manning Model 4050 automatic samplers.

Mitton and Payne (1997) collected grab samples (usually at the upstream end of a flume) within 30 minutes of the onset of runoff, or as soon thereafter as possible. Remaining samples were collected using an automatic sampler that held 28 1-liter bottles. The flow-composited samples were collected based on even increments of flow.

As discussed above, different techniques can be used to collect samples. Selection of a specific sampling technique depends on the specific sampling goals for the study. If the study requires analyzing VOCs, automatic samplers cannot be used because VOCs will likely volatilize as a result of agitation during automatic sampler collection (U.S. EPA, 1992). Table 3-2 shows a comparison between manual and automatic sampling techniques.

Table 3-2: Comparison of Manual and Automatic Sampling Techniques*

Sampling Method	Advantages	Disadvantages
Manual grab	• Appropriate for all pollutants • Minimum equipment required	• Labor-intensive • Environment possibly dangerous to field personnel • May be difficult to get personnel and equipment to the storm water outfall within the 30-minute requirement • Possible human error
Manual flow-weighted composites (multiple grabs)	• Appropriate for all pollutants • Minimum equipment required	• Labor-intensive • Environment possibly dangerous to field personnel • Human error may have significant impact on sample representativeness • Requires flow measurements taken during sampling
Automatic grabs	• Minimizes labor requirements • Low risk of human error • Reduced personnel exposure to unsafe conditions • Sampling may be triggered remotely or initiated according to present conditions	• Samples collected for oil and grease may not be representative • Automatic samplers cannot properly collect samples for volatile organic compounds analysis • Costly if numerous sampling sites require the purchase of equipment • Requires equipment installation and maintenance • Requires operator training • May not be appropriate for pH and temperature • May not be appropriate for parameters with short holding times (for example, fecal streptococcus, fecal coliform, chlorine) • Cross-contamination of aliquot if tubing/bottles not washed
Automatic flow-weighted composites	• Minimizes labor requirements • Low risk of human error • Reduced personnel exposure to unsafe conditions • May eliminate the need for manual compositing of aliquots • Sampling may be triggered remotely or initiated according to on-site conditions	• Not acceptable for volatile organic compounds sampling • Costly if numerous sampling sites require the purchase of equipment • Requires equipment installation and maintenance, may malfunction • Requires initial operator training • Requires accurate flow-measurement equipment tied to sampler • Cross-contamination of aliquot if tubing/bottles not washed

*(Adapted from U.S. EPA 1992).

3.3 Flow Monitoring

Gupta et al. (1981) indicated that two components are required for the measurement of flow in an open channel:

- A calibrated device inserted in a channel.
- A level sensing instrument which measures the water level upstream of the calibrated device.

In this study, V-notch weirs and Palmer-Bowlus flumes were used as calibrated devices.

Flow measurements are used to develop composite water samples. According to the U.S. EPA (1992), flow rates for storm water discharges are most accurately measured using either primary or secondary flow measurement devices. Primary flow measurement devices are man-made flow control structure which is inserted into an open channel, creating a geometric relationship between the depth of the flow and the rate of the flow. The most common primary flow devices are weirs and flumes. Secondary flow measurement devices are automated forms of flow rate and volume measurement. Usually, a secondary device is used in conjunction with a primary device to automatically measure the flow depth or head. Some secondary devices are floats, ultrasonic transducers, pressure transducers, and bubblers.

It is also possible to estimate the flow rates using float methods, bucket and stopwatch, slope and depth, and runoff coefficient. These methods are not as accurate as the primary and secondary devices, but are appropriate for sites where primary or secondary devices are not practical or economically feasible. A full description of these methods can be found in U.S. EPA (1992).

Flow rates have been monitored using several devices or structures. Hoffman et al. (1985) used a Marsh-McBirney portable flow meter mounted on the drain headwall to monitor the flow velocities. A scale was painted on the interior of the drain to measure the water height during a rainfall event. Height measurements were taken at the time of sample collection.

Mitton and Payne. (1997) used Parshall flumes with 3-inch or 6-inch throats to measured runoff flow rates. Flumes with 3-inch throats were used to measure runoff flows ranging from 0.03 to 0.89 ft^3/s, and flumes with 6-inch throats were used to measure flows ranging from 0.05 to 2.06 ft^3/s.

Wu et al. (1998) used an automatic sampler to continuously record flow stages that later were converted to flow rates. They also used a potentiometric water-level recorder to measure the level in the holding tank. These measurements were converted to flow rates.

Barrett et al. (1998) measured water-levels using bubble flow meters (ISCO 3230). These measurements were later converted into flow rates using a rating curve developed for each study site.

Horner et al. (1979) measured flow rates at least once during the period between samples. Flow rates were determined by measuring the level rise in the water collection drums with a meter stick over an interval timed by a stop watch. Measurement of the cross-sectional area of the drums permitted conversion of the timed level rise to units of volume per unit of time.

Desta et al. (2007) used two types of flow meters to measure flow rates. A bubble module (ISCO 730) was used to measure head over a weir which relates water level to flow rate. An area-velocity module (ISCO 750) was used to measure flow in all piped drainage systems where installation of a weir was not possible due to the risk of causing blockage.

Hallberg and Renman (2008) used two Parshall flumes to measure flows. The first Parshall flume was designed for flows between 1 l/s to 20 l/s, and the second flume was used for flows between 20 l/s and 600 l/s. The flow from 1 l/s to 20 l/s was registered with a Chanflo Open Channel (Danfoss) flowmeter (0 to 0.3 m) with a Sonolev sensor (100 KHz). The flow between 20 l/s to 600 l/s was registered with Chanflo Open Channel (Danfoss) flowmeter (0 to 1 m) with a Sonolev sensor (100 KHz). The data from the flow measurements were collected every 60 s during the runoff event with a Campbell Scientific CR 10X data logger.

Thiem et al. (1998) installed a V-notch weir on a paved waterway where the samples were collected. The depth over the crest was measured with a ruler every time a sample was taken. At other sites, Manning's equation was used to determine the flow in partly full pipes.

3.4 Pollutant Concentrations and Loadings

The pollution discharging from a highway can be characterized in terms of concentration or in terms of loading rates. There are several ways to characterize the pollutant concentration in highway runoff. For example, pollutant concentrations can be reported as the concentrations in discrete sequential samples collected at intervals during a single storm event, or they can be reported as event mean concentrations (EMC) (Driscoll et al. 1990). The EMC is the average pollutant concentration found in the total volume of runoff from a storm event (Driscoll et al., 1990).

Loading rates for a storm are typically calculated by multiplying the EMC times the total volume of runoff during the storm. This method gives the mass of a pollutant discharged per time or per event. In a slightly different way, Wu et al. (1998) reported the long-term average pollutant loading rates (kg/ha-year). To obtain these loads, the site mean loading rates are multiplied by the ratio of average storm duration to the average time between storms.

Shinya et al. (2000) reported initial concentration, EMC, and pollutant load. Initial concentration refers to the concentration in the first runoff water. Pollutant load was calculated using Equation 3-1:

$$Cummulative\ load\ per\ drainage\ area = \frac{1}{A}\int C(t)Q(t)dt \qquad \textbf{(3-1)}$$

Where A is the drainage area, C(t) is the time-variable concentration, Q(t) is the time-variable flow, and t is the time elapsed from the start of the event.

Barrett et al. (1998) reported the EMCs and the annual pollutant loads for three selected sites along the MoPac Expressway in the Austin, Texas area. The annual constituent loads were calculated based on the "simple method" described by Schueler (1987). The "simple method" is used to estimate stormwater runoff pollutant loads for urban areas. This method is based on regression correlations to predict loads based on land use. The information required in this method is the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. Equation 3-2 was used to estimate pollutant loads:

$$L = \left[\frac{(P)(CF)(R_v)}{20.4}\right](C_i) \qquad \textbf{(3-2)}$$

where L is the annual pollutant load in kg/ha, P is the annual precipitation (825 mm/yr), CF is the correction factor that adjusts for storms where no runoff occurs (0.9), R_v is the average runoff coefficient, and C_i is the event mean concentration.

The United States Geological Survey (USGS) developed a set of equations based on regression analyses of data from different sites around the country (Driver and Tasker, 1990). These equations can be used to predict storm-runoff loads and volumes, storm-runoff mean concentrations, and mean seasonal or annual loads.

Section 4. Methods

4.1 Site Selection

The site selected was in Omaha, Nebraska. The site is the property of the Nebraska Department of Roads (NDOR). This location was selected for two main reasons: 1) the site is next to the intersection of two major Interstates in Omaha (I-80 and I-680). In 2006, this intersection was ranked the third busiest intersection in the Omaha metro area (Metropolitan Area Planning Agency [MAPA], 2010); and 2) a detention basin is present to collect runoff from the site and to provide flood protection for the area. This basin might help to reduce some of the pollutant load coming from the highway. The location of the study site is shown on Figure 4-1.

4.2 Site Description

The site is located in the southeast corner of the junction between Intestate I-80 and I-680. The Average Daily Traffic (ADT) on the road section under study is 145,100 vehicles per day (MAPA, 2008). For purposes of this study, the site was subdivided into 6 subbasins. Characteristics of each subbasin are given Table 4-1.

Table 4-1: Characteristics of the Study Site

Subbasin	Area (mi^2)	Cover Type
Subbasin 1	0.00969	Construction debris material
Subbasin 2	0.00287	Grass, pavement
Subbasin 3	0.00143	Pavement
Subbasin 4	0.00125	Grass
Subbasin 5	0.006275	Pavement
Subbasin 6	0.00502	Grass

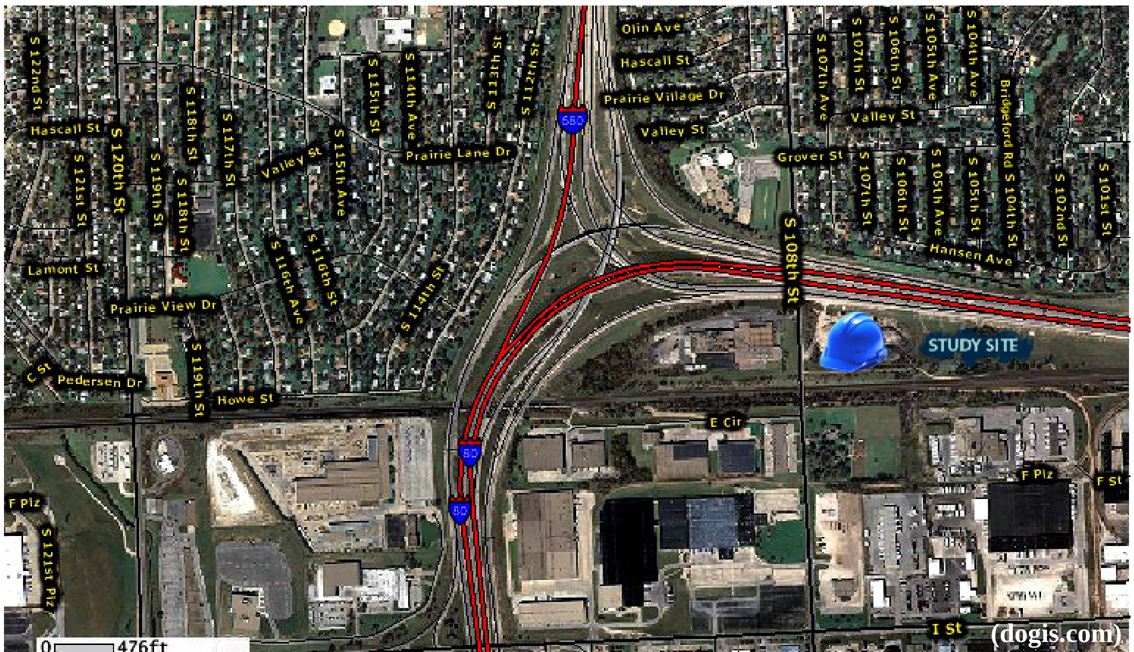

Figure 4-1: Zoom Out to show I-680, I-80, 108th St (Location site)

4.3 Sampling

4.3.1 Sampling Goals

The sampling goals for this project were: obtain first flush and event mean concentration (EMC) for the pollutants found in highway runoff, determine the pollutant loads discharging from the roadway at this site, and evaluate the impacts these contaminants may cause to the receiving waterway. There are five sampling sites (A, B, C, D, and E) shown on Figure 4-2.

Figure 4-2: Study Site. Sub-basins show drainage areas leading to sampling sites A-E

4.3.2 Storm Identification

Since this study required grab samples of the first flush from runoff events, potential runoff-producing storms had to be identified in advance so that preparations for sampling could be made.

To identify potential storms to be sampled, the Weather Channel (Weather, 2009), the National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2009), Accuweather (Accuweather, 2009), and Weather Underground (Weather Underground, 2009) websites were monitored. The main data used to identify the storms were the predicted chance of precipitation and the Doppler weather radar. The sampling team was notified of a possible sampling event if the chance of precipitation approached 70 percent. After the team was notified, the weather was closely monitored to report any change that may affect the sample collection. Storms were targeted for potential sampling if they were predicted to be at least 1-hr long and have a minimum depth of 0.5 in.

4.3.3 Flow Measurement

4.3.3.1 Flow Monitoring

To measure the flow at the site, three different kinds of structures were built and installed. At site A (discharge point from the construction debris lot), a rectangular sharp-crested weir made of 1 in thick treated wood supported by a 2 X 4 (treated wood) frame was constructed and covered by 1/16" plastic (to make impermeable and provide sharp crest). This weir was installed at the east side of the lot where discharge from the lot enters the basin. Figure 4-3 shows the weir being installed at site A. At site B (ditch), a V-notch weir was installed where flow in the ditch discharged to the basin. A 6-in high berm lined with plastic sheeting (i.e., creating a long "sand bag") was built along the fence to direct all flow toward weir and basin. Figure 4-4 shows the V-notch weir installed at site B. For sites A and B, a metallic ruler was used to determine the flow depth at the rectangular and v-notch weir, respectively. Measurements were taken when samples were collected at each site.

Figure 4-3: Rectangular Weir Installed at Site A

For sites C and D (west pipe and east pipe outlets), 8-in wide by 6 ft long rectangular flumes were installed. At site E (basin outlet pipe), a 24-in by 6 ft long rectangular flume was installed (Figure 4-5). In sites C, D, and E, Isco 2150 Area Velocity (AV) Flow Modules and Sensors were installed. At first, the sensors were mounted 2-in above the channel's bottom on a vertical PVC pipe placed at the end of each flume. After the first two sampling events, the pipes were removed because debris was getting trapped in the channel, affecting the sensor readings. From the third storm, sensors were mounted on the bottom of each flume. Flow modules were set to obtain a reading every five minutes. Also, during the first three storms, manual depth and velocity monitoring measurements were taken with a ruler and float to corroborate sensor readings.

Figure 4-4: V-Notch Weir Installed at Site B

Figure 4-5: Rectangular Flume Installed at Site E

The flow at site A, was calculated using the following equation for a rectangular sharp-crested weir with end contractions (U.S. Department of Interior Bureau of Reclamation, 2001).

$$Q = \frac{2}{3} C_d \sqrt{2g} (L - 0.1nH) \left[\left(H + \frac{v_0^2}{2g} \right)^{3/2} - \left(\frac{v_0^2}{2g} \right)^{3/2} \right] \quad \textbf{(4-1)}$$

Where:

C_d = Discharge coefficient, 0.6

g = Gravitational acceleration (32.2 ft/sec^2)

L = Weir length (ft)

n = Number of end contractions

H = Water height above the crest of the weir (ft)

v_0 = Approach velocity (ft/sec)

The weir installed at site A was contracted at both ends; therefore, the value of n was 2. The approach velocity was estimated by using Equation 4-1 iteratively until the discharge (Q) and head (H) in the equation matched.

Methods to estimate the flow in site B have not been applied because there has not been flow in this site during the sampled storms. It was believed that the sampled storms had insufficient intensity to produce measurable runoff at site B (generally high intensity storms were not sampled because of dangerous lightning). However, on July 4, 2010, the sampling team had the chance to sample a high intensity storm that did not produce any lightning. During this storm, it was found that significant amounts of runoff were leaking through the berm at the fence and bypassing site B. As a result, the flow estimates for this site were developed from the HEC-HMS model.

For sites C, D, and E, the flow was measured by the AV flow modules and sensors. The AV sensor has an internal differential pressure transducer that measures the flow depth. The AV sensor has a pair of ultrasonic transducers which measure the average velocity using sound waves and the Doppler Effect. The first transducer sends the ultrasonic wave, and the second transducer receives the wave reflected by bubbles and particles in the stream (Isco, 2005). Using the information obtained by the AV sensor, the AV flow module internally estimates the flow rate in the channels based on the channel dimensions and the sensor's height above the channel bottom.

4.3.3.2 Hydrologic Model

An HEC-HMS model of the site was developed and calibrated using data obtained from 2008 and 2009 storm events. The six sub-basins shown in Figure 4-1 were further divided into eight different sub-basins by splitting sub-basin 1 and sub-basin 5 into two sub-basins each. Table 4-2 shows the identification name and the description of each sub-basin created in the model.

Table 4-2: HEC-HMS Subbasins

Identification Name	Description
Subbasin 1A	Hard packed driveway in the construction debris lot.
Subbasin 1B	Construction material piles and soil in the construction debris lot.
Subbasin 2	Area along the fence, interstate shoulder, and some of I-80 Eastbound entrance lane.
Subbasin 3	Tributary area for the west pipe inlet. This area includes the two outside lanes of the I-80 East bound and interstate shoulder.
Subbasin 4	Grass and shoulder area and some pavement from the center lanes that provide runoff directly into the detention basin.
Subbasin 5A	Tributary area for the east pipe inlet. This area includes the two inside lanes of the I-80 Eastbound and the four lanes of the I-80 Westbound.
Subbasin 5B	Tributary area for the East pipe inlet. This area includes a segment of the two outside lanes of the I-80 Westbound and the grass area between I-80 Westbound and the Exit 445 ramp.
Subbasin 6	Detention basin.

The construction debris area and the tributary area of the East pipe were each divided into two sub-areas because these sub-areas exhibit different runoff characteristics. For example, water coming from the hard packed driveway in the construction debris area moves faster compared to water coming from the construction material piles. In a similar way, water coming from the pavement on I-80 moves faster than water coming from the grass strip between I-80 and the Exit 445 ramp.

The HEC-HMS model provided hydrographs of the flows at each sampling point. These flows were used to determine the aliquots to use in the sample compositing process as described below. A full description of the HEC-HMS model and its application is given in Appendix B.

4.3.4 Sample Collection

Samples were collected using grab sampling methods. Nalgene and glass bottles were used to collect samples. Bottles were rinsed twice with the stormwater prior to sample collection. In the construction debris lot, samples were collected downstream of the rectangular weir. For the east and west pipe inlet, samples were collected as close as possible to the pipe outlets, before the water reached the flumes. For the outlet pipe, samples were collected after water flowed through the flume and before it reached the outlet pipe.

Two sets of samples were taken during the first sampling round. The first set of samples captured the first flush, and the second set was used as part of the composite sample. To catch the first flush required the first sampling round to be taken within about 15 minutes after the beginning of the storm. Samples used in the composite were then taken approximately every 20 minutes from the beginning of the storm. Table 4-3 summarizes the date each sample was taken, type of bottles used, and sample preservation.

Table 4-3: Type of Bottles and Preservatives Used for Each Sampling Event

Date	Analytes	Type of Bottle Used	Preservative
11/10/2008	Metals, COD, BOD, TP, SP, TS, TSS,TDS, TVS, VSS, VDS, VOCs, PAH, F^-, Br, Cl^-, PO_4P, SO_4^{2-}, HCO_3^-, NO_3^{-2}, NO_2^-, O&G	2-L Nalgene	Ice
5/12/2009	Metals, COD, BOD, TP, SP, TS, TSS,TDS, TVS, VSS, VDS, VOCs, PAH, F^-, Br, Cl^-, PO_4P, SO_4^{2-}, HCO_3^-, NO_3^{-2}, NO_2^-, O&G	2-L Nalgene	Ice
6/1/2009	Metals, COD, BOD, TP, SP, TS, TSS,TDS, TVS, VSS, VDS, VOCs, PAH, F^-, Br, Cl^-, PO_4P, SO_4^{2-}, HCO_3^-, NO_3^{-2}, NO_2^-, O&G	2-L Nalgene	Ice
7/3/2009	Metals, COD, BOD, TP, SP, TS, TSS,TDS, TVS, VSS, VDS, PAH, F^-, Br, Cl^-, PO_4P, SO_4^{2-}, HCO_3^-,O&G	2-L Nalgene	Ice
	VOCs,	300 mL glass	Ice
7/31/2009	O&G, F^-, Br, Cl^-, PO_4P, SO_4^{2-},Si, HCO_3^-, TP, SP, TS, TSS, TDS, TVS, VSS, VDS, COD	2-L Nalgene	Ice
	PAH	1-L glass	Ice, H_2SO_4
	Heavy metals	500 mL glass	Ice, HNO_3
	TKN, NO_2N, NO_3N	250 mL glass	Ice, H_2SO_4
	VOCs	40 mL vials	Ice, HCL
9/3/2009	O&G, F^-, Br^-, Cl^-, PO_4P, SO_4^{2-},Si, HCO_3^-, TP, SP, TS, TSS, TDS, TVS, VSS, VDS, COD	2-L Nalgene	Ice
	PAH	1-L glass	Ice, H_2SO_4
	Heavy metals	500 mL glass	Ice, HNO_3
	TKN, NO_2N, NO_3N	250 mL glass	Ice, H_2SO_4
	VOCs	40 mL vials	Ice, HCL
3/27/2010 5/7/2010 5/20/2010 7/4/2010 9/13/2010 11/12/2010	Ca, Mg, Na	500 mL Nalgene	Ice, HNO_3
	BOD, TSS, TDS, Cl^-, Diss. Ortho P	1-L Nalgene	Ice
	COD, NO_3, TKN, TP	250 mL Nalgene	Ice, H_2SO_4
	Heavy metals	1-L glass	Ice
	VOCs	40 mL vials	Ice, H_2SO_4
	SVOCs	1-L glass	Ice

4.4 Pollutant Concentration Calculation

4.4.1 Chemical/Biological Analyses

The samples from the first six storms were analyzed by the University of Nebraska – Lincoln Water Sciences Laboratory, and the samples from the remaining six storms were analyzed by Midwest Laboratories. The specific analyte lists from these two labs are slightly different, but the primary analytes of interest were quantified by both labs. A complete list of the analytes and the methods used at each laboratory can be found in Appendix C.

4.4.2 Sample Compositing Method

There are generally two potential methods of sample composting, flow-weighted or time-weighted. In flow-weighted compositing, the time interval between samples is held constant, and the volume of each aliquot in the composited sample is proportional to the flow at the time each sample was taken. In time-weighted sampling, the sampler must monitor the flow through time, calculating the runoff volume at the sampling point during each sampling period. Then, the sampler would collect samples representing equal volumes (i.e., after a preset amount of runoff passes the sampling point).

For this project, the flow-weighted compositing process was used. Samples were taken approximately every 30 minutes. Each sample was assumed to be representative of the time period between half-way to the previous sample and half-way to the next sample. Flow rate data from the HEC-HMS model and time intervals were used to calculate the volume of stormwater for each sampling period. A volume fraction from each sample (i.e., aliquot) was taken such that the aliquot's fraction of the total composite sample was equivalent to that sample's fraction of the total storm volume. That is, if a sample represented 10 percent of the total storm volume, its aliquot would make up 10 percent of the total composite sample volume. Figure 4-6 shows a typical hydrograph used to determine the aliquot for each of the samples taken during this sample storm. .

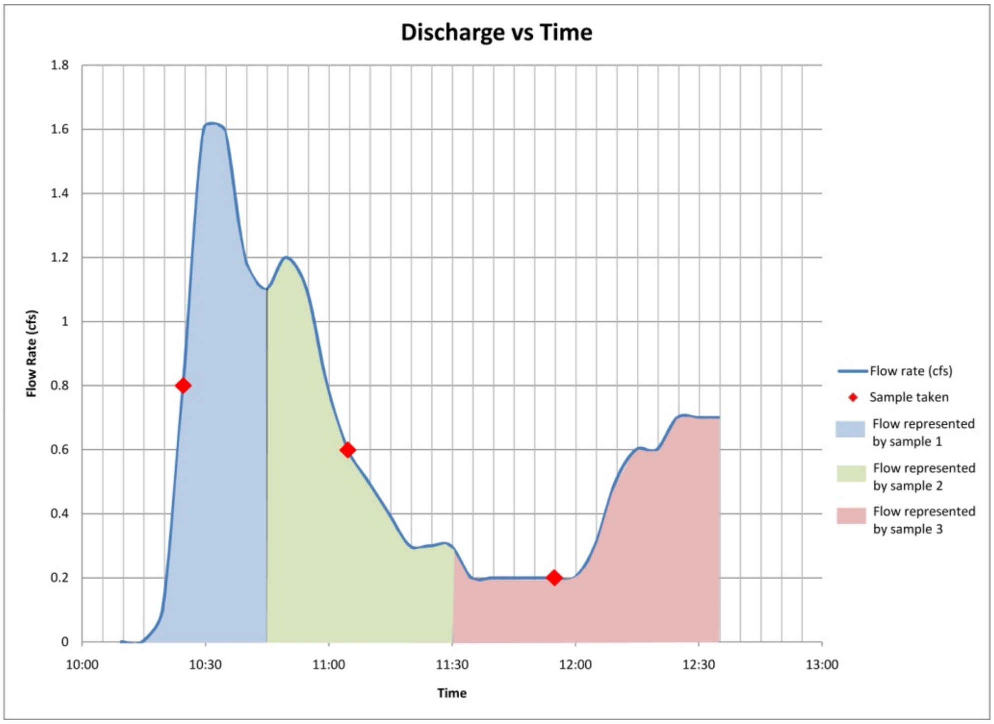

Figure 4-6: Typical Hydrograph Used in the Compositing Process

4.5 Pollutant Load Calculations

4.5.1 Event Pollutant Load Calculations

To determine the event pollutant loads, it is necessary to use the area of each subbasin, the volume of runoff, and the EMC from each individual storm. The volume of runoff can be obtained from the HEC-HMS hydrologic model. Equation 4-2 was used to calculate the pollutant loads.

$$L = C \times V \quad \textbf{(4-2)}$$

Where:

L = event pollutant load (Kg/event)

C = event mean concentration (Kg/m^3)

V = volume of runoff (m^3/event)

4.5.2 Annual Pollutant Load Calculations

To determine the annual pollutant loads, total precipitation for all rainfall events for 2009 and 2010 were collected from the weather station located at the Millard Airport, (located at 2.6 miles southwest from the study site) (Weather Underground, 2010). The volume of runoff for the not-sampled rainfall events were obtained from a rating graph (total precipitation vs. volume of runoff) for the east and west outlet pipes for the sampled events. The volume of runoff from each individual storm was multiplied by the annual (2009 and 2010) mean EMC for the east and west outlet pipe; then, the pollutant loads were summed to obtain the annual pollutant load for each location. Finally, an average between the 2009 and 2010 pollutant loads were calculated for the east and west pipe outlets.

4.6 Efficiency of Existing Detention Basin

Loads from the different subbasins were used to evaluate the efficiency of the detention basin. The construction debris lot, the west and the east outlet pipes are the major pollutant contributors. Pollutants from the construction debris lot are not highway related; therefore, loads should be excluded from the total loads at the detention basin outlet. Once the loads from the construction debris lot are subtracted, the adjusted total pollutant loads are compared to the combined pollutant loads from the east and west pipe outlets. If the pollutant loads at the detention basin outlet are significantly smaller, the detention basin would have some effectiveness in reducing pollutant loads. If the pollutant loads are approximately the same, the detention would not be effective in reducing pollutant loads.

Section 5. Results

5.1 Highway Runoff Rates

5.1.1 Precipitation

Precipitation was measured using an ISCO 6700 rain gauge. Table 5-1 shows a summary of the 2009 and 2010 rainfall events, duration, antecedent dry days, and total rainfall. Antecedent dry days are defined as the number of days since a precipitation event of at least 0.10 inches.

Table 5-1 Summary of Rainfall Events Sampled

Date	Duration (hr)	Antecedent Dry Days	Total Rainfall (in)
November 10, 2008	3.8	1	0.17
May 12, 2009	3	10	0.18
June 1, 2009	2	6	0.03
July 3, 2009	9	7	0.50
July 31, 2009	2.5	10	0.32
September 3, 2009	7	7	5.1
March 27, 2010	3	7	0.14
May 7, 2010	2	4	0.24
May 20, 2010	7	8	0.38
July 4, 2010	2.8	11	1.38
September 13, 2010	1.5	11	0.19
November 12, 2010	2.5	17	0.74

5.2 Highway Runoff Pollutant Concentrations

Analyses to determine the First Flush (FF) and Event Mean Concentrations (EMC) were conducted. The mean and median values for the FF and EMC results for each site across all the storm events are shown in Table 5-2 through Table 5-5. The complete results can be seen in Appendix B.

Table 5-2: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site A for all Sampled Events

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Antimony (total)	(mg/L)	0.0007	0.0007	0.001	0.0008
Arsenic (total)	(mg/L)	0.0063	0.006	0.006	0.0055
Beryllium (total)	(mg/L)	0.001	0.001	0.001	0.001
Cadmium (dissolved)	(mg/L)	0.002	0.002	0.004	0.004
Cadmium (total)	(mg/L)	N.D	N.D	N.D	N.D
Calcium (dissolved)	(mg/L)	91.9	58.6	56.1	13.6
Calcium (total)	(mg/L)	65.6	59.6	53.0	59.6
Chromium (dissolved)	(mg/L)	0.02	0.02	0.01	0.01
Chromium (total)	(mg/L)	0.03	0.03	0.02	0.02
Copper (dissolved)	(mg/L)	0.01	0.01	0.01	0.01
Copper (total)	(mg/L)	0.02	0.02	0.01	0.01
Iron (dissolved)	(mg/L)	0.60	0.02	0.75	0.12
Lead (dissolved)	(mg/L)	0.0	0.00	0.01	0.00
Lead (total)	(mg/L)	0.01	0.01	0.01	0.01
Magnesium (dissolved)	(mg/L)	21.4	7.90	10.1	6.30
Magnesium (total)	(mg/L)	27.2	36.9	21.7	22.3
Mercury (dissolved)	(mg/L)	0.02	0.00	0.01	0.00
Mercury (total)	(mg/L)	N.D	N.D	N.D	N.D
Nickel (dissolved)	(mg/L)	0.01	0.01	0.01	0.01
Nickel (total)	(mg/L)	0.01	0.01	0.01	0.01
Potassium (dissolved)	(mg/L)	32.7	25.4	36.5	21.3
Selenium (total)	(mg/L)	0.0	0.0	0.0	0.00
Silver (total)	(mg/L)	N.D	N.D	N.D	N.D
Sodium (dissolved)	(mg/L)	239.5	252.0	253.4	183.0
Sodium (total)	(mg/L)	258.3	278.0	254.1	295.0
Thallium (total)	(mg/L)	N.D	N.D	N.D	N.D
Zinc (dissolved)	(mg/L)	12.5	0.1	7.5	0.1
Zinc (total)	(mg/L)	0.03	0.03	0.03	0.03
Silica	(mg/L)	19.1	18.9	16.6	14.9

N.D: Non-detected
[a] Total metal concentrations were analyzed for 2010 samples.
[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-2: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site A for all Sampled Events (cont.)

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Bromide	(mg/L)	0.15	0.10	0.21	0.10
Chloride	(mg/L)	315.3	247.0	340.7	328.0
Fluoride	(mg/L)	0.15	0.12	0.17	0.14
Nitrate	(mg/L)	1.10	1.29	1.43	1.36
Nitrite	(mg/L)	0.10	0.10	0.10	0.10
Nitrate/Nitrite Nitrogen	(mg/L)	1.30	1.30	0.90	1.00
Phosphate	(mg/L)	0.10	0.10	0.10	0.10
Sulfate	(mg/L)	142.9	101.2	155.1	170.2
Soluble Phosphate	(mg P/L)	0.19	0.02	0.12	0.03
Phosphorus (dissolved ortho)	(mg/L)	N.D	N.D	0.06	0.06
Total Phosphorus	(mg P/L)	0.17	0.10	0.17	0.15
Total Kjeldahl Nitrogen	(mg/L)	1.81	1.58	1.60	1.61
Total Dissolved Solids	(mg/L)	1030.7	1178.0	1012.5	1212.0
Total Suspended Solids	(mg/L)	748.3	377.0	393.9	223.5
Total Solids	(mg/L)	2544.4	2506.0	1608.8	1422.0
Volatile Dissolved Solids	(mg/L)	160.0	196.0	155.4	110.0
Volatile Suspended Solids	(mg/L)	144.4	136.0	69.4	54.0
Total Volatile Solids	(mg/L)	304.4	338.0	224.8	264.0
Alkalinity as $CaCO_3$	(mg/L)	142.2	137.1	116.5	142.2
Oil and Grease	(mg/L)	25.9	25.9	28.5	28.5
TEH as Diesel	(µg/L)	208.3	155.0	170.0	120.0
BOD	(mg/L)	8.3	7.0	7.5	8.0
COD	(mg/L)	109.5	101.2	97.3	83.6
n-Hexane	(µg/L)	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	(µg/L)	N.D	N.D	N.D	N.D
Benzene	(µg/L)	N.D	N.D	N.D	N.D
Toluene	(µg/L)	N.D	N.D	N.D	N.D
Ethylbenzene	(µg/L)	N.D	N.D	N.D	N.D
Napthalene	(µg/L)	0.114	0.11	0.1	0.1

N.D: Non-detected

Table 5-3: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site C for all Sampled Events

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Antimony (total)	(mg/L)	0.0053	0.0031	0.0051	0.0037
Arsenic (total)	(mg/L)	0.005	0.002	0.005	0.005
Beryllium (total)	(mg/L)	0.001	0.001	0.001	0.001
Cadmium (dissolved)	(mg/L)	0.004	0.004	0.002	0.002
Cadmium (total)	(mg/L)	0.004	0.004	0.003	0.003
Calcium (dissolved)	(mg/L)	24.5	21.6	16.2	15.6
Calcium (total)	(mg/L)	82.4	56.6	77.4	57.7
Chromium (dissolved)	(mg/L)	0.017	0.005	0.014	0.003
Chromium (total)	(mg/L)	0.05	0.03	0.04	0.03
Copper (dissolved)	(mg/L)	10.5	5.9	6.8	5.0
Copper (total)	(mg/L)	0.100	0.060	0.048	0.030
Iron (dissolved)	(mg/L)	0.267	0.071	0.067	0.080
Lead (dissolved)	(mg/L)	0.011	0.001	0.007	0.003
Lead (total)	(mg/L)	0.039	0.018	0.019	0.007
Magnesium (dissolved)	(mg/L)	1.60	1.15	1.05	0.65
Magnesium (total)	(mg/L)	8.77	4.00	5.05	3.20
Mercury (dissolved)	(mg/L)	0.004	0.004	0.004	0.004
Mercury (total)	(mg/L)	N.D	N.D	N.D	N.D
Nickel (dissolved)	(mg/L)	0.012	0.006	0.008	0.004
Nickel (total)	(mg/L)	0.03	0.03	0.03	0.03
Potassium (dissolved)	(mg/L)	32.7	25.4	36.5	21.3
Selenium (total)	(mg/L)	0.001	0.001	0.001	0.001
Silver (total)	(mg/L)	N.D	N.D	N.D	N.D
Sodium (dissolved)	(mg/L)	53.0	56.2	39.0	27.3
Sodium (total)	(mg/L)	120.8	159.0	290.4	103.0
Thallium (total)	(mg/L)	N.D	N.D	N.D	N.D
Zinc (dissolved)	(mg/L)	26.039	3.750	20.879	0.098
Zinc (total)	(mg/L)	0.57	0.29	0.27	0.12
Silica	(mg/L)	4.22	2.51	3.20	2.60

N.D: Non-detected
[a] Total metal concentrations were analyzed for 2010 samples.
[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-3: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site C for all Sampled Events (cont.)

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Bromide	(mg/L)	0.10	0.10	0.10	0.10
Chloride	(mg/L)	105.5	112.2	48.6	21.0
Fluoride	(mg/L)	0.460	0.430	0.342	0.275
Nitrate	(mg/L)	1.00	1.19	0.88	0.90
Nitrite	(mg/L)	0.680	0.000	0.020	0.000
Nitrate/Nitrite Nitrogen	(mg/L)	1.33	0.40	0.90	0.50
Phosphate	(mg/L)	0.64	0.49	0.43	0.35
Sulfate	(mg/L)	47.4	43.7	29.5	18.4
Soluble Phosphate	(mg P/L)	0.150	0.143	0.230	0.120
Phosphorus (dissolved ortho)	(mg/L)	0.107	0.100	0.095	0.090
Total Phosphorus	(mg P/L)	0.82	0.60	0.39	0.27
Total Kjeldahl Nitrogen	(mg/L)	5.02	5.57	2.53	1.64
Total Dissolved Solids	(mg/L)	207.0	106.0	514.3	122.0
Total Suspended Solids	(mg/L)	520.9	321.0	258.6	116.0
Total Solids	(mg/L)	637.3	584.0	379.0	223.0
Volatile Dissolved Solids	(mg/L)	83.3	83.5	37.8	23.0
Volatile Suspended Solids	(mg/L)	117.5	72.0	101.2	52.5
Total Volatile Solids	(mg/L)	157.7	139.0	116.0	94.0
Alkalinity as $CaCO_3$	(mg/L)	80.0	77.9	51.4	51.5
Oil and Grease	(mg/L)	10.4	10.4	14.0	14.0
TEH as Diesel	(μg/L)	963.7	880.0	411.3	455.0
BOD	(mg/L)	32.3	28.0	14.3	12.5
COD	(mg/L)	120.1	82.4	95.6	47.0
n-Hexane	(μg/L)	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	(μg/L)	N.D	N.D	N.D	N.D
Benzene	(μg/L)	N.D	N.D	N.D	N.D
Toluene	(μg/L)	N.D	N.D	N.D	N.D
Ethylbenzene	(μg/L)	N.D	N.D	N.D	N.D
Napthalene	(μg/L)	0.09	0.08	0.0833	0.08

N.D: Non-detected

Table 5-4: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site D for all Sampled Events

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Antimony (total)	(mg/L)	0.005	0.005	0.004	0.003
Arsenic (total)	(mg/L)	0.005	0.005	0.003	0.002
Beryllium (total)	(mg/L)	0.0010	0.0010	0.0010	0.0010
Cadmium (dissolved)	(mg/L)	0.0023	0.0023	0.0022	0.0022
Cadmium (total)	(mg/L)	0.003	0.003	0.003	0.003
Calcium (dissolved)	(mg/L)	22.97	21.65	14.67	15.15
Calcium (total)	(mg/L)	65.6	93.7	47.7	46.5
Chromium (dissolved)	(mg/L)	0.011	0.004	0.011	0.003
Chromium (total)	(mg/L)	0.035	0.035	0.027	0.020
Copper (dissolved)	(mg/L)	0.04	0.02	0.02	0.01
Copper (total)	(mg/L)	0.10	0.06	0.05	0.03
Iron (dissolved)	(mg/L)	0.47	0.01	0.23	0.01
Lead (dissolved)	(mg/L)	0.007	0.002	0.006	0.003
Lead (total)	(mg/L)	0.023	0.014	0.014	0.006
Magnesium (dissolved)	(mg/L)	1.33	1.35	0.92	1.00
Magnesium (total)	(mg/L)	5.27	4.03	3.60	2.16
Mercury (dissolved)	(mg/L)	0.0034	0.0030	0.0033	0.0030
Mercury (total)	(mg/L)	N.D	N.D	N.D	N.D
Nickel (dissolved)	(mg/L)	0.011	0.003	0.007	0.002
Nickel (total)	(mg/L)	0.03	0.03	0.02	0.02
Potassium (dissolved)	(mg/L)	3.6	3.2	1.9	1.6
Selenium (total)	(mg/L)	0.0025	0.0025	N.D	N.D
Silver (total)	(mg/L)	N.D	N.D	N.D	N.D
Sodium (dissolved)	(mg/L)	70.8	59.5	50.4	38.2
Sodium (total)	(mg/L)	172.0	106.0	166.7	128.2
Thallium (total)	(mg/L)	N.D	N.D	N.D	N.D
Zinc (dissolved)	(mg/L)	36.6	1.7	33.5	0.4
Zinc (total)	(mg/L)	0.41	0.30	0.24	0.13
Silica	(mg/L)	4.57	2.09	3.40	2.30

N.D: Non-detected

[a] Total metal concentrations were analyzed for 2010 samples.

[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-4: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site D for all Sampled Events (cont.)

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Bromide	(mg/L)	N.D	N.D	N.D	N.D
Chloride	(mg/L)	162.9	190.0	150.0	109.3
Fluoride	(mg/L)	0.44	0.44	0.29	0.24
Nitrate	(mg/L)	0.4	0.4	0.4	0.4
Nitrite	(mg/L)	1.20	1.20	N.D	N.D
Nitrate/Nitrite Nitrogen	(mg/L)	1.10	0.50	0.97	0.70
Phosphate	(mg/L)	0.42	0.35	0.29	0.23
Sulfate	(mg/L)	30.1	27.3	24.0	9.9
Soluble Phosphate	(mg P/L)	0.090	0.075	0.153	0.086
Phosphorus (dissolved ortho)	(mg/L)	0.107	0.100	0.095	0.090
Total Phosphorus	(mg P/L)	0.28	0.25	0.22	0.18
Total Kjeldahl Nitrogen	(mg/L)	2.63	2.63	1.76	1.18
Total Dissolved Solids	(mg/L)	497.8	328.0	336.6	157.0
Total Suspended Solids	(mg/L)	231.0	197.5	142.5	92.0
Total Solids	(mg/L)	529.0	560.0	432.7	370.0
Volatile Dissolved Solids	(mg/L)	47.2	48.0	60.0	37.0
Volatile Suspended Solids	(mg/L)	68.0	63.0	72.7	66.0
Total Volatile Solids	(mg/L)	103.7	106.0	109.0	101.0
Alkalinity as $CaCO_3$	(mg/L)	58.1	55.8	44.0	39.4
Oil and Grease	(mg/L)	9.7	9.7	9.6	9.6
TEH as Diesel	(µg/L)	610.7	260.0	401.0	420.0
BOD	(mg/L)	19.7	18.0	13.3	11.5
COD	(mg/L)	72.7	29.2	53.5	29.0
n-Hexane	(µg/L)	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	(µg/L)	N.D	N.D	N.D	N.D
Benzene	(µg/L)	N.D	N.D	N.D	N.D
Toluene	(µg/L)	N.D	N.D	N.D	N.D
Ethylbenzene	(µg/L)	N.D	N.D	N.D	N.D
Napthalene	(µg/L)	N.D	N.D	N.D	N.D

N.D: Non-detected

Table 5-5: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site E for all Sampled Events

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Antimony (total)[a]	(mg/L)	0.002	0.002	0.003	0.003
Arsenic (total)[a]	(mg/L)	0.0035	0.0035	0.0028	0.003
Beryllium (total)[a]	(mg/L)	N.D	N.D	N.D	N.D
Cadmium (dissolved)[b]	(mg/L)	0.0010	0.0010	0.0023	0.0023
Cadmium (total)[a]	(mg/L)	N.D	N.D	N.D	N.D
Calcium (dissolved)[b]	(mg/L)	27.70	23.35	24.55	20.95
Calcium (total)[a]	(mg/L)	70.4	85.7	41.4	32.8
Chromium (dissolved)[b]	(mg/L)	0.007	0.003	0.009	0.006
Chromium (total)[a]	(mg/L)	0.020	0.020	0.018	0.020
Copper (dissolved)[b]	(mg/L)	0.01	0.01	0.01	0.01
Copper (total)[a]	(mg/L)	0.02	0.02	0.02	0.03
Iron (dissolved)[b]	(mg/L)	0.04	0.01	0.03	0.01
Lead (dissolved)[b]	(mg/L)	0.003	0.002	0.003	0.003
Lead (total)[a]	(mg/L)	0.007	0.005	0.008	0.007
Magnesium (dissolved)[b]	(mg/L)	3.85	3.15	5.80	3.25
Magnesium (total)[a]	(mg/L)	8.83	7.84	6.56	4.27
Mercury (dissolved)[b]	(mg/L)	0.0032	0.0027	0.0031	0.0027
Mercury (total)[a]	(mg/L)	N.D	N.D	N.D	N.D
Nickel (dissolved)[b]	(mg/L)	0.010	0.010	N.D	N.D
Nickel (total)[a]	(mg/L)	0.00	0.00	0.00	0.00
Potassium (dissolved)[b]	(mg/L)	8.0	6.4	10.2	8.5
Selenium (total)[a]	(mg/L)	0.0020	0.0020	0.0300	0.0300
Silver (total)[a]	(mg/L)	N.D	N.D	N.D	N.D
Sodium (dissolved)[b]	(mg/L)	130.9	114.0	123.6	105.5
Sodium (total)[a]	(mg/L)	343.9	380.0	171.6	128.5
Thallium (total)[a]	(mg/L)	N.D	N.D	N.D	N.D
Zinc (dissolved)[b]	(mg/L)	52.3	10.0	31.3	2.3
Zinc (total)[a]	(mg/L)	0.11	0.07	0.09	0.08
Silica	(mg/L)	7.25	2.34	6.28	4.70

N.D: Non-detected

[a] Total metal concentrations were analyzed for 2010 samples.

[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-5: Arithmetic Mean and Median for First Flush and Event Mean Concentrations for Site E for all Sampled Events (cont.)

Analyte	Unit	First Flush		EMC	
		Mean	Median	Mean	Median
Bromide	(mg/L)	N.D	N.D	N.D	N.D
Chloride	(mg/L)	343.4	242.6	207.0	167.0
Fluoride	(mg/L)	0.39	0.38	0.26	0.22
Nitrate	(mg/L)	0.6	0.7	0.6	0.6
Nitrite	(mg/L)	0.37	0.37	0.37	0.37
Nitrate/Nitrite Nitrogen	(mg/L)	0.73	0.40	0.78	0.50
Phosphate	(mg/L)	0.32	0.38	0.26	0.23
Sulfate	(mg/L)	55.5	36.6	55.2	40.6
Soluble Phosphate	(mg P/L)	0.187	0.069	0.066	0.060
Phosphorus (dissolved ortho)	(mg/L)	0.055	0.055	0.105	0.105
Total Phosphorus	(mg P/L)	0.17	0.15	0.18	0.16
Total Kjeldahl Nitrogen	(mg/L)	1.79	1.77	1.50	1.19
Total Dissolved Solids	(mg/L)	717.8	537.0	516.7	470.0
Total Suspended Solids	(mg/L)	239.4	172.5	248.6	190.0
Total Solids	(mg/L)	871.7	785.0	843.0	825.0
Volatile Dissolved Solids	(mg/L)	59.8	45.0	98.7	52.0
Volatile Suspended Solids	(mg/L)	92.2	84.0	69.2	55.0
Total Volatile Solids	(mg/L)	128.0	97.0	117.0	91.0
Alkalinity as $CaCO_3$	(mg/L)	83.9	88.3	84.3	68.8
Oil and Grease	(mg/L)	11.5	11.5	8.8	8.8
TEH as Diesel	(µg/L)	310.3	200.0	407.8	275.0
BOD	(mg/L)	11.0	11.0	13.8	11.0
COD	(mg/L)	66.8	49.6	69.5	52.3
n-Hexane	(µg/L)	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	(µg/L)	N.D	N.D	N.D	N.D
Benzene	(µg/L)	0.06	0.06	0.06	0.06
Toluene	(µg/L)	0.11	0.1	0.08	0.08
Ethylbenzene	(µg/L)	N.D	N.D	N.D	N.D
Napthalene	(µg/L)	0.105	0.105	0.08	0.08

N.D: Non-detected

5.3 Pollutant loads

The mean and median values for the pollutant loads from the east, west, and basin outlet pipes are shown in Table 5-6 and Table 5-7. Table 5-6 included the pollutant loads for the September 3, 2009 rainfall event. This event was the largest rainfall event sampled in this study; therefore, runoff from subbasin 2 (ditch), subbasin 4 (grass strip), and subbasin 6 (detention basin) contributed to the pollutant loads at the detention basin outlet. Table 5-7 excluded the pollutant loads from this rainfall event. The average annual loads for the east, west, basin outlet pipes are shown in Table 5-8. The complete results can be seen in Appendix D.

Table 5-6: Arithmetic Mean and Median for Pollutant Loads for the West, East, and Basin Outlet Pipes for all Sampled Events

Analyte	Load (Kg/event)					
	West Outlet Pipe		East Outlet Pipe		Basin Outlet Pipe	
	Mean	Median	Mean	Median	Mean	Median
Antimony (total)[a]	3.12E-05	3.24E-05	2.74E-05	3.24E-05	1.25E-04	7.76E-05
Arsenic (total)[a]	3.81E-05	3.81E-05	1.68E-05	1.36E-05	5.62E-04	1.03E-04
Beryllium (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Cadmium (dissolved)[b]	1.62E-05	1.62E-05	2.03E-05	2.03E-05	7.66E-05	7.66E-05
Cadmium (total)[a]	1.84E-05	1.84E-05	1.84E-05	1.84E-05	N.D	N.D
Calcium (dissolved)[b]	1.27	0.306	1.22	0.251	18.3	1.77
Calcium (total)[a]	0.675	0.241	0.35	0.193	5.53	1.72
Chromium (dissolved)[b]	2.07E-04	1.17E-04	2.78E-04	1.21E-04	0.00308	0.00065
Chromium (total)[a]	2.59E-04	3.67E-04	1.73E-04	2.45E-04	0.00280	0.00176
Copper (dissolved)[b]	4.71E-04	2.43E-04	4.84E-04	2.13E-04	0.00370	0.00114
Copper (total)[a]	2.88E-04	2.98E-04	2.28E-04	2.11E-04	0.00293	0.00155
Iron (dissolved)[b]	0.00134	0.0013	0.00671	0.0015	0.017	0.0011
Lead (dissolved)[b]	6.98E-05	2.89E-05	6.66E-05	3.58E-05	7.16E-04	7.66E-05
Lead (total)[a]	1.02E-04	4.76E-05	7.48E-05	4.46E-05	0.00159	4.08E-04
Magnesium (dissolved)[b]	0.0481	0.0112	0.106	0.0122	4.48	0.242
Magnesium (total)[a]	0.033	0.0156	0.0203	0.0123	0.825	0.135
Mercury (dissolved)[b]	N.D	N.D	N.D	N.D	N.D	N.D
Mercury (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)[b]	1.22E-04	1.03E-04	1.48E-04	1.22E-04	0.0016	0.000240
Nickel (total)[a]	1.84E-04	1.84E-04	1.22E-04	1.22E-04	0.0016	0.000240
Potassium (dissolved)[b]	0.153	0.0298	0.147	0.0276	14.8	0.675
Selenium (total)[a]	1.36E-05	1.36E-05	N.D	N.D	0.00228	0.00228
Silver (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)[b]	1.62	0.64	2.39	1.04	94.1	7.54
Sodium (total)[a]	2.85	0.265	1.35	0.228	14.0	5.5
Thallium (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)[b]	0.00159	1.02E-03	0.001374	6.84E-04	0.00714	0.00256
Zinc (total)[a]	0.00157	1.04E-03	0.00143	1.19E-03	0.00915	0.00465
Silica	0.0419	0.0529	0.0531	0.0427	0.347	0.278
Bromide	0.0476	0.0476	N.D	N.D	N.D	N.D
Chloride	3.35	0.417	2.46	1.13	74.0	10.6
Fluoride	0.0193	0.00651	0.0164	0.00727	0.116	0.0203
Nitrate	0.0606	0.0180	0.0313	0.00858	0.590	0.0422
Nitrite	N.D	N.D	N.D	N.D	N.D	N.D
Nitrate/Nitrite Nitrogen	0.01014	0.00306	0.01018	0.00809	0.099	0.075
Phosphate	0.0416	0.0104	0.0323	0.00892	0.254	0.0351
Sulfate	0.856	0.338	0.907	0.329	43.4	3.21
Soluble Phosphate	0.0125	0.0026	0.0109	0.0034	0.034	0.00717
Phosphorus (dissolved ortho)	6.83E-04	5.51E-04	6.34E-04	7.22E-04	0.0515	0.0041
Total Phosphorus	0.00829	0.00356	0.00758	0.00350	0.0471	0.0107
Total Kjeldahl Nitrogen	0.103	0.02	0.0712	0.0150	0.603	0.0731
Total Dissolved Solids	12.5	2.50	5.46	3.06	274	19.2
Total Suspended Solids	7.04	1.28	4.70	1.21	184	7.20
Total Solids	26.1	4.19	17.5	7.16	721	32.1
Volatile Dissolved Solids	2.43	0.82	2.33	0.84	103	39.9
Volatile Suspended	11.4	0.61	6.58	1.45	17.8	3.94

Analyte	Load (Kg/event)					
	West Outlet Pipe		East Outlet Pipe		Basin Outlet Pipe	
	Mean	Median	Mean	Median	Mean	Median
Solids						
Total Volatile Solids	13.4	1.18	8.31	2.30	69.3	5.23
Alkalinity as $CaCO_3$	3.19	0.810	3.43	0.76	61.4	4.98
Oil and Grease	N.D	N.D	N.D	N.D	N.D	N.D
TEH as Diesel	1.21	0.00318	1.10	0.0035	0.0348	0.0522
BOD	0.101	0.0651	0.100	0.07	1.60	0.67
COD	1.13	0.298	0.523	0.41	30.5	2.48
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D
Toluene	N.D	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	N.D	N.D

N.D: Non-detected

[a] Total metal concentrations were analyzed for 2010 samples.

[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-7: Arithmetic Mean and Median for Pollutant Loads for the West, East, and Basin Outlet Pipes for all Sampled Events (excluding 9/03/09 event)

Analyte	Load (Kg/event)					
	West Outlet Pipe		East Outlet Pipe		Basin Outlet Pipe	
	Mean	Median	Mean	Median	Mean	Median
Antimony (total)[a]	3.12E-05	3.24E-05	2.74E-05	3.24E-05	1.25E-04	7.76E-05
Arsenic (total)[a]	3.81E-05	3.81E-05	1.68E-05	1.36E-05	5.62E-04	1.03E-04
Beryllium (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Cadmium (dissolved)[b]	1.62E-05	1.62E-05	2.03E-05	2.03E-05	7.66E-05	7.66E-05
Cadmium (total)[a]	1.84E-05	1.84E-05	1.84E-05	1.84E-05	N.D	N.D
Calcium (dissolved)[b]	0.244	0.258	0.193	0.246	1.66	1.77
Calcium (total)[a]	0.675	0.241	0.354	0.193	4.51	1.72
Chromium (dissolved)[b]	1.48E-04	1.16E-04	1.14E-04	9.32E-05	1.55E-03	6.53E-04
Chromium (total)[a]	2.59E-04	3.67E-04	1.73E-04	2.45E-04	0.00280	0.00176
Copper (dissolved)[b]	2.43E-04	2.02E-04	2.23E-04	2.01E-04	0.00163	0.00114
Copper (total)[a]	2.88E-04	2.98E-04	2.28E-04	2.11E-04	0.00237	0.00155
Iron (dissolved)[b]	8.87E-04	1.02E-03	6.71E-03	8.30E-04	0.0202	0.00109
Lead (dissolved)[b]	6.17E-05	2.02E-05	5.81E-05	3.53E-05	6.28E-04	7.66E-05
Lead (total)[a]	1.02E-04	4.76E-05	7.48E-05	4.46E-05	0.001276	4.08E-04
Magnesium (dissolved)[b]	0.0125	0.00973	0.0137	0.0117	0.329	0.242
Magnesium (total)[a]	0.0332	0.0156	0.0203	0.0123	0.687	0.135
Mercury (dissolved)[b]	7.84E-05	5.42E-05	9.63E-05	8.14E-05	4.33E-04	3.34E-04
Mercury (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)[b]	8.03E-05	2.24E-05	1.14E-04	7.60E-05	5.06E-04	2.40E-04
Nickel (total)[a]	1.84E-04	1.84E-04	1.22E-04	1.22E-04	#DIV/0!	#NUM!
Potassium (dissolved)[b]	0.0251	0.0260	0.0290	0.0267	0.636	0.675
Selenium (total)[a]	1.36E-05	1.36E-05	N.D	N.D	0.00228	0.00228
Silver (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)[b]	0.531	0.506	0.866	0.942	8.24	7.54
Sodium (total)[a]	2.85	0.265	1.35	0.228	11.5	5.53
Thallium (total)[a]	N.D	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)[b]	0.00159	0.00102	0.00137	6.84E-04	0.00722	0.00455
Zinc (total)[a]	0.00157	0.00104	0.00143	0.00119	0.00744	0.00465
Silica	0.0524	0.0555	0.0664	0.0643	0.521	0.456
Bromide	N.D	N.D	N.D	N.D	N.D	N.D
Chloride	3.00	0.407	1.75	0.786	12.2	10.6
Fluoride	0.00633	0.00603	0.00623	0.00638	0.0214	0.0203
Nitrate	0.0141	0.0134	0.00821	0.00755	0.0416	0.0422
Nitrite	N.D	N.D	N.D	N.D	N.D	N.D
Nitrate/Nitrite Nitrogen	0.0101	0.00306	0.0102	0.00809	0.0821	0.0748
Phosphate	0.00785	0.00773	0.00659	0.00746	0.0308	0.0351
Sulfate	0.295	0.313	0.258	0.277	3.94	3.21
Soluble Phosphate	0.00531	0.00185	0.00399	0.00240	0.00783	0.00717
Phosphorus (dissolved ortho)	6.83E-04	5.51E-04	6.34E-04	7.22E-04	0.0347	0.00413
Total Phosphorus	0.00255	0.00303	0.00277	0.00312	0.0357	0.0107

Analyte	Load (Kg/event)					
	West Outlet Pipe		East Outlet Pipe		Basin Outlet Pipe	
	Mean	Median	Mean	Median	Mean	Median
Total Kjeldahl Nitrogen	0.0171	0.0184	0.0167	0.0117	0.162	0.0731
Total Dissolved Solids	6.86	2.17	3.85	2.52	37.9	19.2
Total Suspended Solids	1.58	1.07	0.990	0.759	30.4	7.20
Total Solids	4.02	3.88	7.41	5.94	89.1	32.1
Volatile Dissolved Solids	0.697	0.749	2.33	0.843	21.9	21.9
Volatile Suspended Solids	0.701	0.554	1.08	1.09	3.64	3.94
Total Volatile Solids	1.23	1.12	2.77	1.68	14.6	5.23
Alkalinity as $CaCO_3$	0.726	0.719	0.717	0.681	6.68	4.98
Oil and Grease	N.D	N.D	N.D	N.D	N.D	N.D
TEH as Diesel	1.21	0.00318	1.10	0.00349	1.80	0.0522
BOD	0.101	0.0651	0.0996	0.0683	1.37	0.673
COD	1.13	0.298	0.523	0.409	7.15	2.48
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D
Toluene	N.D	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	N.D	N.D

N.D: Non-detected

[a] Total metal concentrations were analyzed for 2010 samples.

[b] Dissolved metal concentrations were analyzed for 2008 and 2009 samples.

Table 5-8: Annual Pollutant Loads for the West, East, and Basin Outlet Pipes

Analyte	Annual Load (Kg/year)		
	West Outlet Pipe	East Outlet Pipe	Total Pollutant Load
Antimony (total)	0.0091	0.21	0.217
Arsenic (total)	0.010	0.17	0.185
Beryllium (total)	0.0020	0.058	0.060
Cadmium (dissolved)	0.0029	0.16	0.168
Cadmium (total)	0.0060	0.17	0.180
Calcium (dissolved)	19.1	50.1	69.1
Calcium (total)	131	2368	2499
Chromium (dissolved)	0.029	0.77	0.796
Chromium (total)	0.074	1.55	1.62
Copper (dissolved)	0.040	0.92	0.964
Copper (total)	0.085	1.89	1.97
Iron (dissolved)	0.070	0.88	0.953
Lead (dissolved)	0.012	0.27	0.280
Lead (total)	0.032	0.67	0.702
Magnesium (dissolved)	0.90	2.89	3.79
Magnesium (total)	8.55	177	186
Mercury (dissolved)	0.0049	0.012	0.0165
Nickel (dissolved)	0.017	0.59	0.605
Nickel (total)	0.060	1.16	1.22
Potassium (dissolved)	2.99	6.69	9.68
Selenium (total)	0.0020	N.D	0.0020
Sodium (dissolved)	52.3	199	251
Sodium (total)	475	7934	8409
Zinc (dissolved)	0.25	5.97	6.21
Zinc (total)	0.47	11.9	12.3
Silica	3.02	8.26	11.3
Chloride	432	6189	6621
Fluoride	0.38	0.87	1.25
Nitrate	0.85	1.60	2.45
Nitrate/Nitrite Nitrogen	1.85	53.8	55.6
Phosphate	0.57	1.03	1.60
Sulfate	41.5	95.1	137
Soluble Phosphate	0.33	0.58	0.906
Phosphorus (dissolved ortho)	0.20	5.09	5.29
Total Phosphorus	0.44	8.58	9.02
Total Kjeldahl Nitrogen	3.82	51.5	55.3
Total Dissolved Solids	1074	12826	13899
Total Suspended Solids	378	4154	4532
Total Solids	578	1191	1769
Volatile Dissolved Solids	27.4	214	241
Volatile Suspended Solids	147	237	384
Total Volatile Solids	147	349	496
Alkalinity as $CaCO_3$	64.9	157	222
Oil and Grease	18.5	34	52.3
TEH as Diesel	0.826	22.96	23.8
BOD	26.6	721	748
COD	168	2341	2509

N.D: Non-detected

Section 6. Data Analysis and Discussion of Results

6.1 Correlations Between Pollutant Concentrations and Factors Affecting Highway Runoff

Previous studies on highway runoff pollution found that several factors may have an influence on the pollutant concentrations and loads (Hoffman et al., 1985; Kerri et al., 1985; Dricoll et al., 1991). For this study, concentration of total suspended solids, antecedent dry period (ADP), rainfall amount, and volume of runoff were compared against pollutant concentrations and loads to see if they are correlated. Chromium (Cr), copper (Cu), lead (Pb), chloride (Cl^-), and total phosphorus (TP) were selected because these pollutants were present in all the rainfall events sampled.

6.1.1 Pollutant Relationship with Total Suspended Solids

Concentrations and loads for chromium (Cr), copper (Cu), lead (Pb), chloride (Cl^-), and total phosphorus (TP) were compared to the concentration of total suspended solids for each of the sampled events for the west, east, and basin outlet pipes. These comparisons are shown on Figures 6-1 through 6-15. From these figures, it is noticeable that most of the samples have a TSS concentration between 0 to 300 mg/L. Results from the literature showed a high correlation between TSS and the runoff pollutants (Driscoll et al., 1990; Sansalone et al., 1995). A poor linear correlation can be observed for the EMC for heavy metals (Cr, Cu, and Pb) and TP concentrations from the West and East outlet pipes. This correlation is not evident for the Basin outlet pipe, or for Cl^- in any of the pipes.

A strong correlation between TSS and heavy metals was expected because these elements tend to adsorb onto suspended solids. This relationship is important because if the metals are sorbed to suspended solids, treating or removing solids would reduce the concentrations and loads of the pollutants associated with suspended solids. This relationship may not be well observed in this study due to the high variability of TSS concentrations at the east and west pipe outlets.

6.1.2 Pollutant Relationship with Antecedent Dry Period

Concentrations and loads for chromium (Cr), copper (Cu), lead (Pb), chloride (Cl^-), and total phosphorus (TP) were compared to the antecedent dry periods for each of the sampled events for the west, east, and basin outlet pipes. This comparison is shown on Figures 6-16 through 6-30. It was expected that concentrations, especially the first flush concentrations, would be higher for longer ADP; however, the figures do not show not any type of trend. It seems that concentrations are independent from ADP.

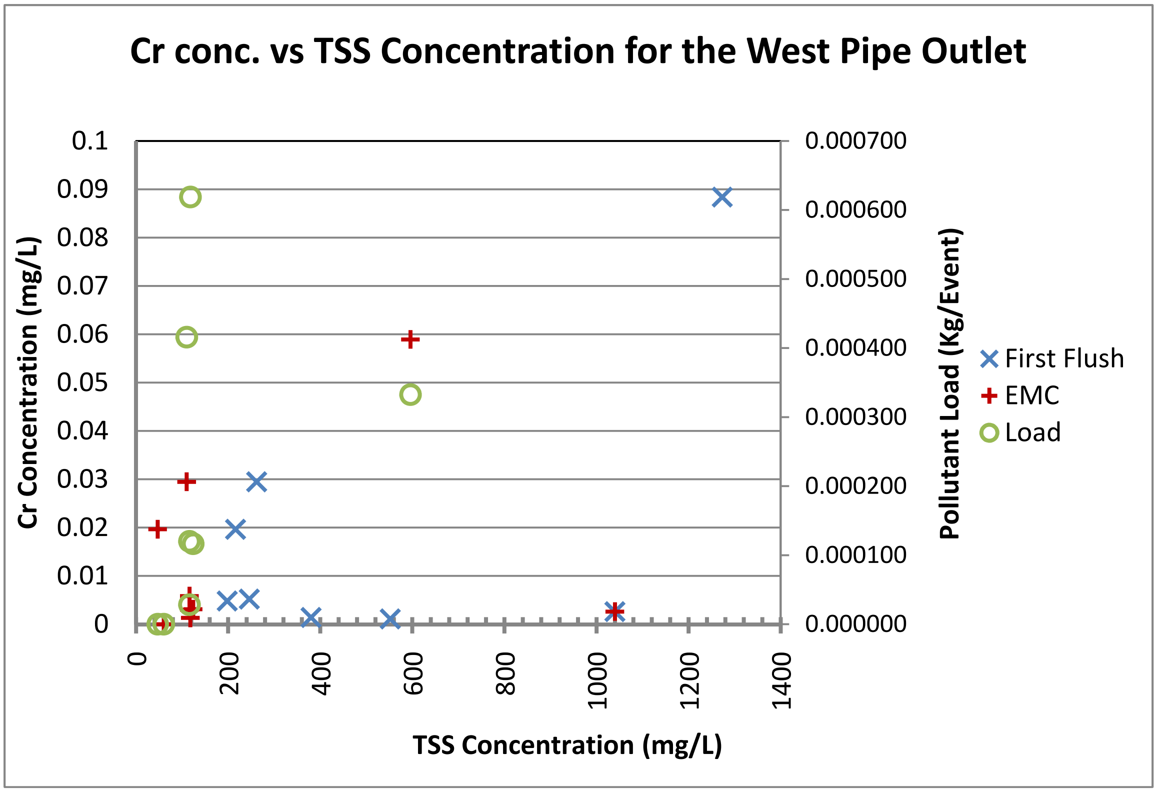

Figure 6-1 Cr and TSS Concentrations for the West Pipe Outlet

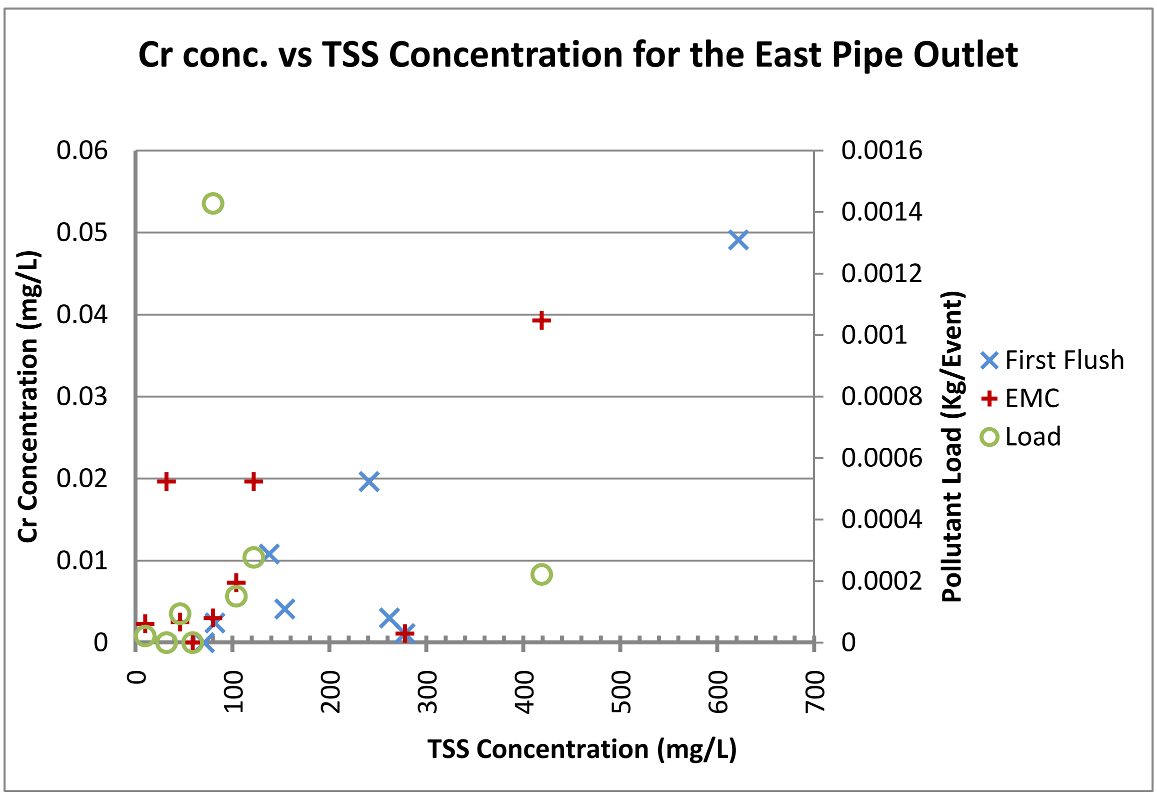

Figure 6-2 Cr and TSS Concentrations for the East Pipe Outlet

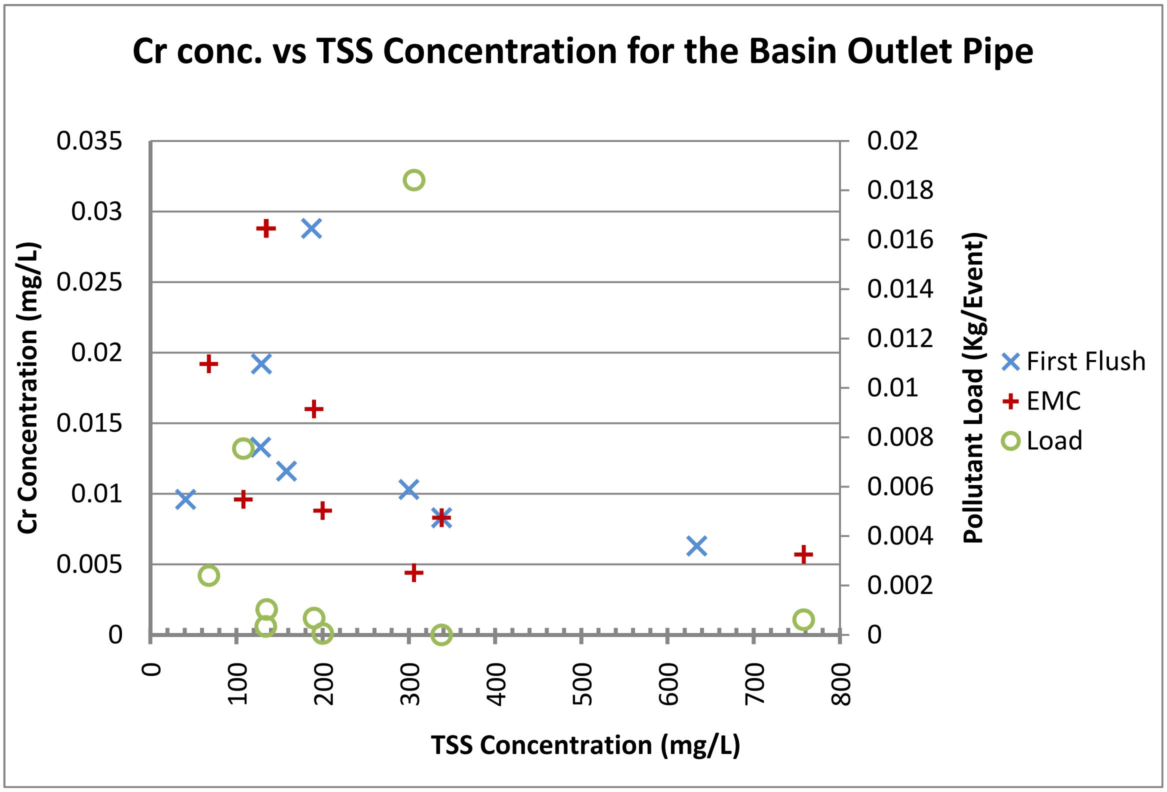

Figure 6-3 Cr and TSS Concentrations for the Basin Outlet Pipe

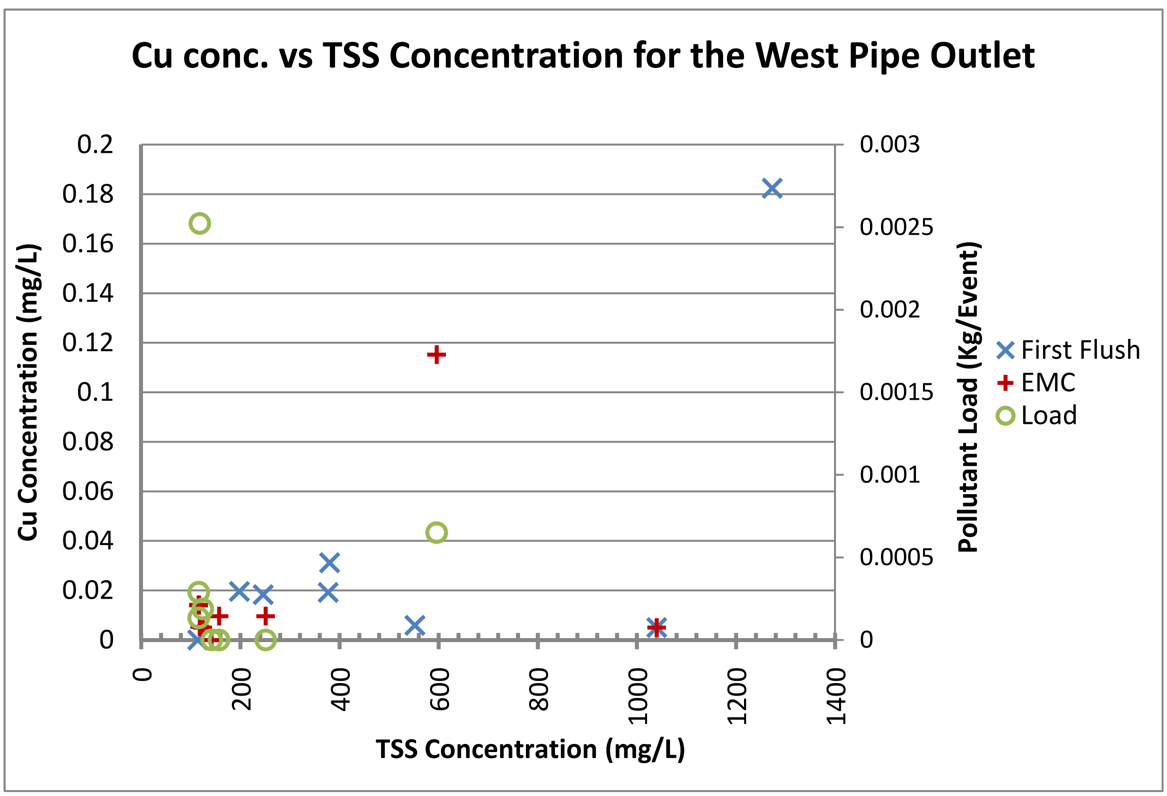

Figure 6-4 Cu and TSS Concentrations for the West Pipe Outlet

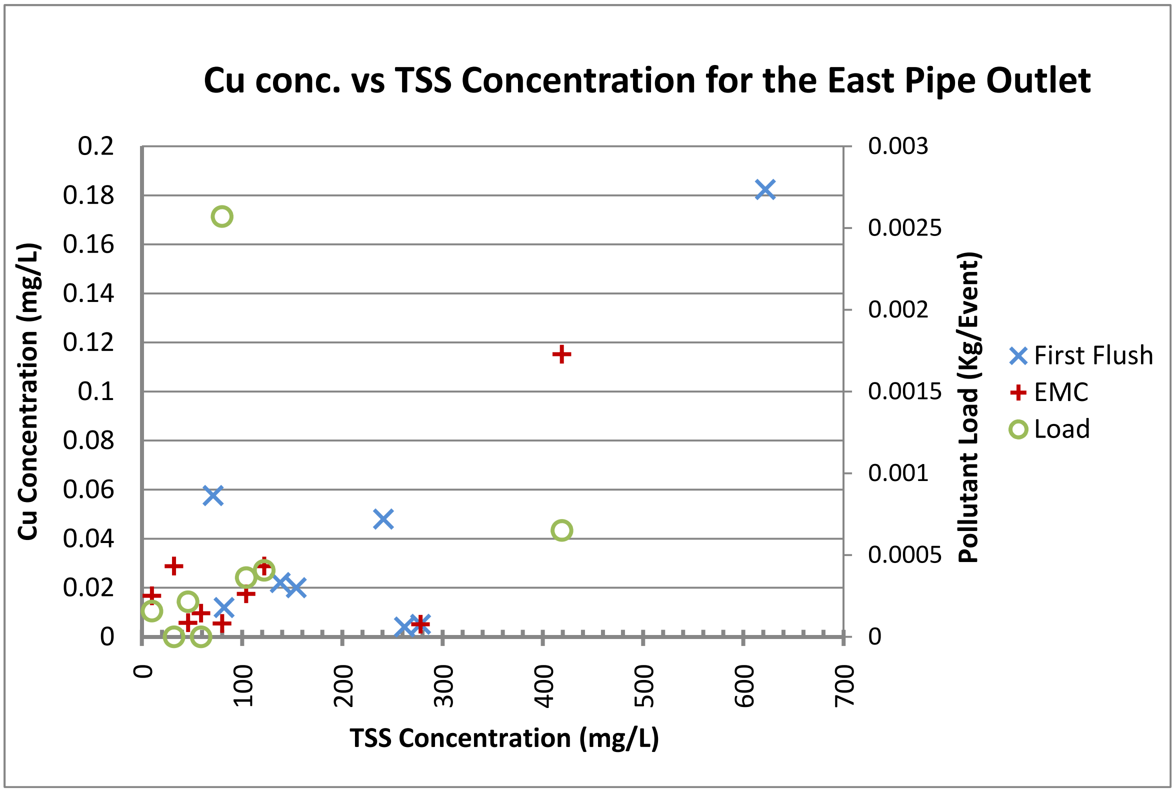

Figure 6-5 Cu and TSS Concentrations for the East Pipe Outlet

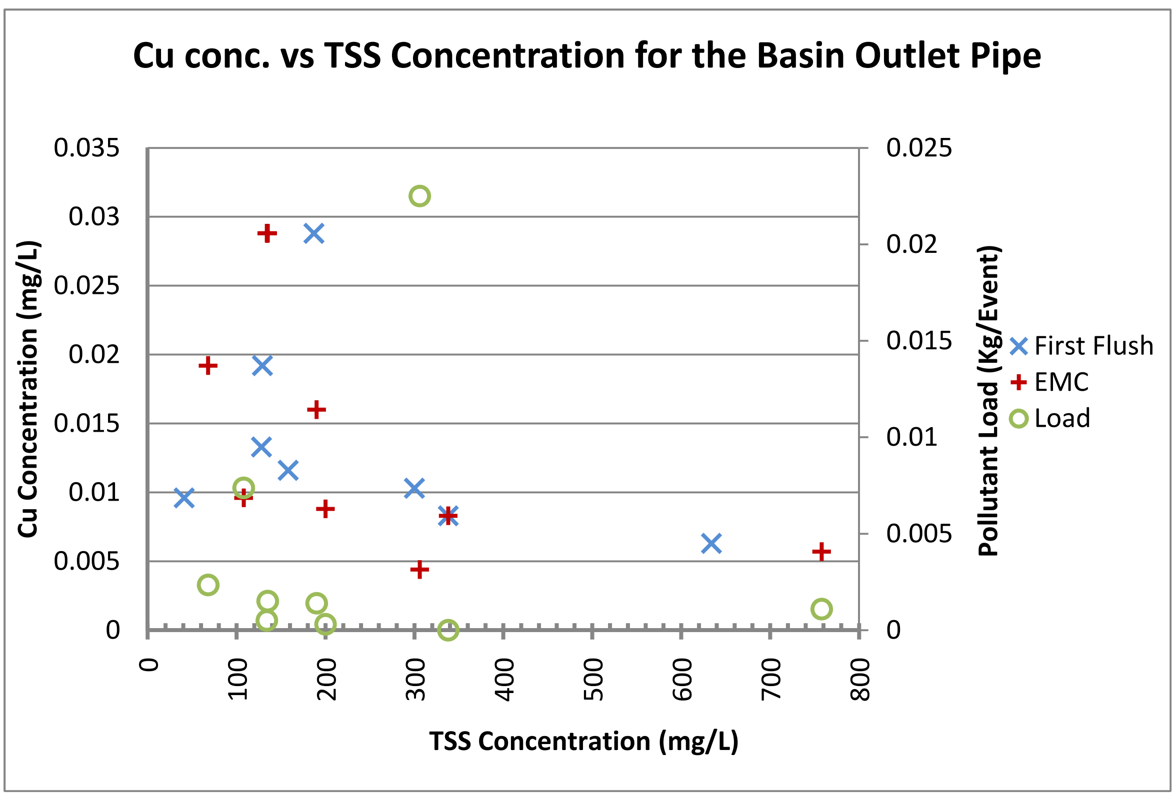

Figure 6-6 Cu and TSS concentrations for the Basin Outlet Pipe

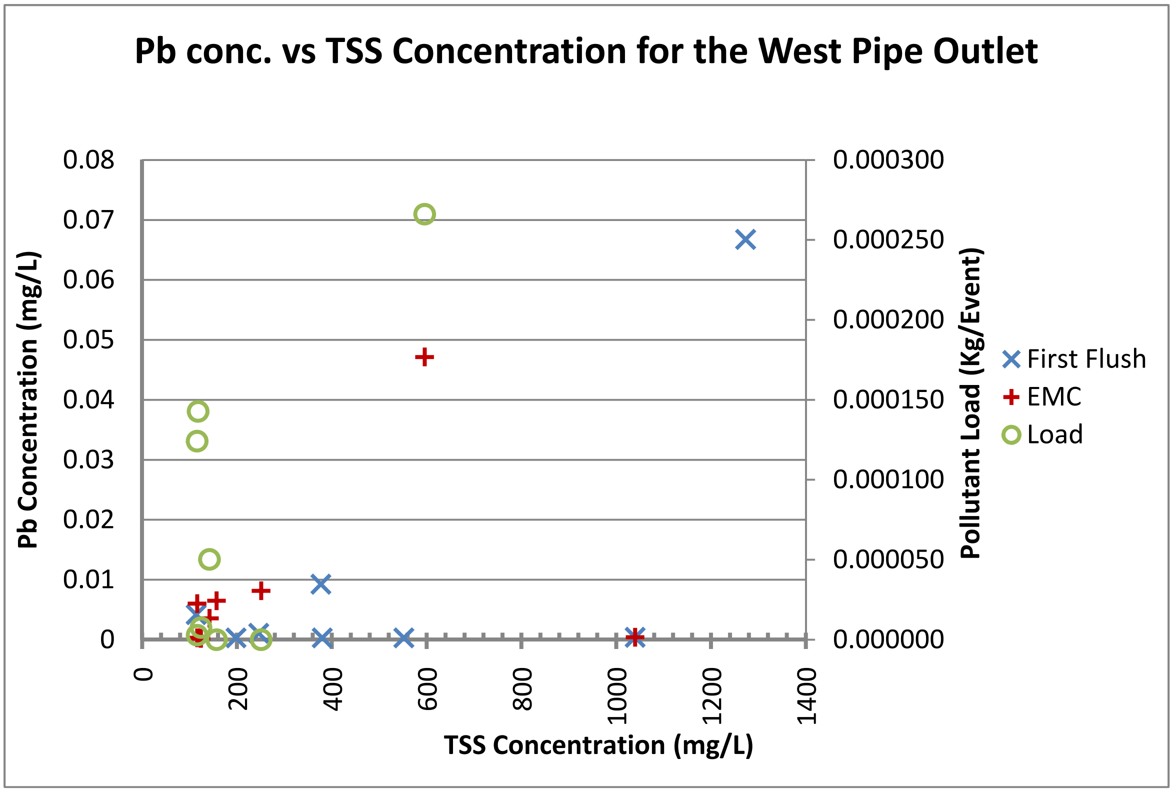

Figure 6-7 Pb and TSS Concentrations for the West Pipe Outlet

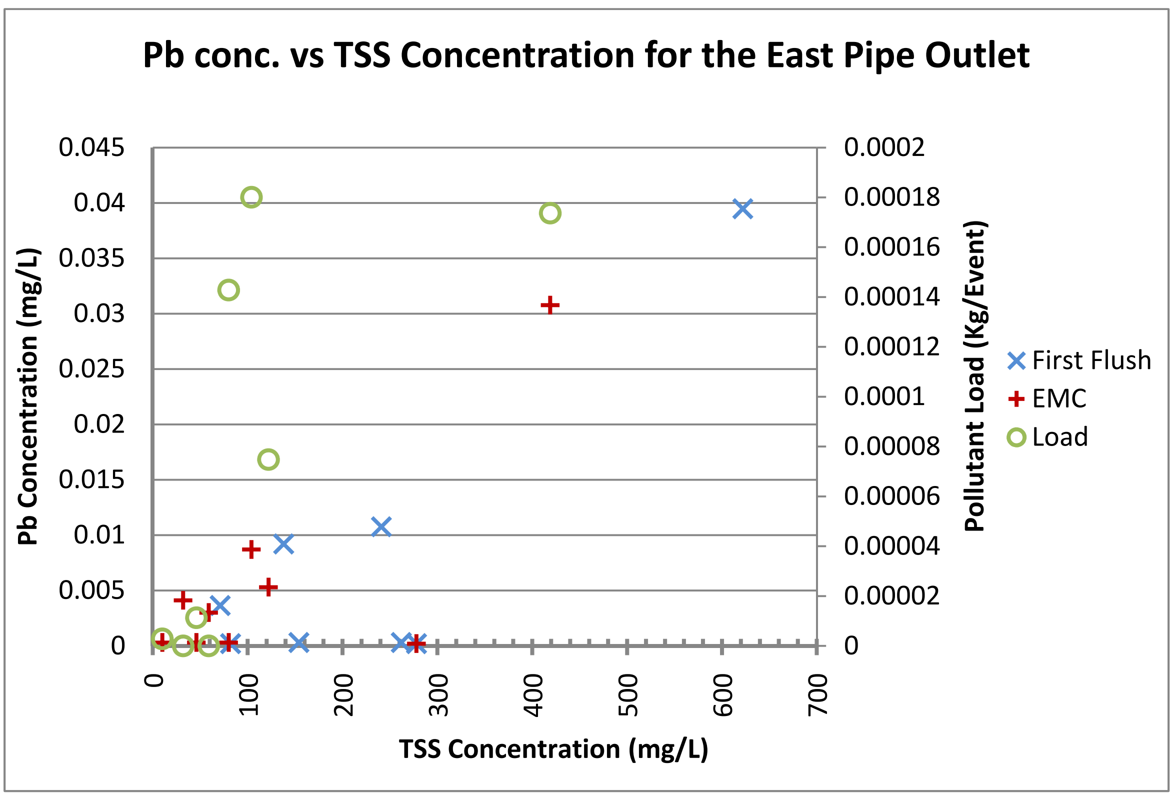

Figure 6-8 Pb and TSS concentrations for the East Pipe Outlet

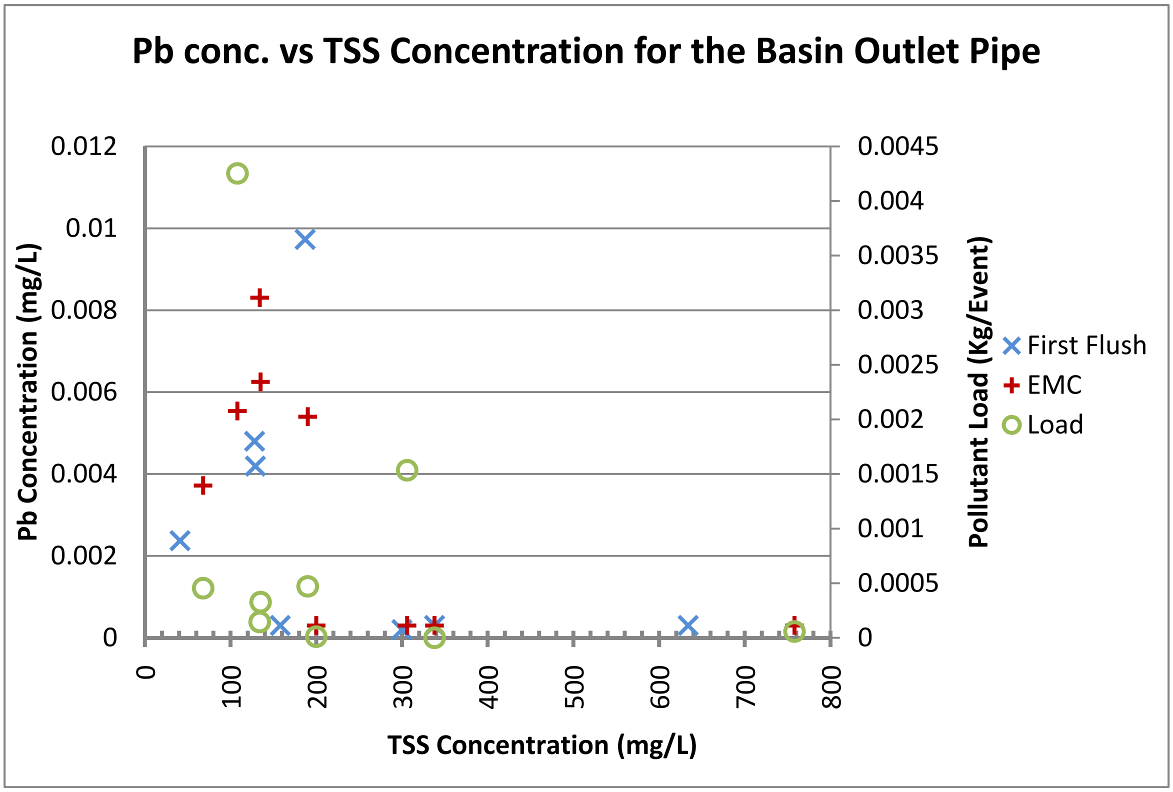

Figure 6-9 Pb and TSS Concentrations for the Basin Outlet Pipe

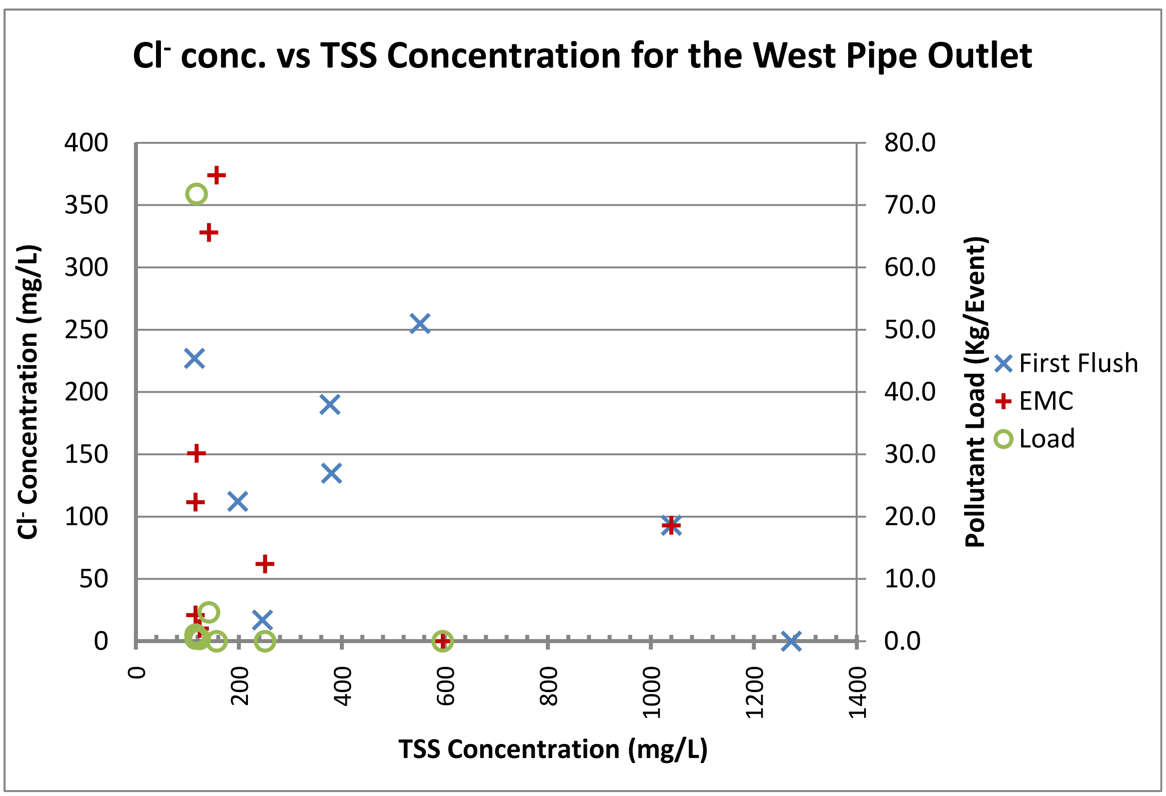

Figure 6-10 Cl^- and TSS Concentrations for the West Pipe Outlet

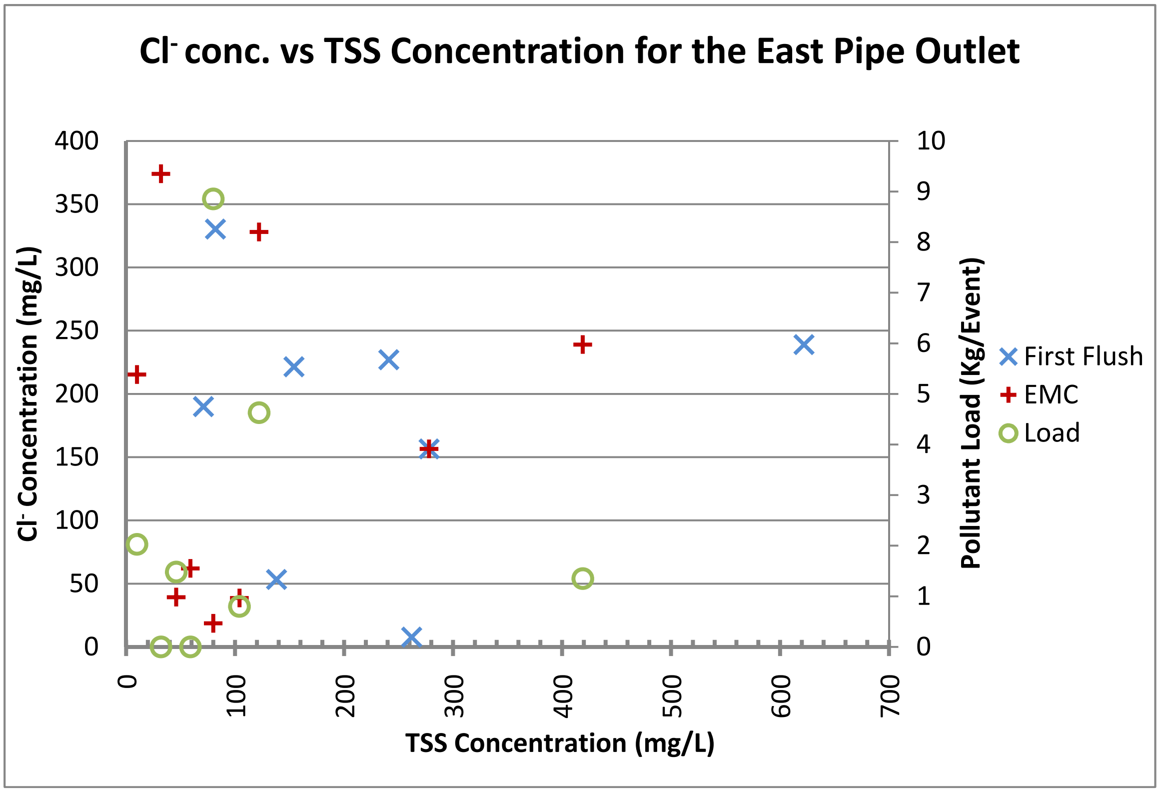

Figure 6-11 Cl$^-$ and TSS concentrations for the East Pipe Outlet

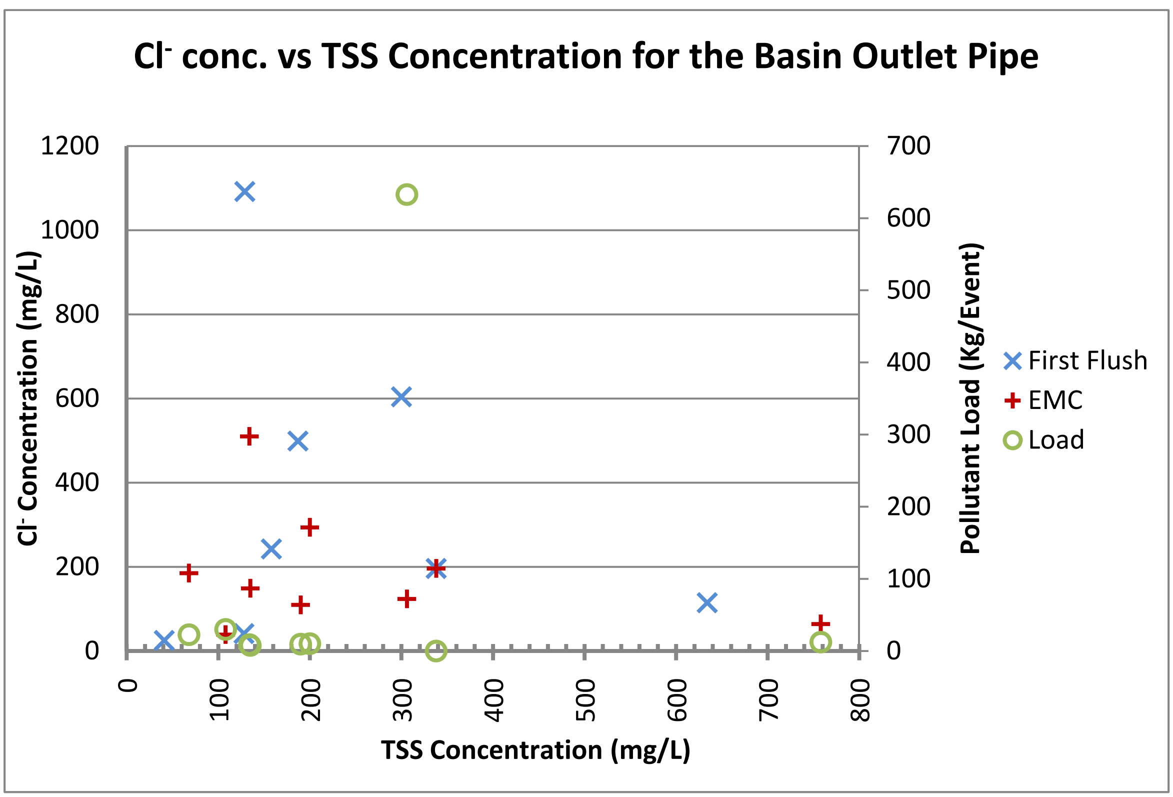

Figure 6-12 Cl$^-$ and TSS concentrations for the Basin Outlet Pipe

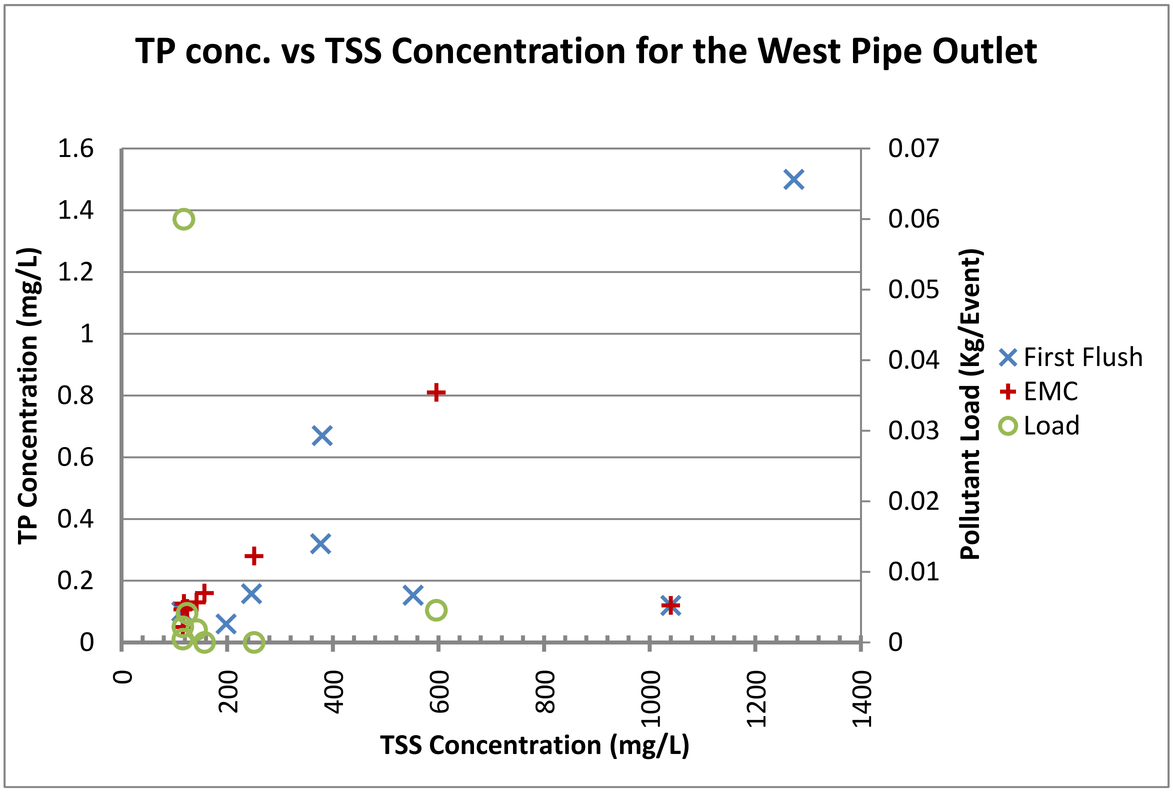

Figure 6-13 TP and TSS Concentrations for the West Pipe Outlet

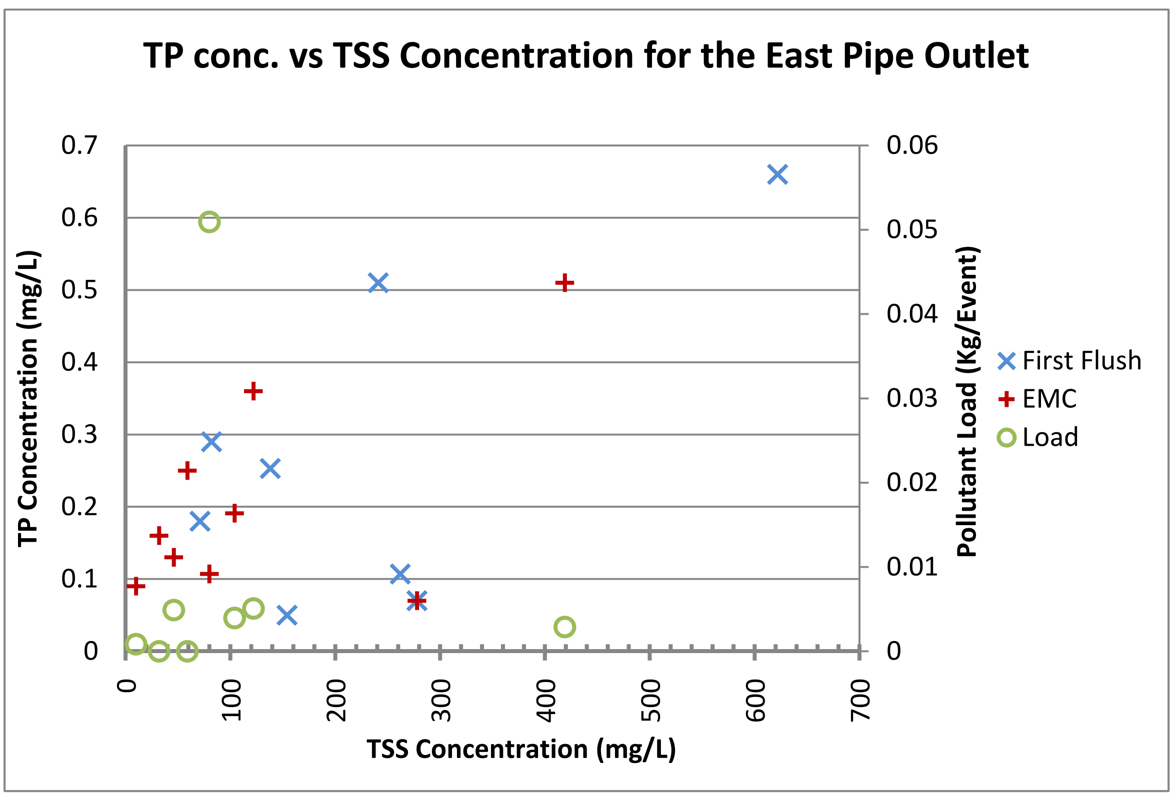

Figure 6-14 TP and TSS Concentrations for the East Pipe Outlet

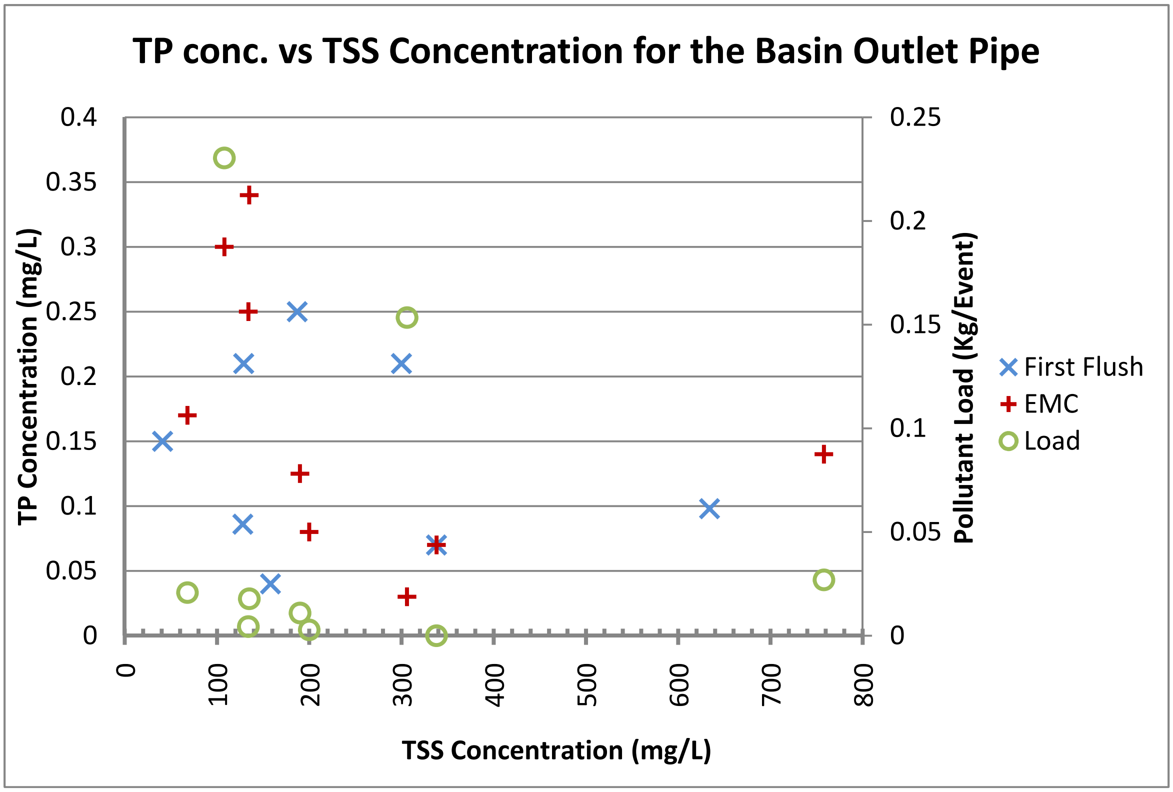

Figure 6-15 TP and TSS Concentrations for the Basin Outlet Pipe

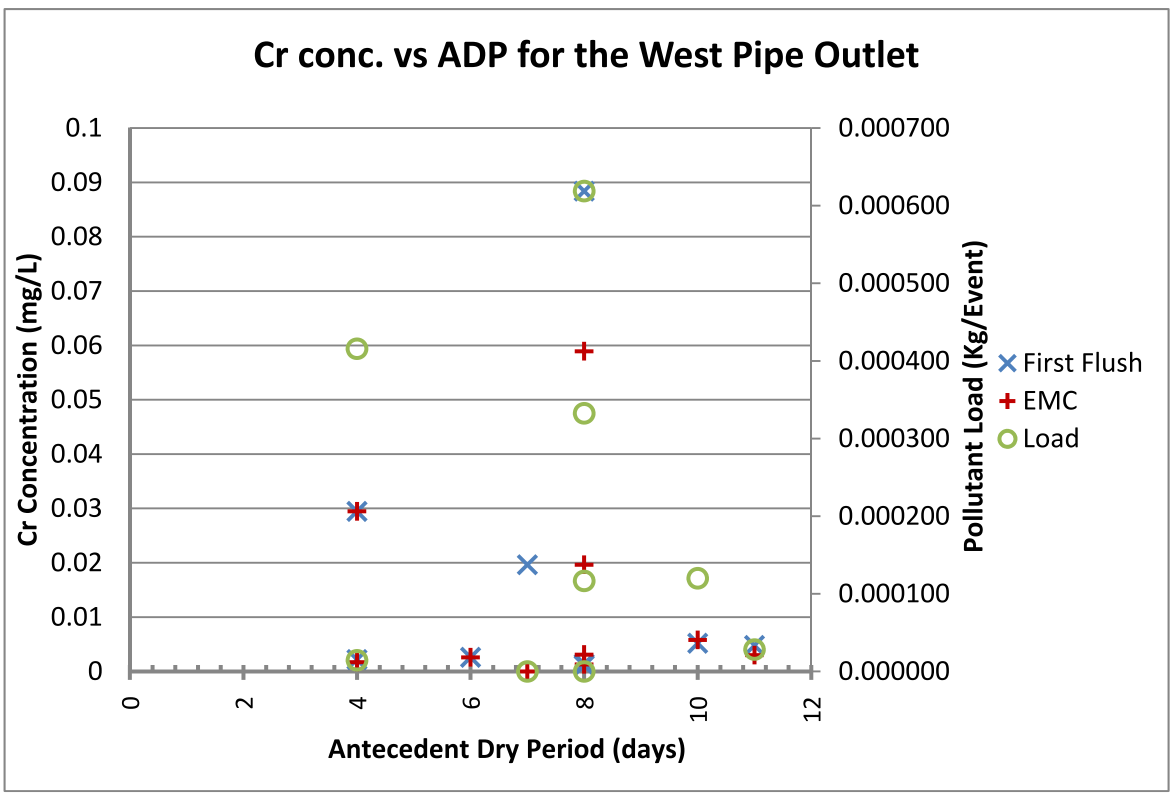

Figure 6-16 Cr and ADP for the West Pipe Outlet

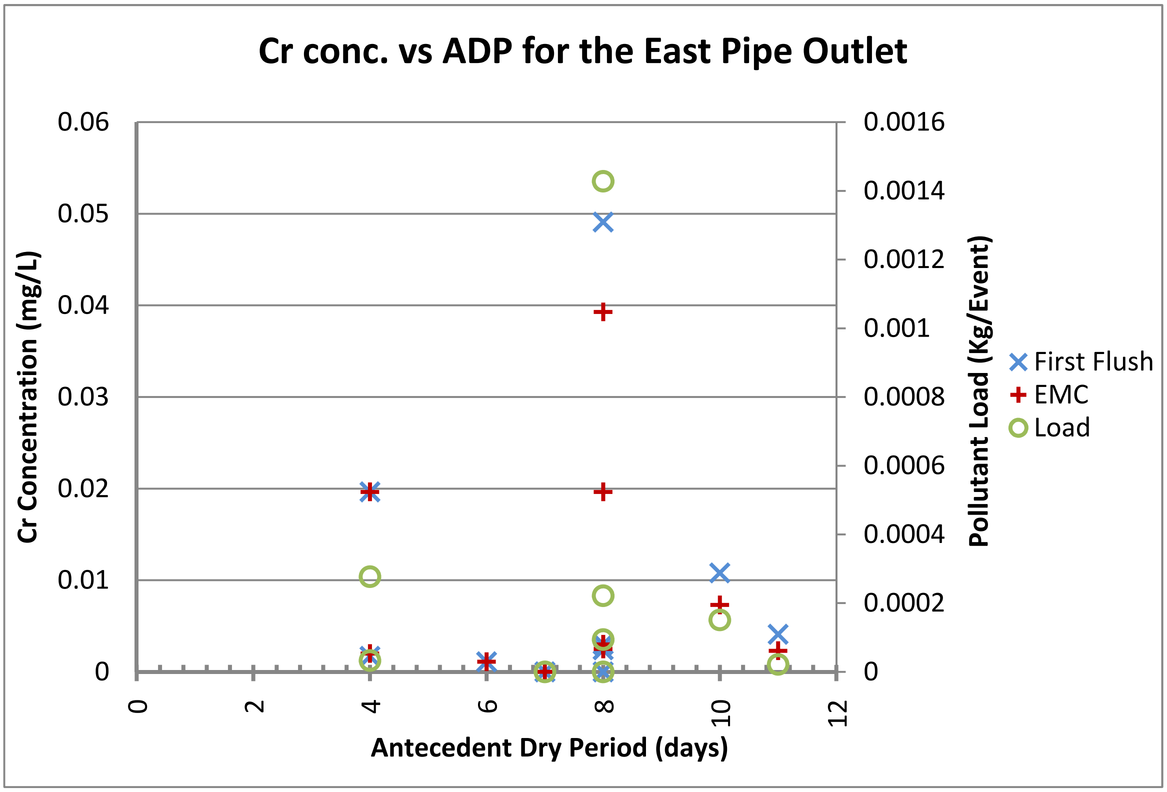

Figure 6-17 Cr and ADP for the East Pipe Outlet

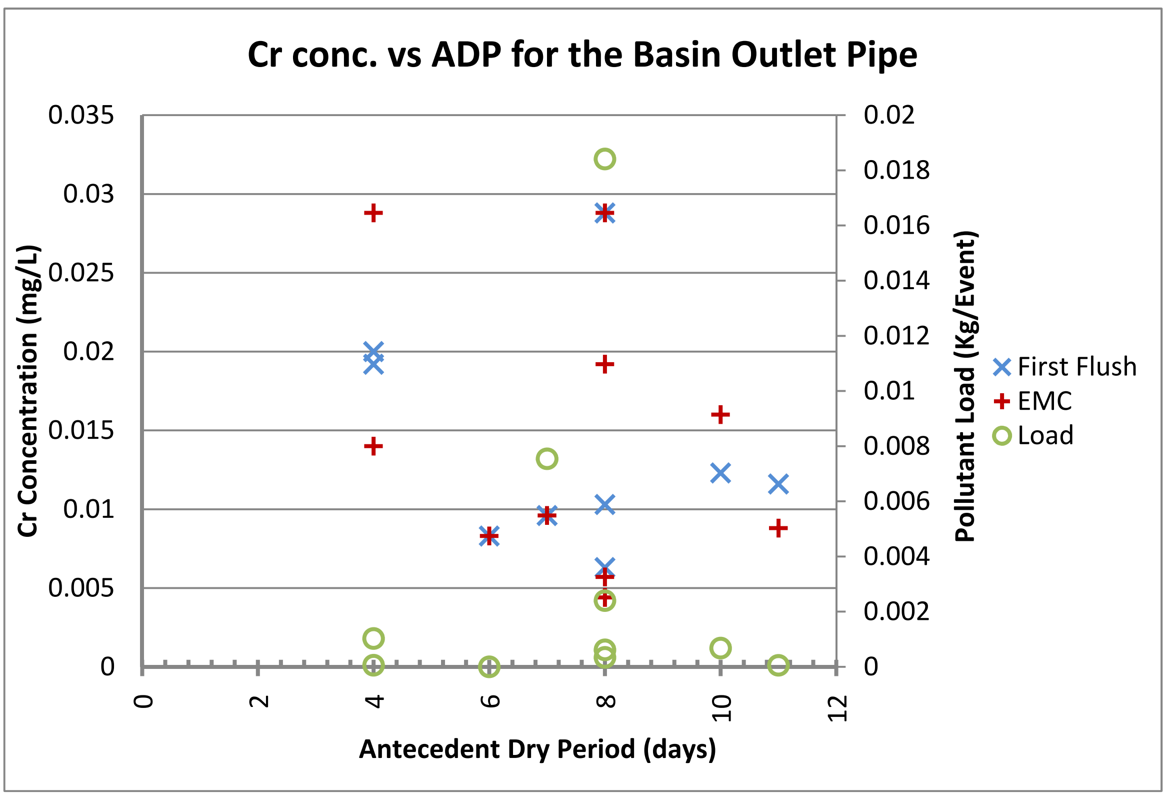

Figure 6-18 Cr and ADP for the Basin Outlet Pipe

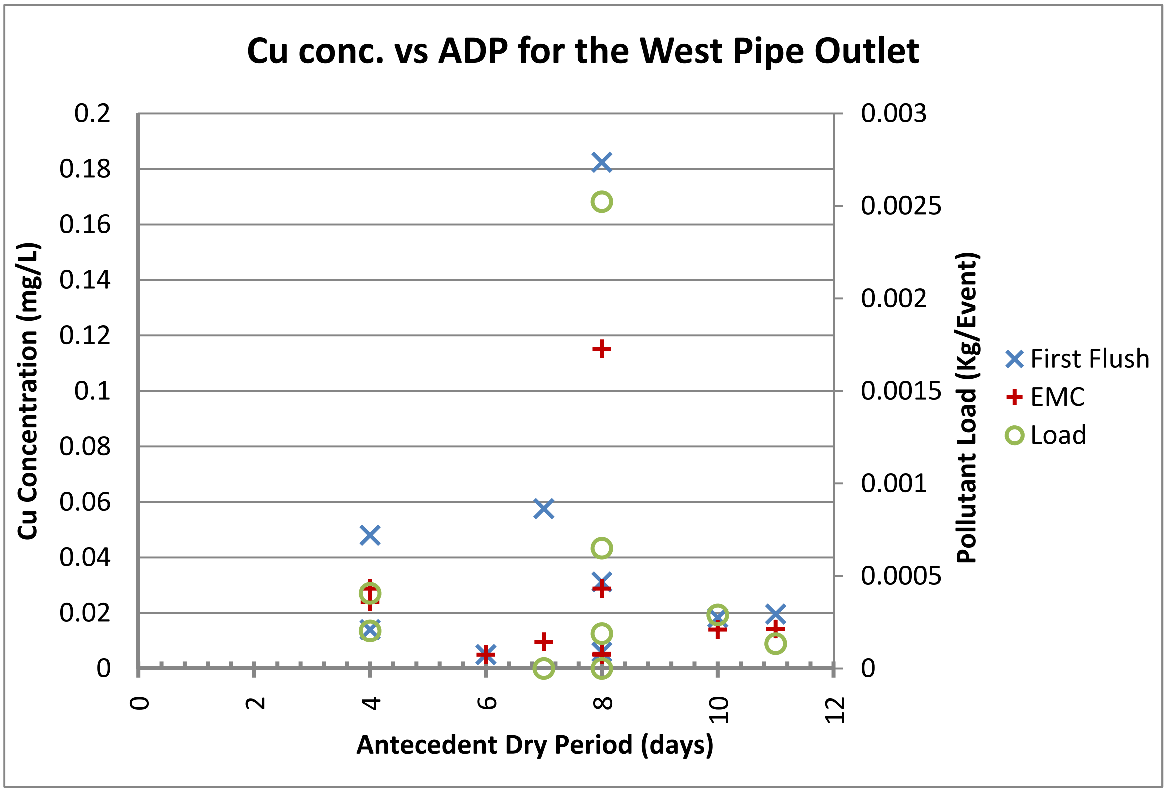

Figure 6-19 Cu and ADP for the West Pipe Outlet

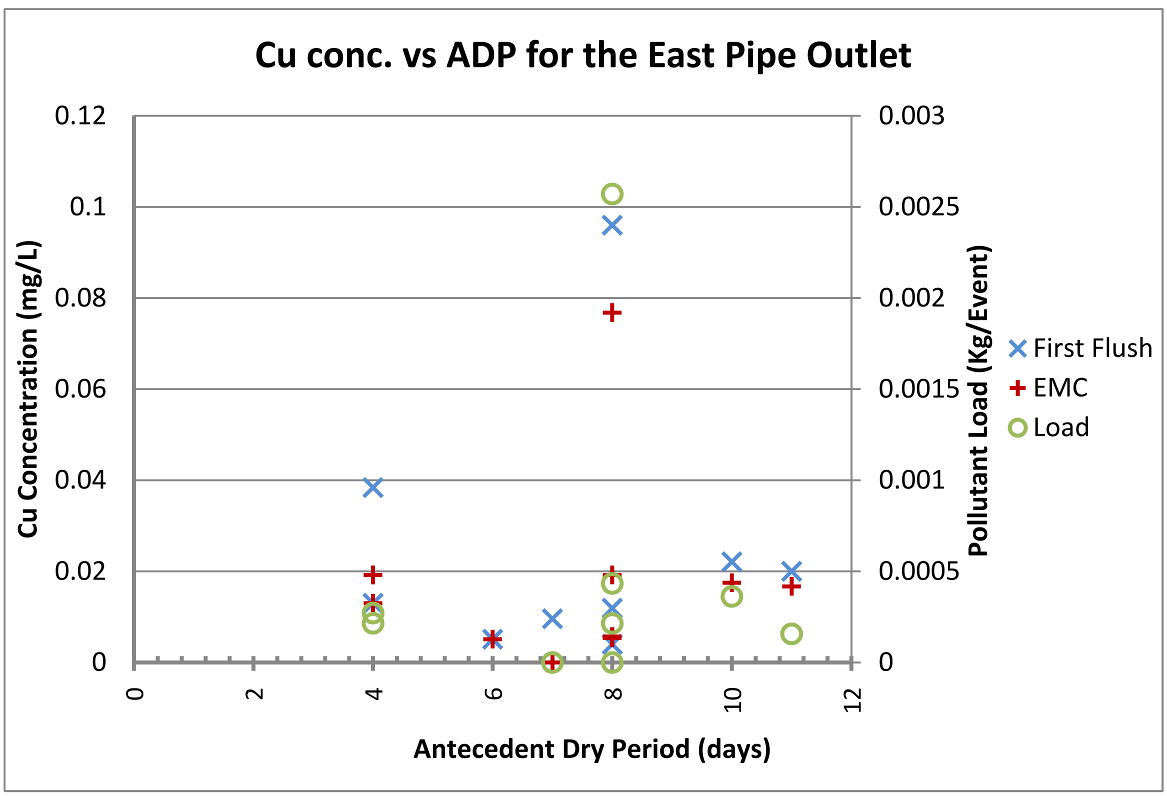

Figure 6-20 Cu and ADP for the East Pipe Outlet

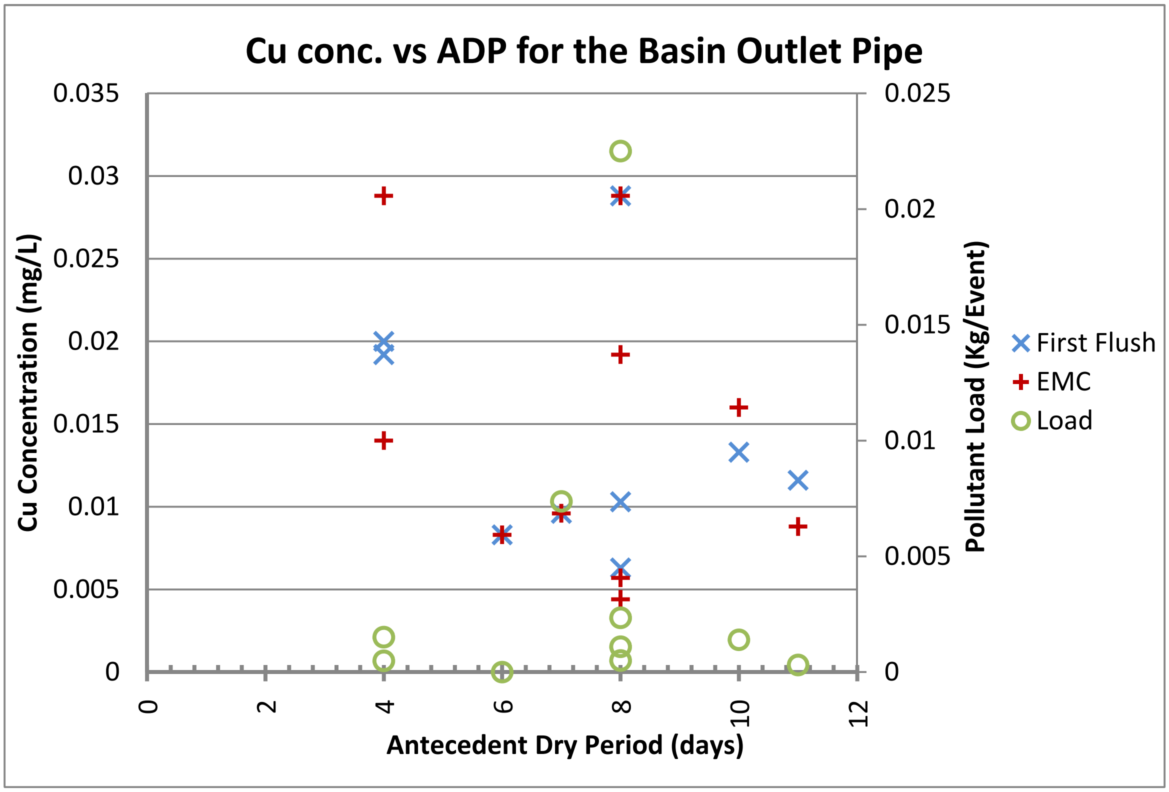

Figure 6-21 Cu and ADP for the Basin Outlet Pipe

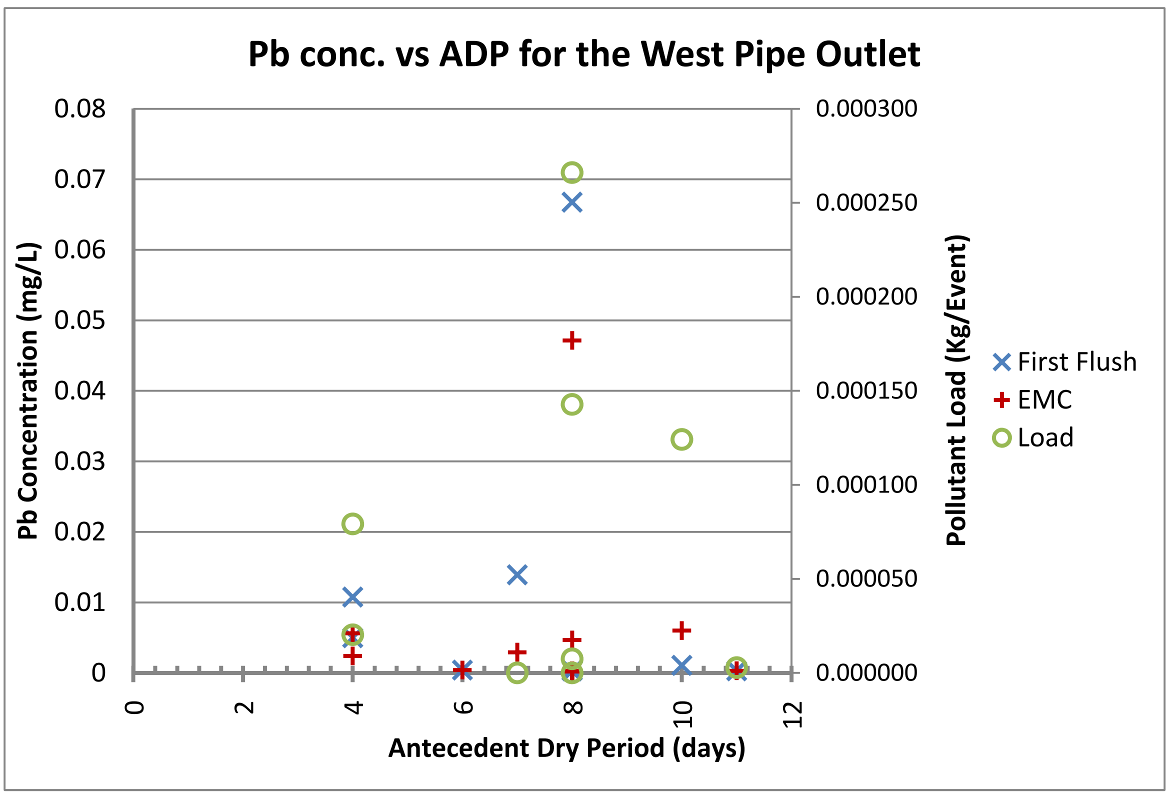

Figure 6-22 Pb and ADP for the West Pipe Outlet

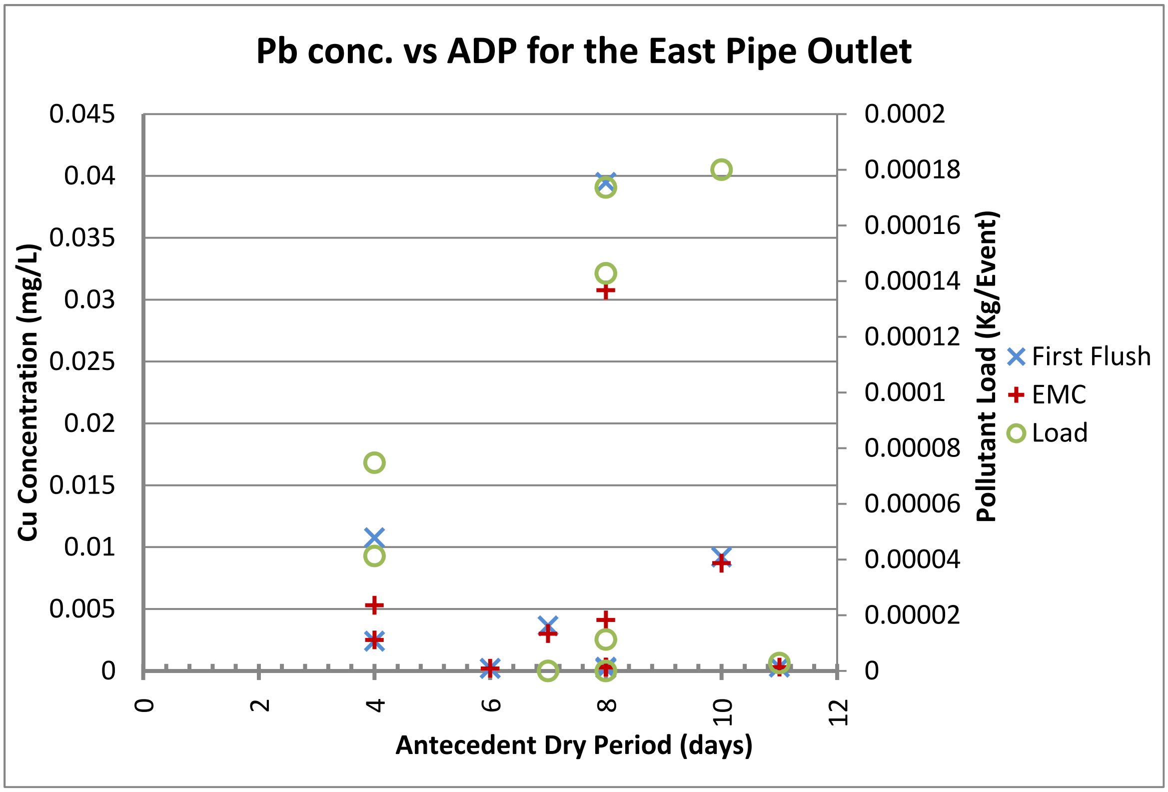

Figure 6-23 Pb and ADP for the East Pipe Outlet

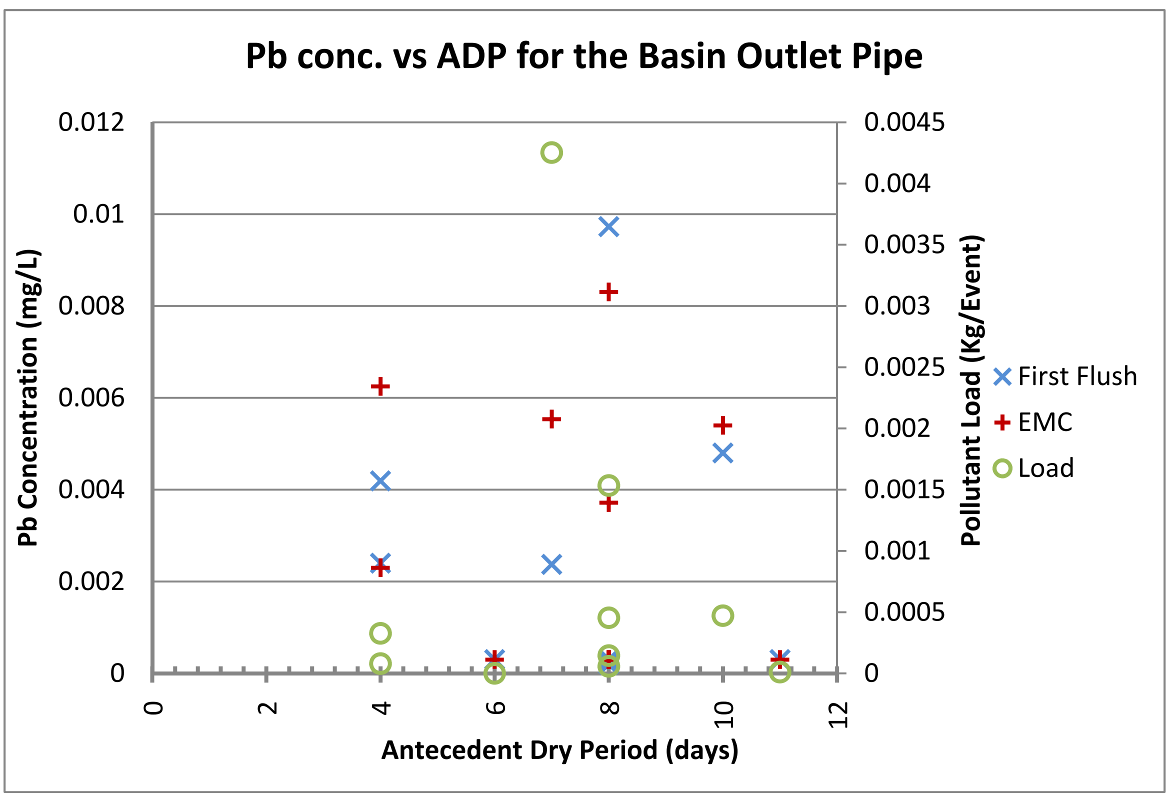

Figure 6-24 Pb and ADP for the Basin Outlet Pipe

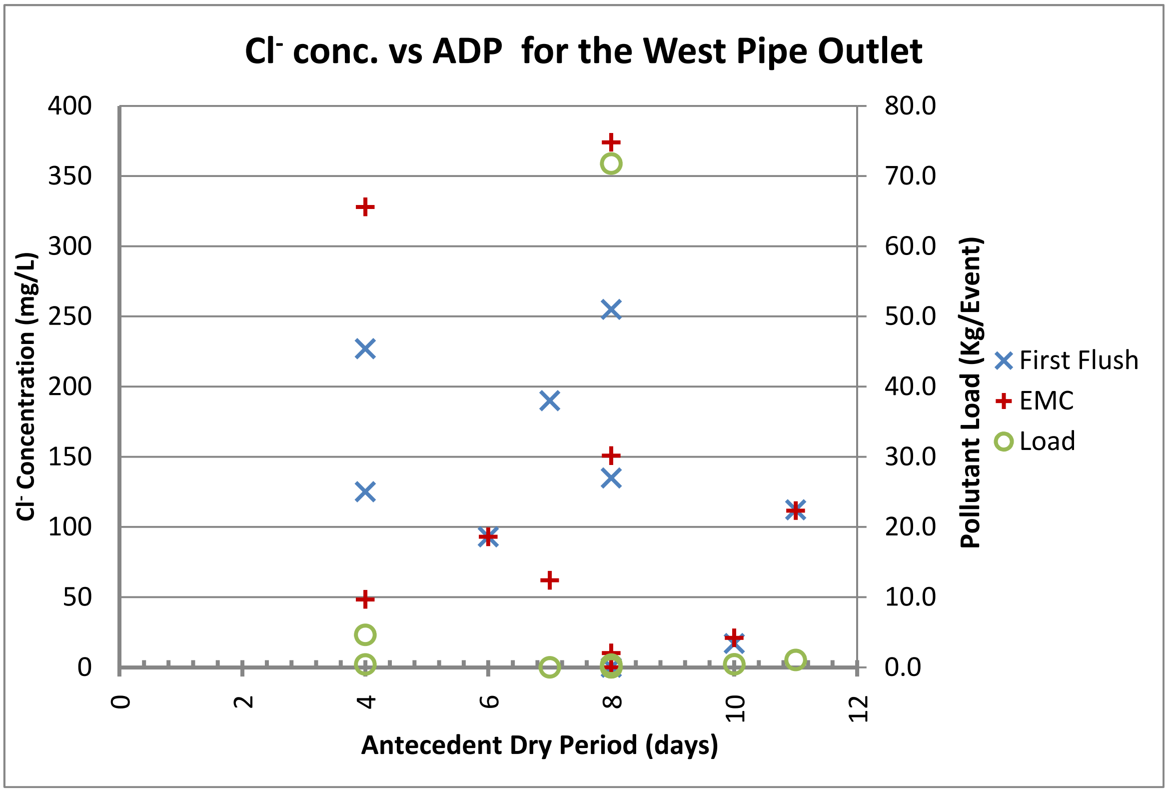

Figure 6-25 Cl- and ADP for the West Pipe Outlet

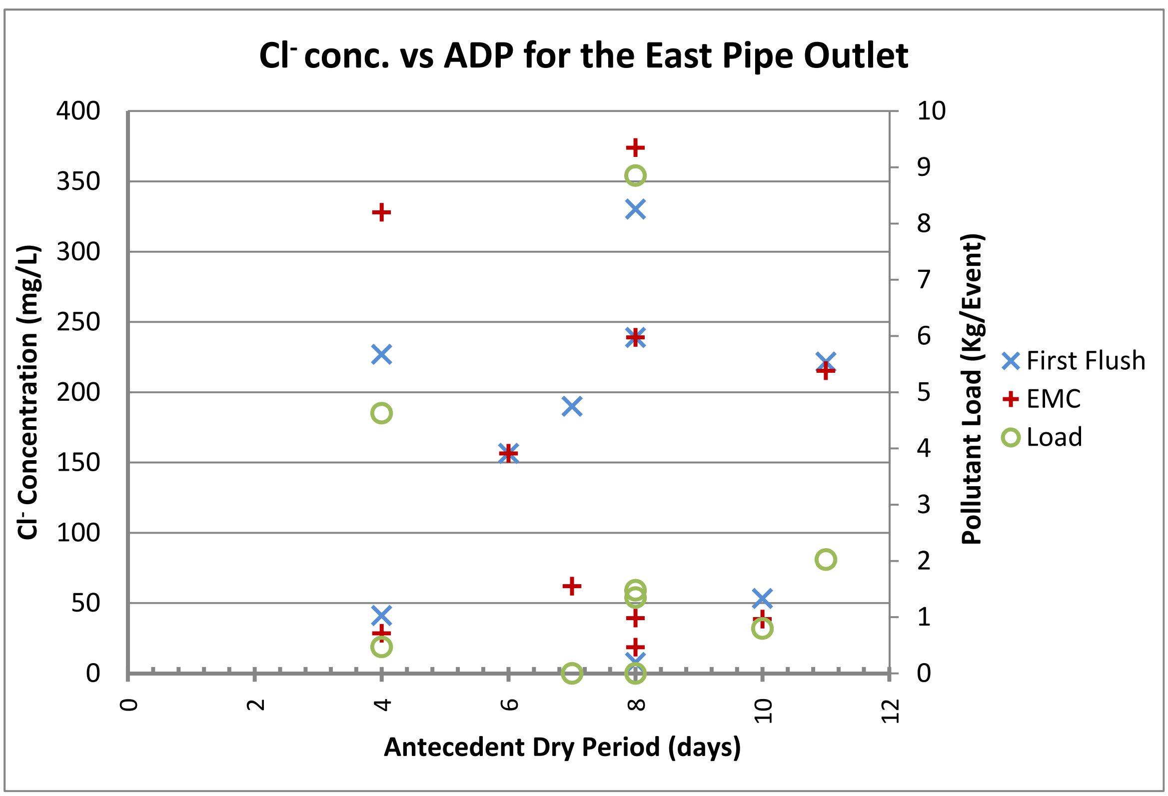

Figure 6-26 Cl- and ADP for the East Pipe Outlet

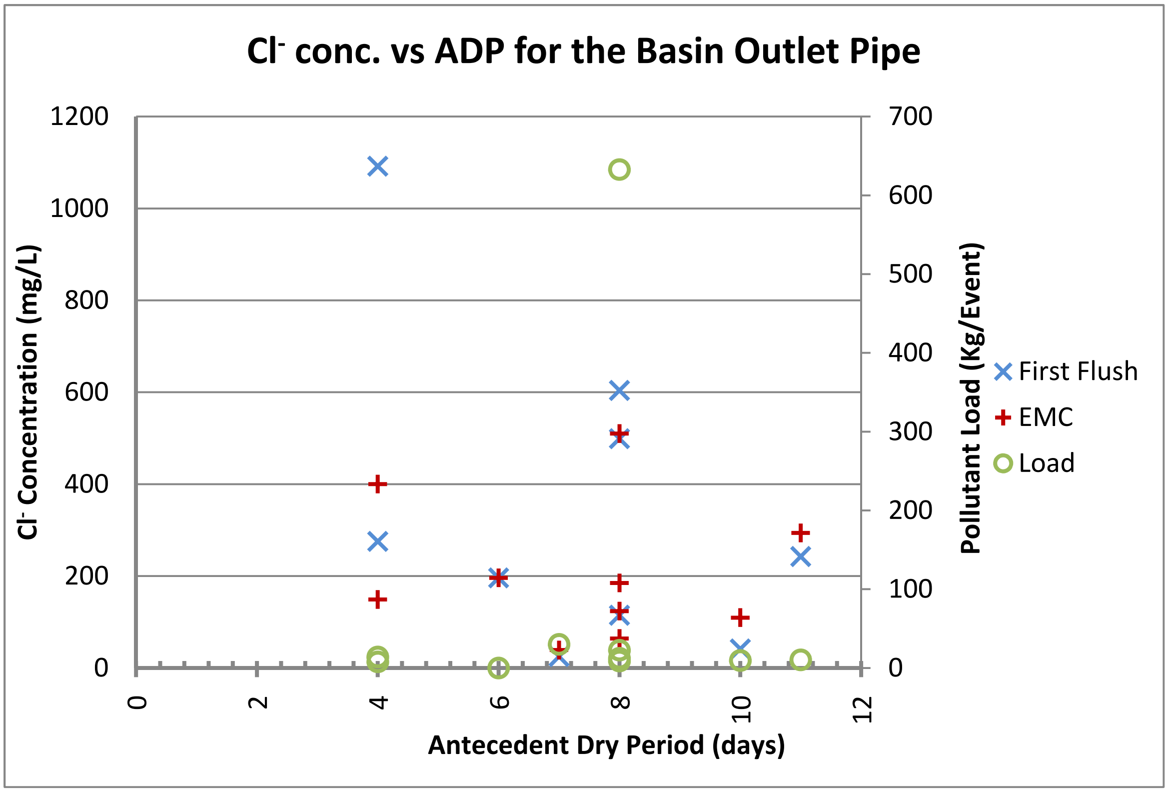

Figure 6-27 Cl^- and ADP for the Basin Outlet Pipe

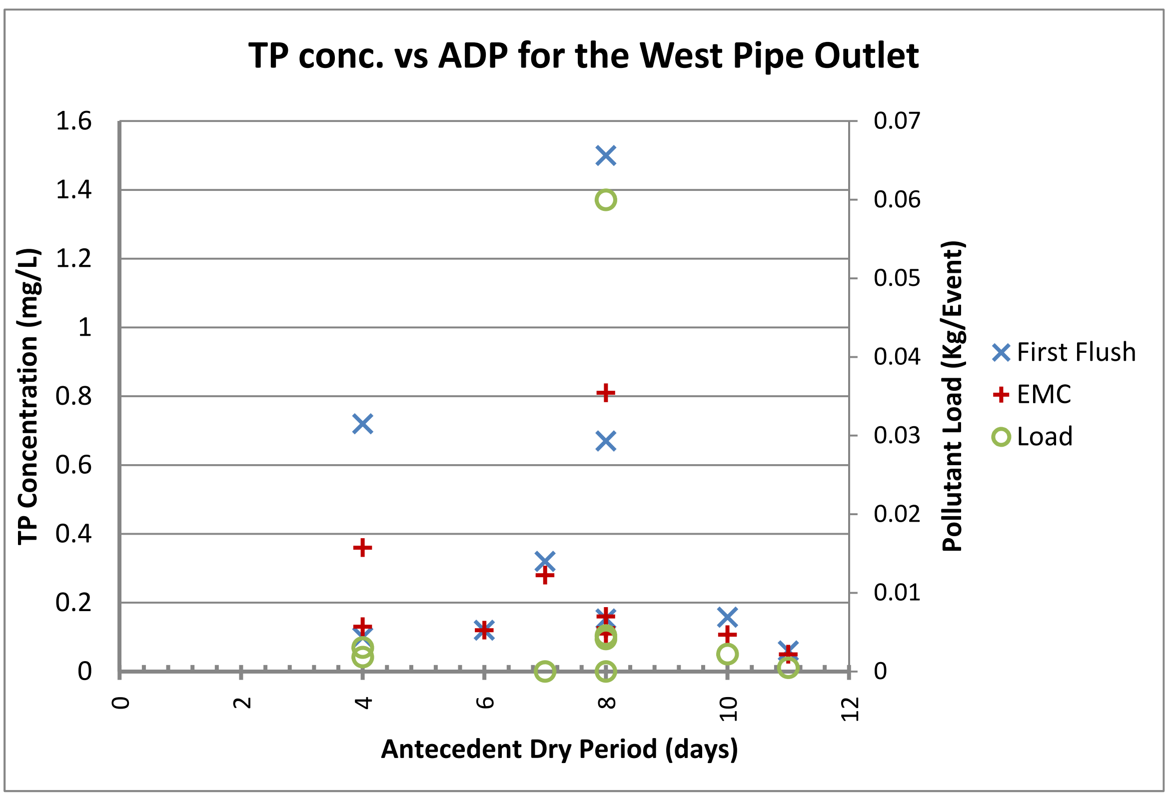

Figure 6-28 TP and ADP for the West Pipe Outlet

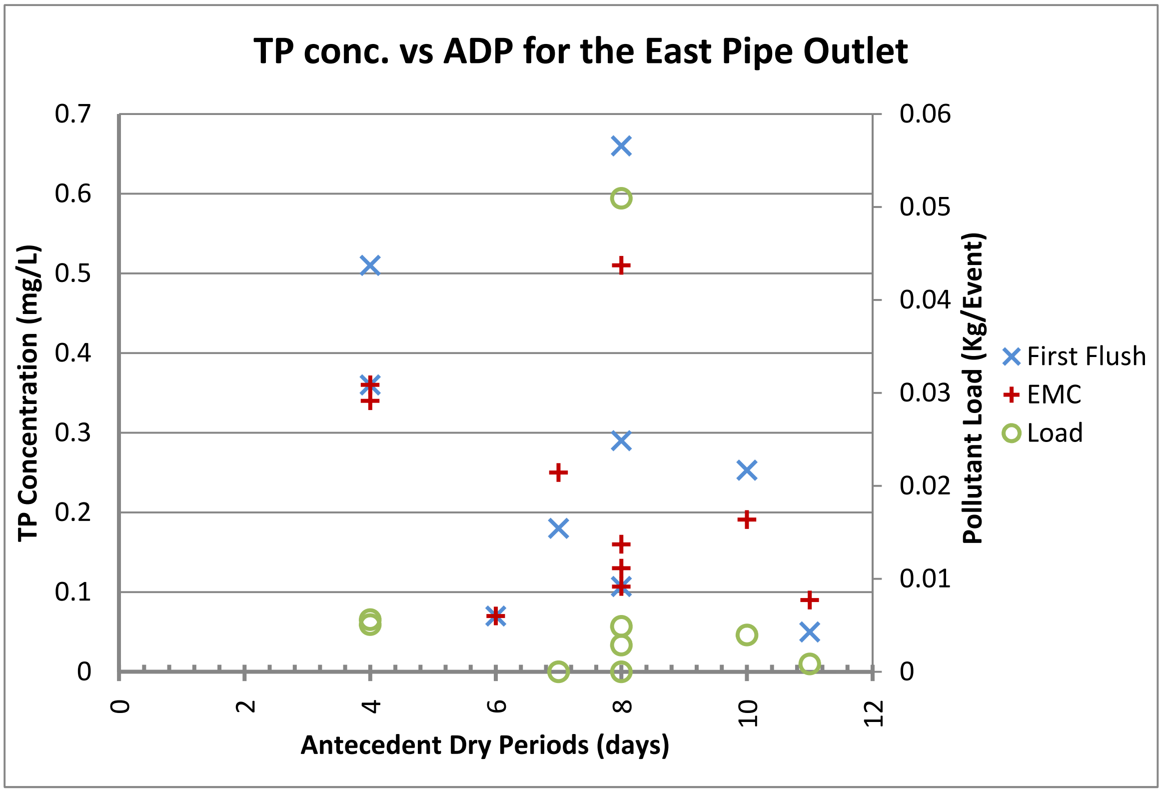

Figure 6-29 TP and ADP for the East Pipe Outlet

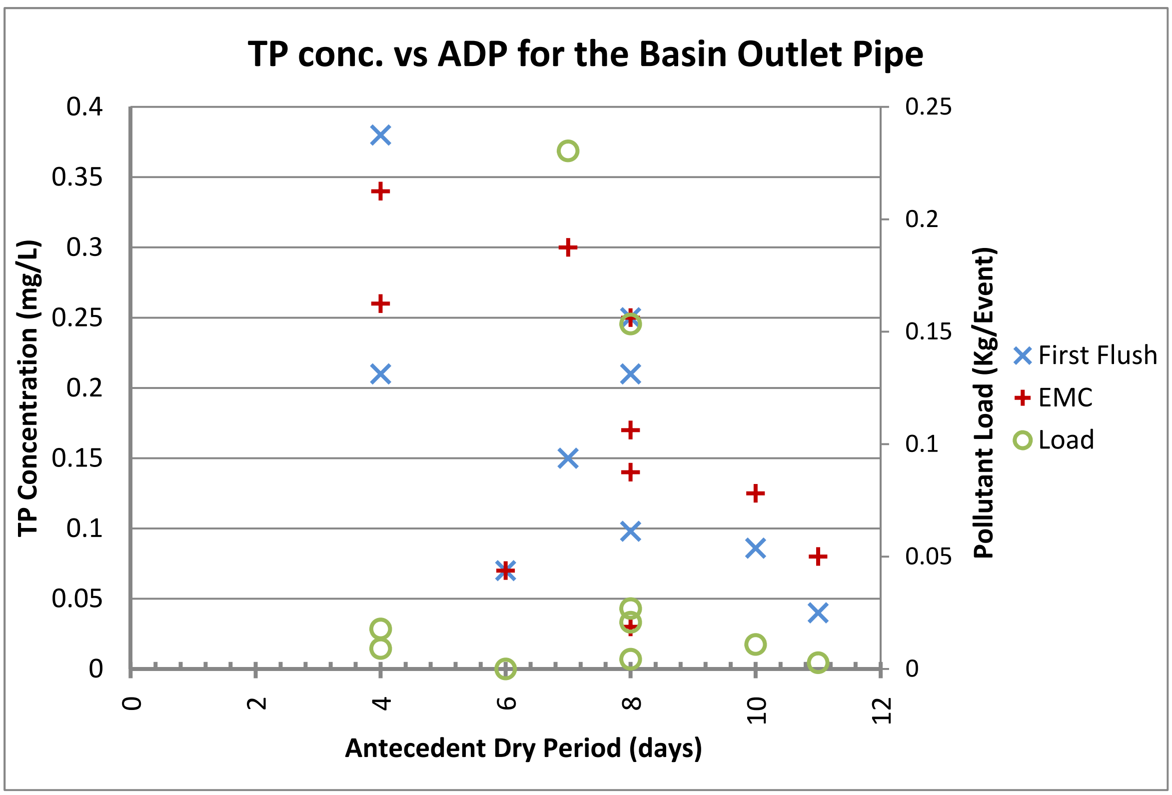

Figure 6-30 TP and ADP for the Basin Outlet Pipe

6.1.3 Pollutant Relationship with Total Rainfall

Concentrations and loads for chromium (Cr), copper (Cu), lead (Pb), chloride (Cl^-), and total phosphorus (TP) were compared to the total rainfall for each of the sampled events for the west, east, and basin outlet pipes. This comparison is shown on Figures 6-31 through 6-45. The figures do not show a clear relationship between concentrations and total rainfall for any of the analytes used in the comparison. Concentrations for high intensity events seem to be lower than for lower intensity storms. However, during the study, few high intensity were sampled; therefore, it is not possible to be complete sure about this trend.

6.1.4 Pollutant Relationship with Volume of Runoff

Concentrations and loads for chromium (Cr), copper (Cu), lead (Pb), chloride (Cl^-), and total phosphorus (TP) were compared to the volume of runoff for each of the sampled events for the west, east, and basin outlet pipes. This comparison is shown on Figures 6-46 through 6-60. Concentrations for chromium, copper, lead, and total phosphorus seem to be unaffected by the volume of runoff for the east and west pipe.

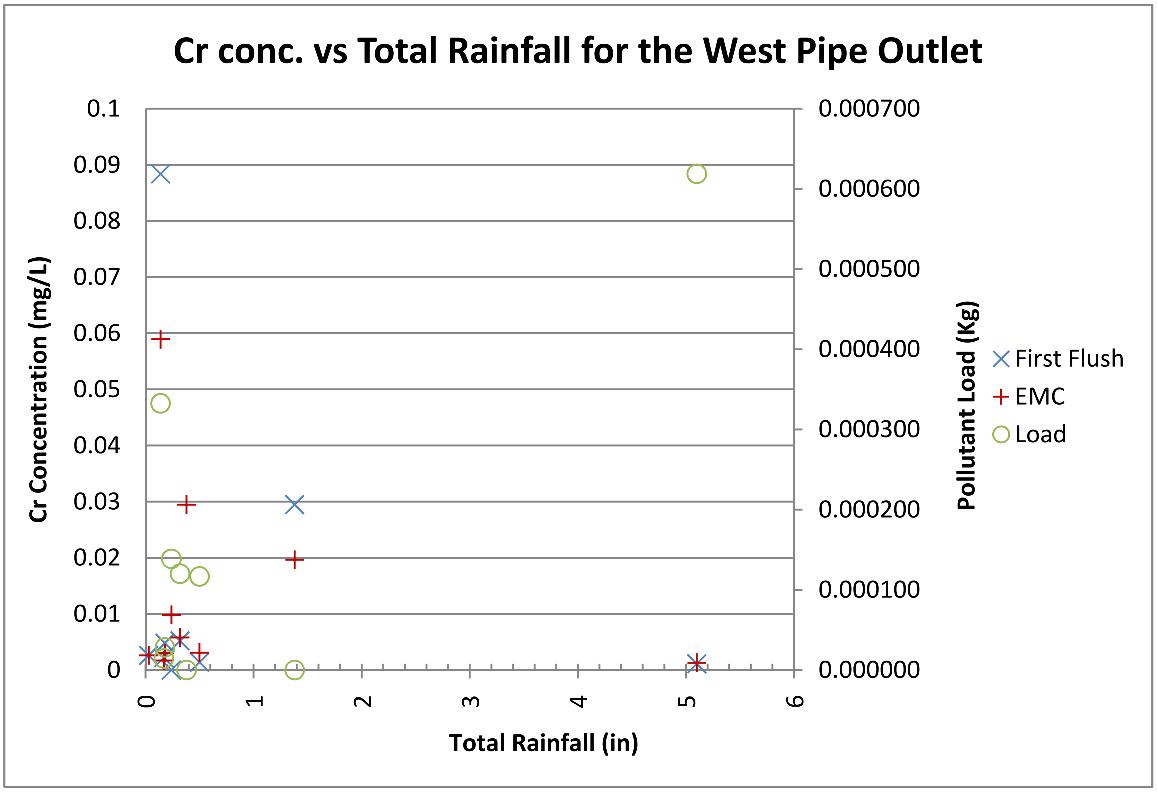

Figure 6-31 Cr Concentration and Total Rainfall for the West Pipe Outlet

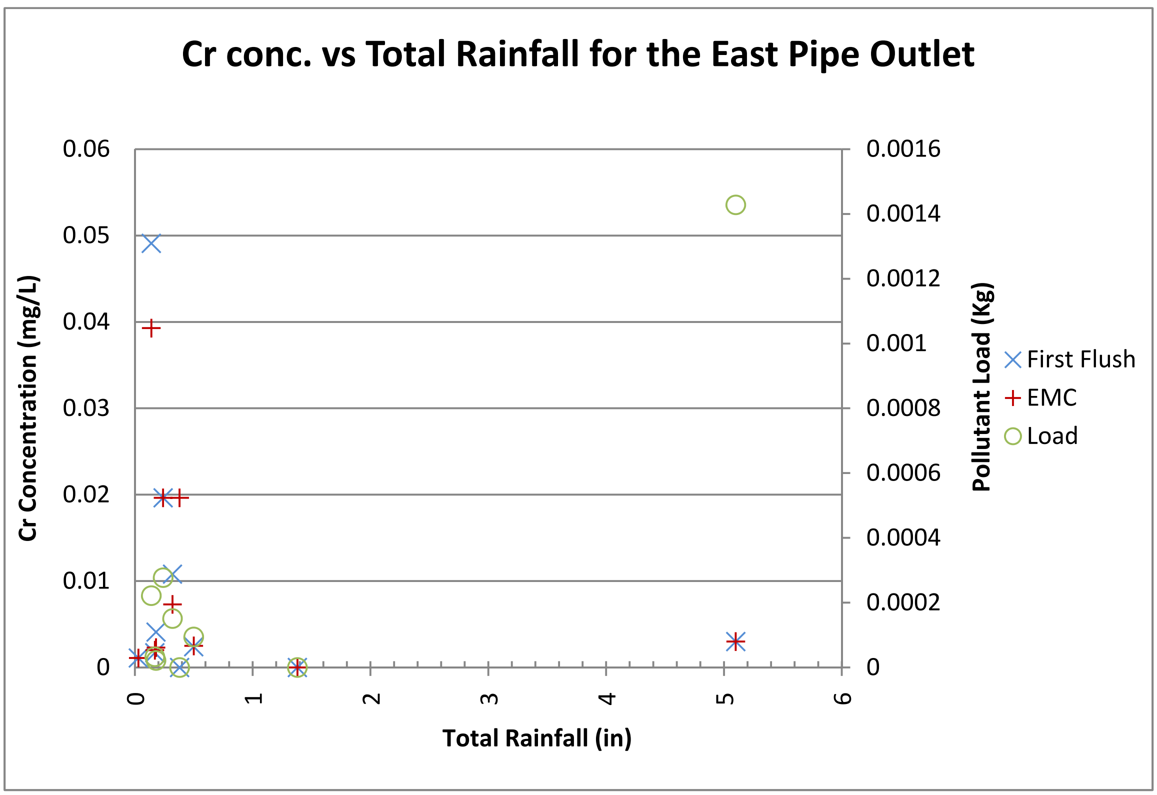

Figure 6-32 Cr Concentration and Total Rainfall for the West Pipe Outlet

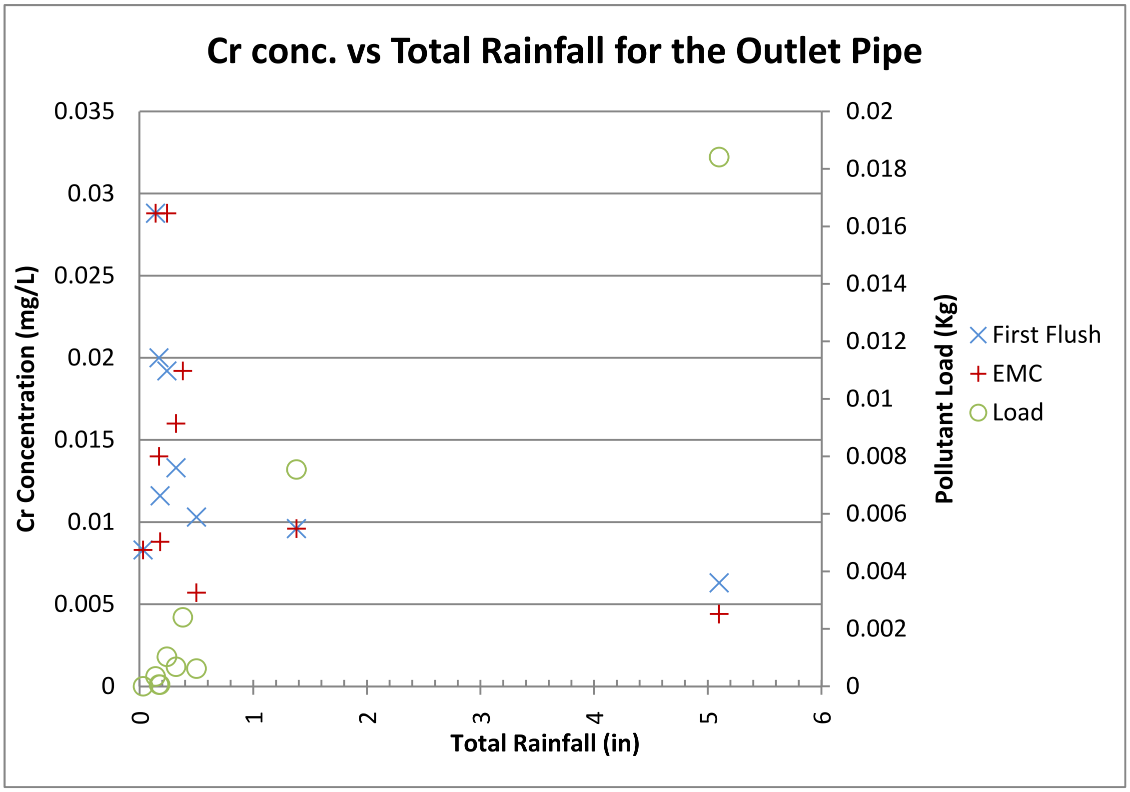

Figure 6-33 Cr Concentration and Total Rainfall for the Basin Outlet Pipe

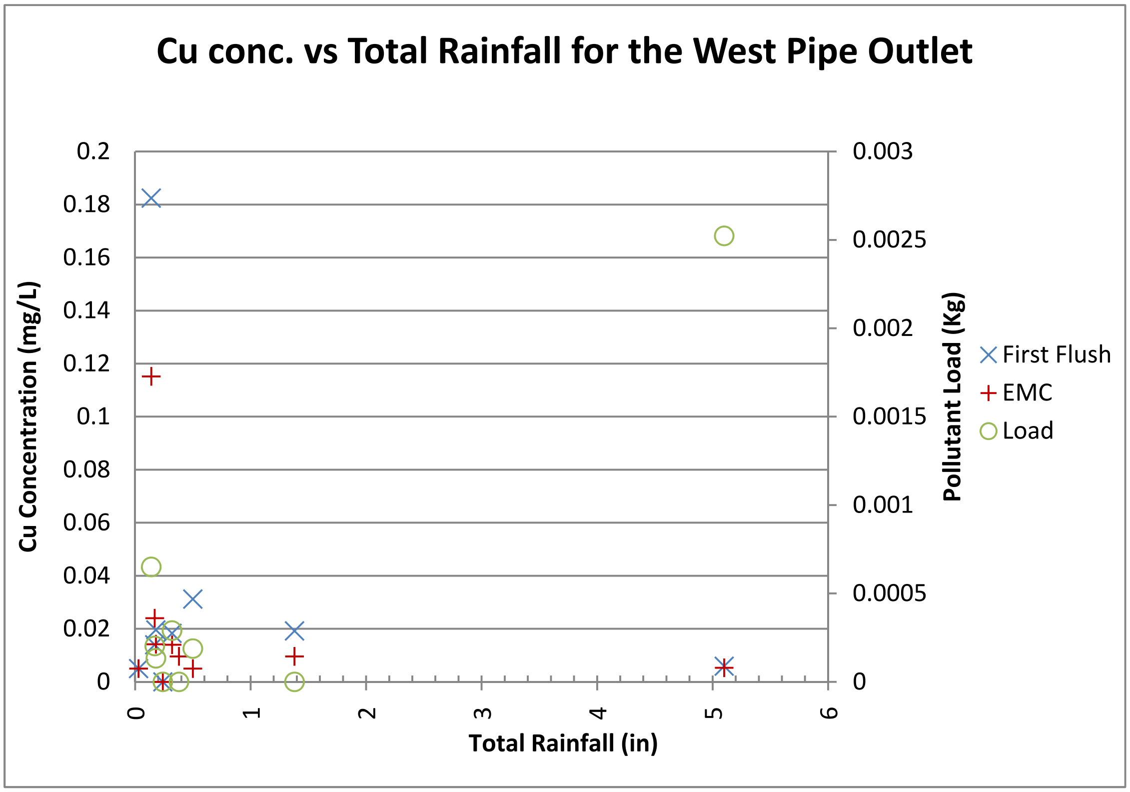

Figure 6-34 Cu Concentration and Total Rainfall for the West Pipe Outlet

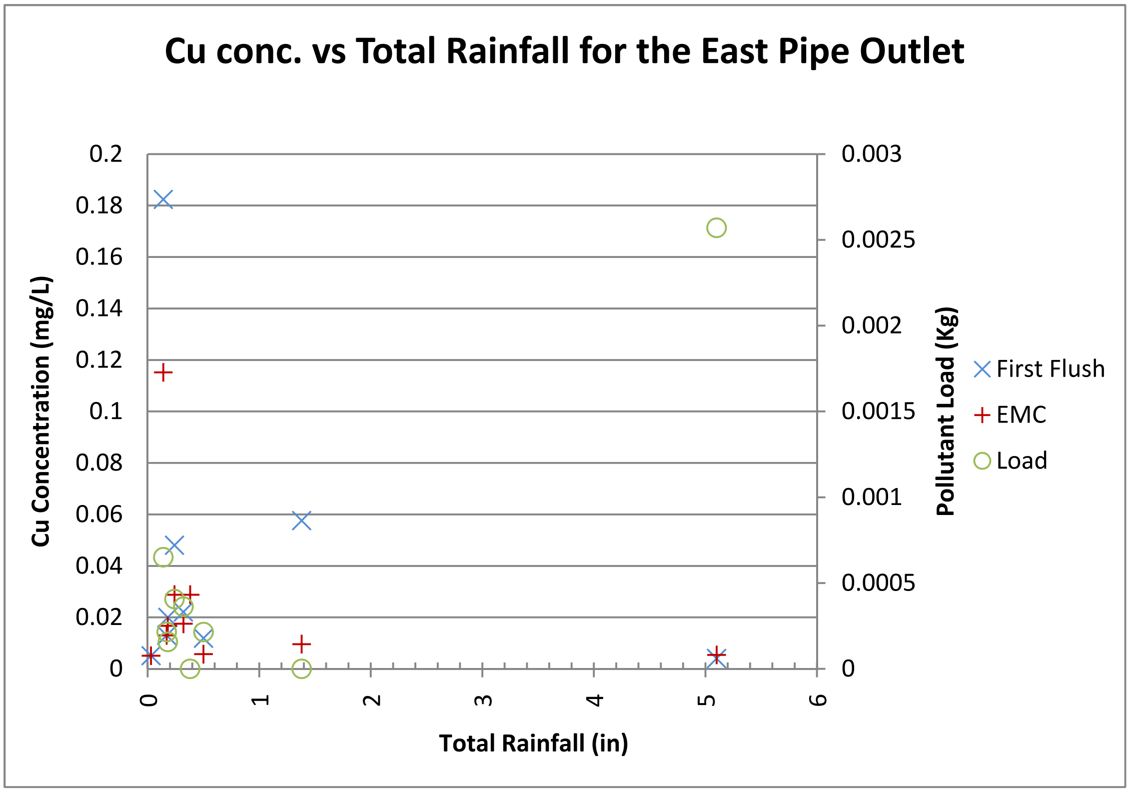

Figure 6-35 Cu Concentration and Total Rainfall for the East Pipe Outlet

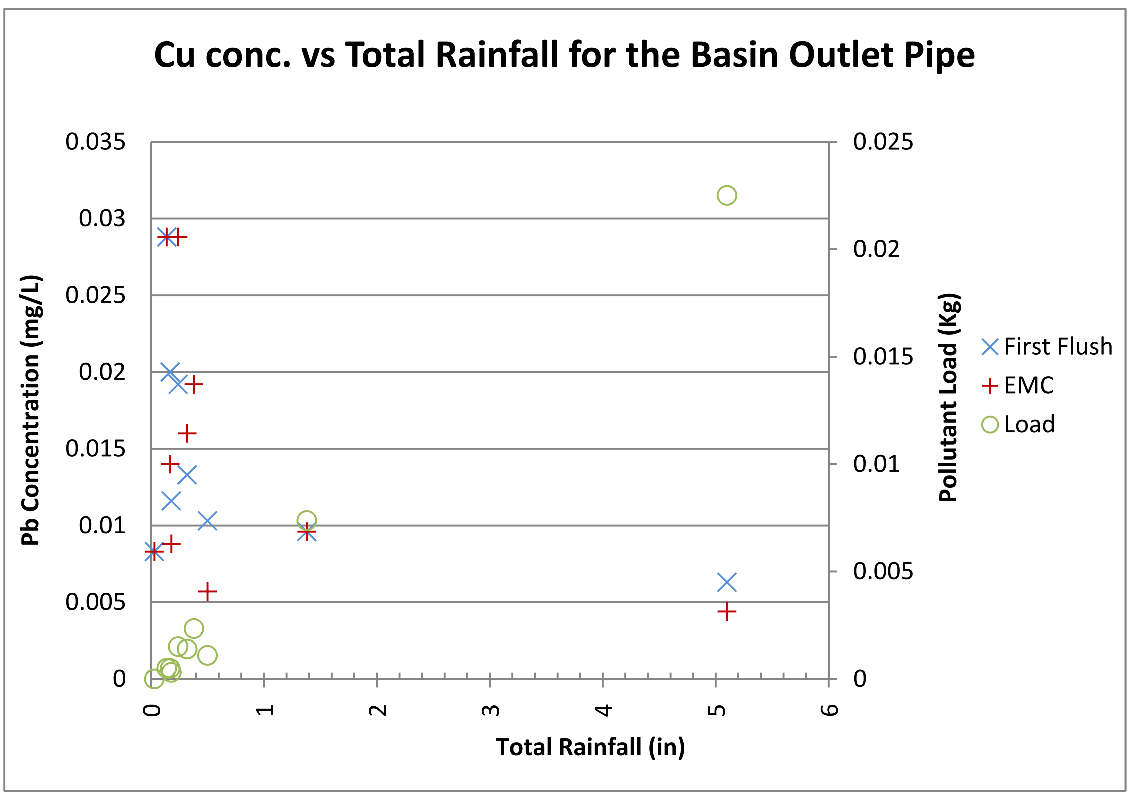

Figure 6-36 Cu Concentration and Total Rainfall for the Basin Outlet Pipe

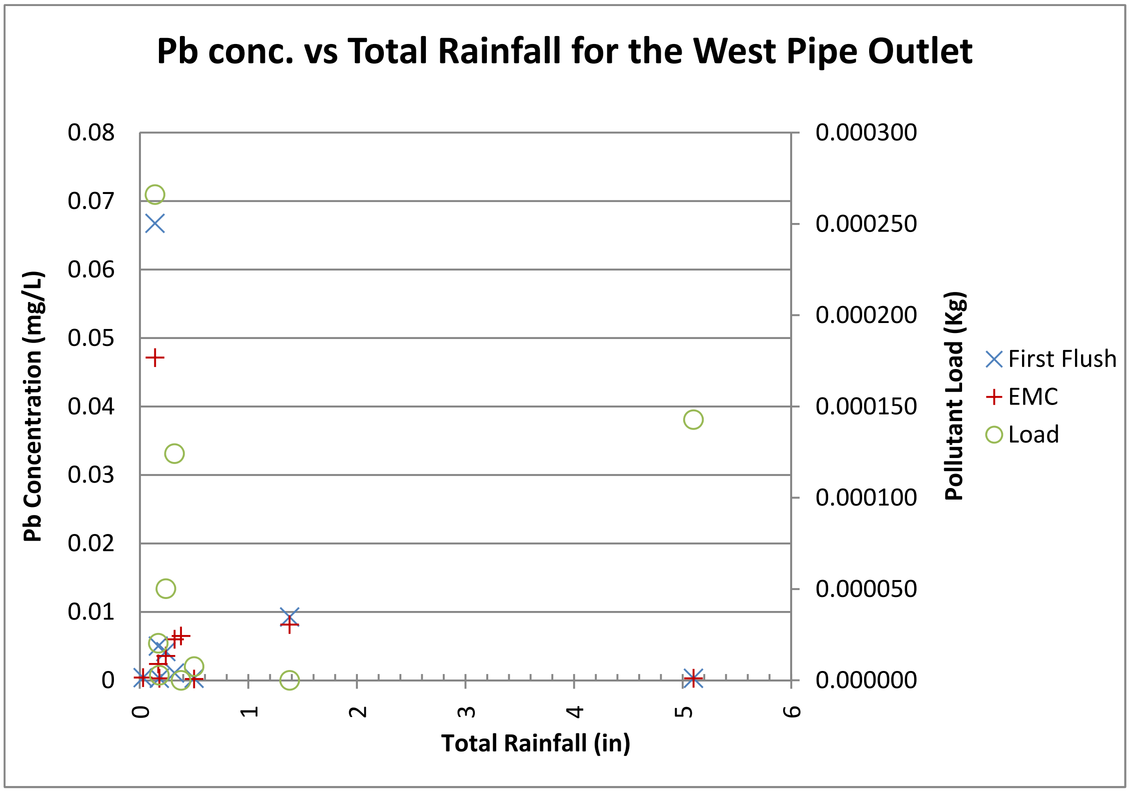

Figure 6-37 Pb Concentration and Total Rainfall for the West Pipe Outlet

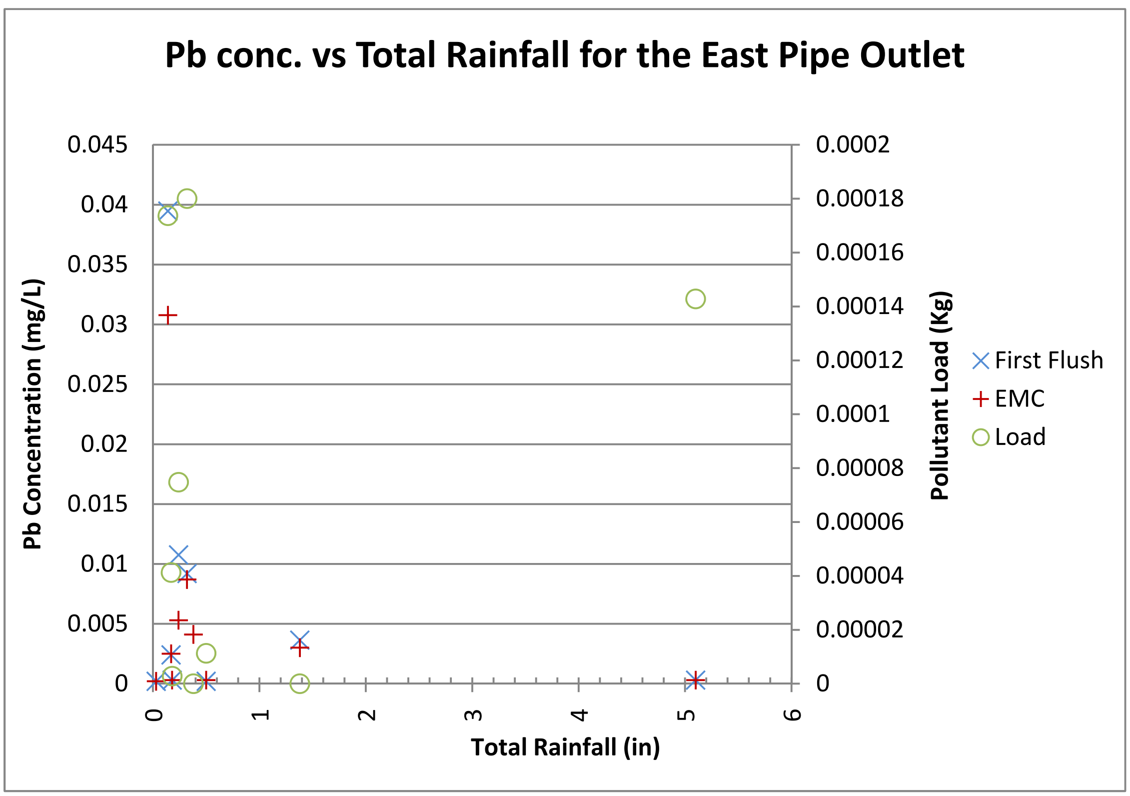

Figure 6-38 Pb Concentration and Total Rainfall for the East Pipe Outlet

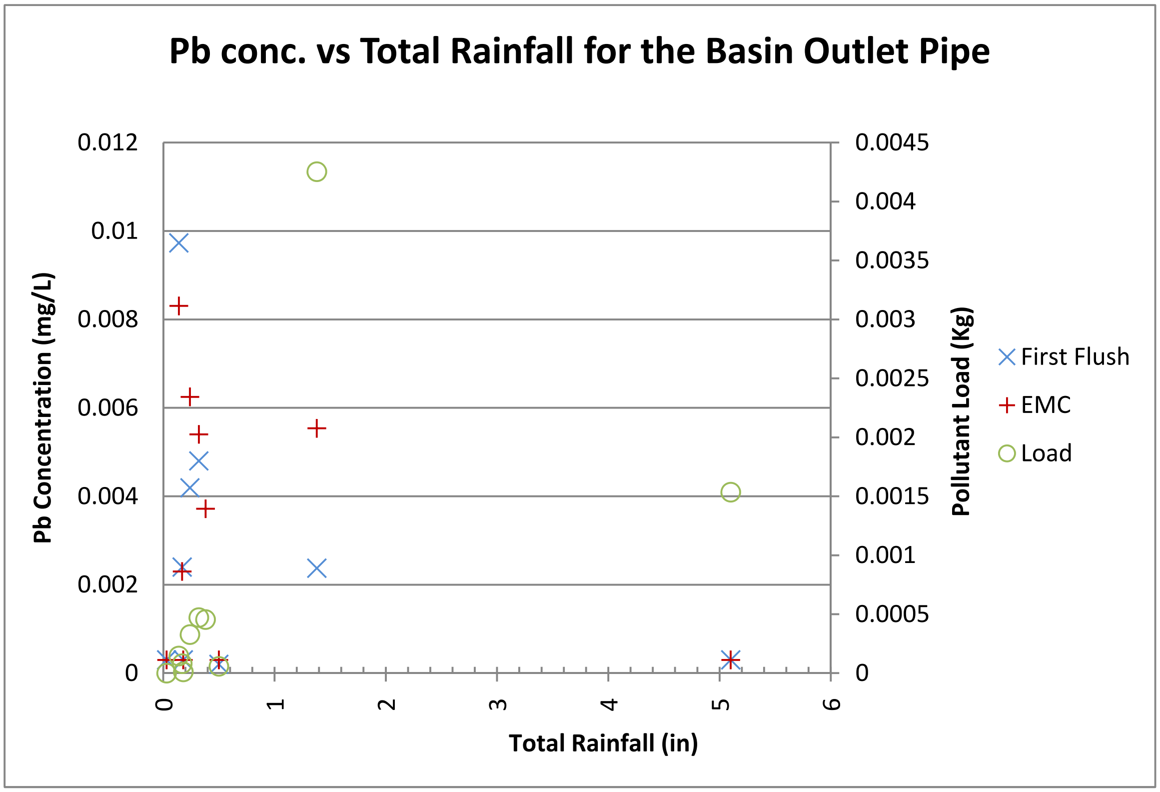

Figure 6-39 Pb Concentration and Total Rainfall for the Basin Outlet Pipe

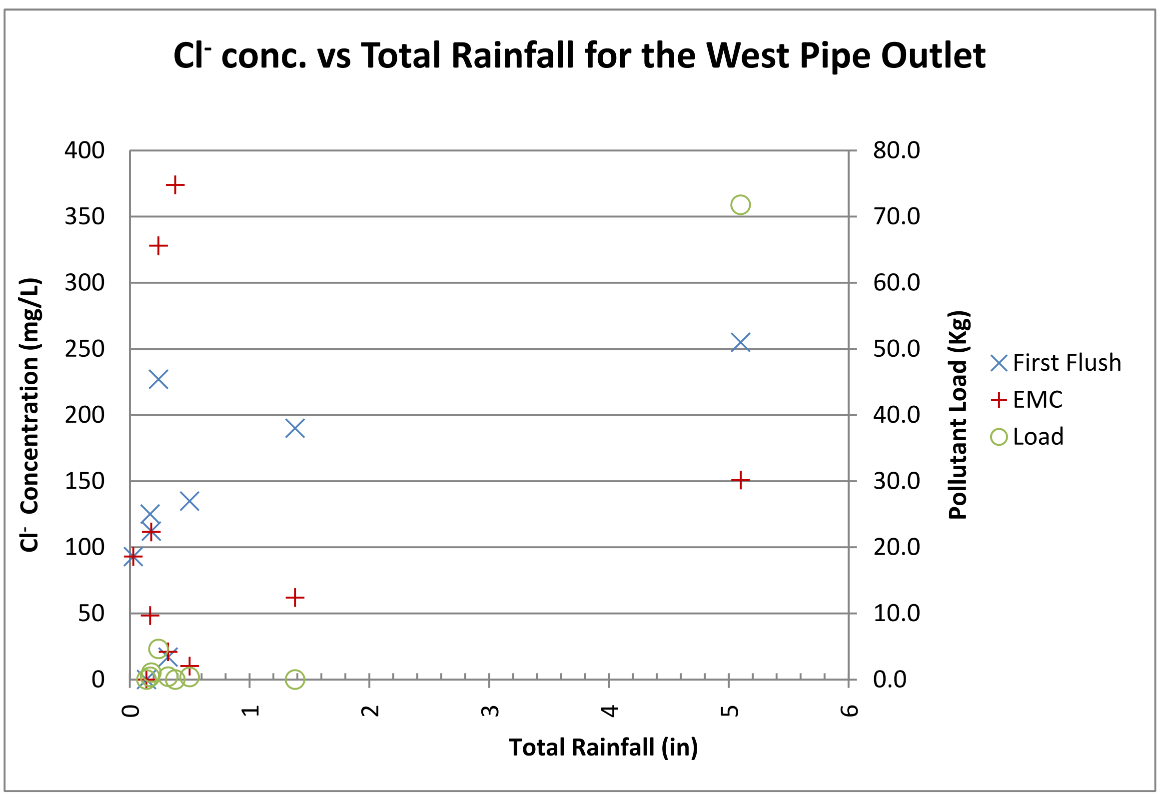

Figure 6-40 Cl^- Concentration and Total Rainfall for the West Pipe Outlet

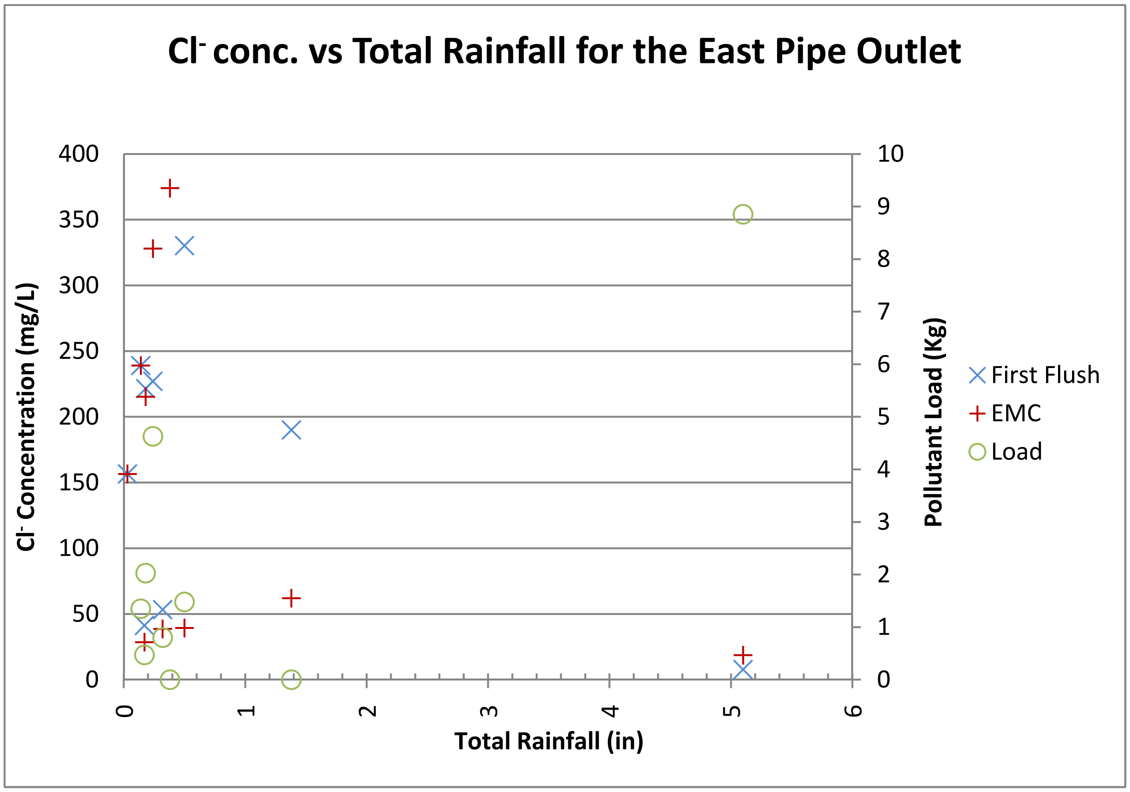

Figure 6-41 Cl⁻ Concentration and Total Rainfall for the East Pipe Outlet

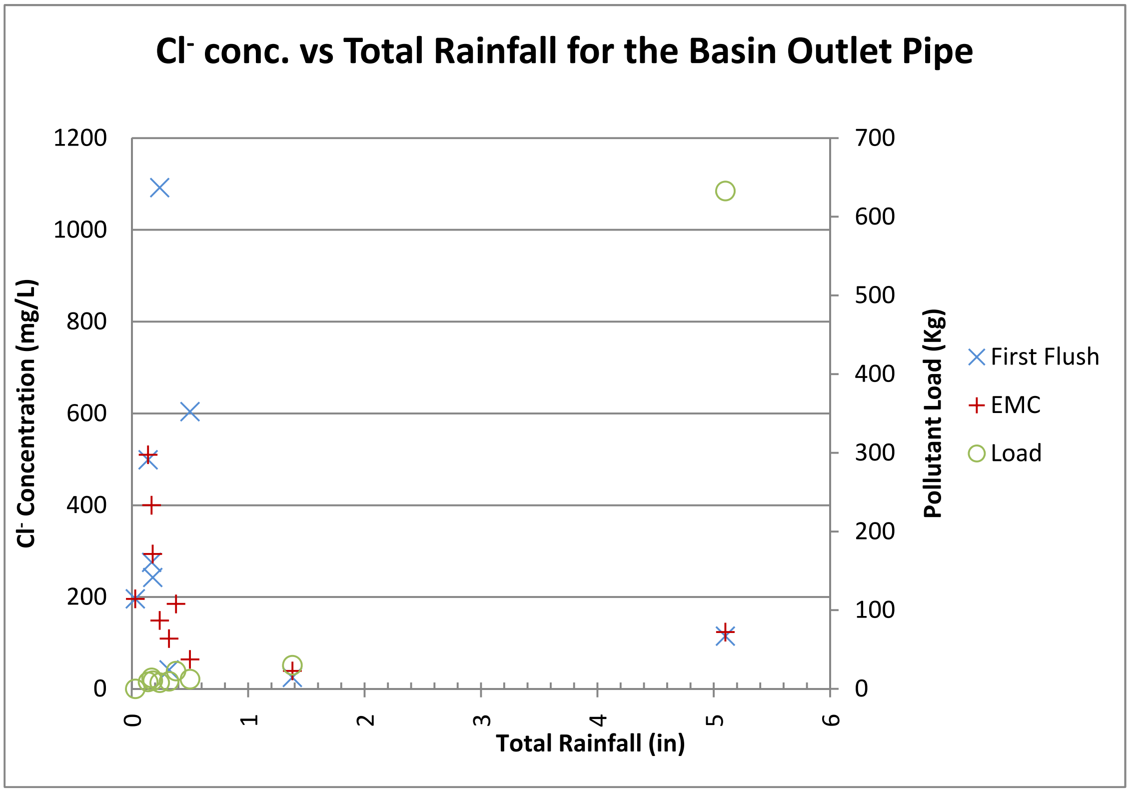

Figure 6-42 Cl⁻ Concentration and Total Rainfall for the Basin Outlet Pipe

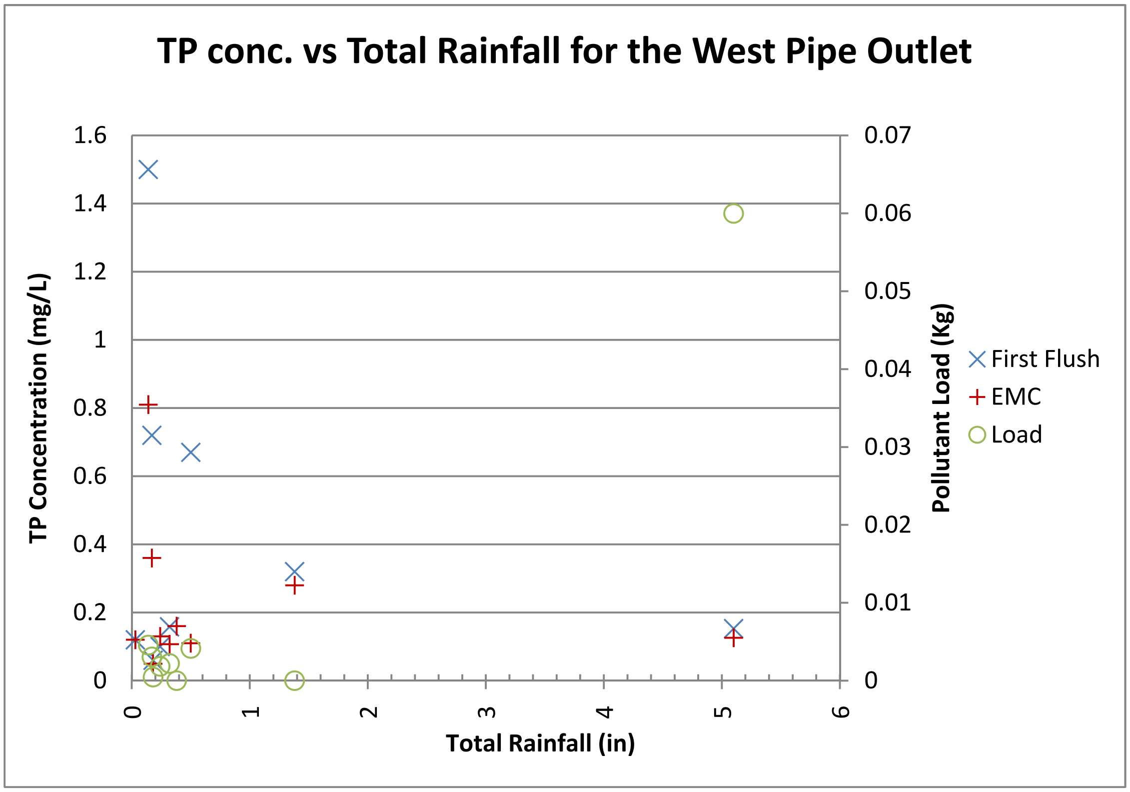

Figure 6-43 TP Concentration and Total Rainfall for the West Pipe Outlet

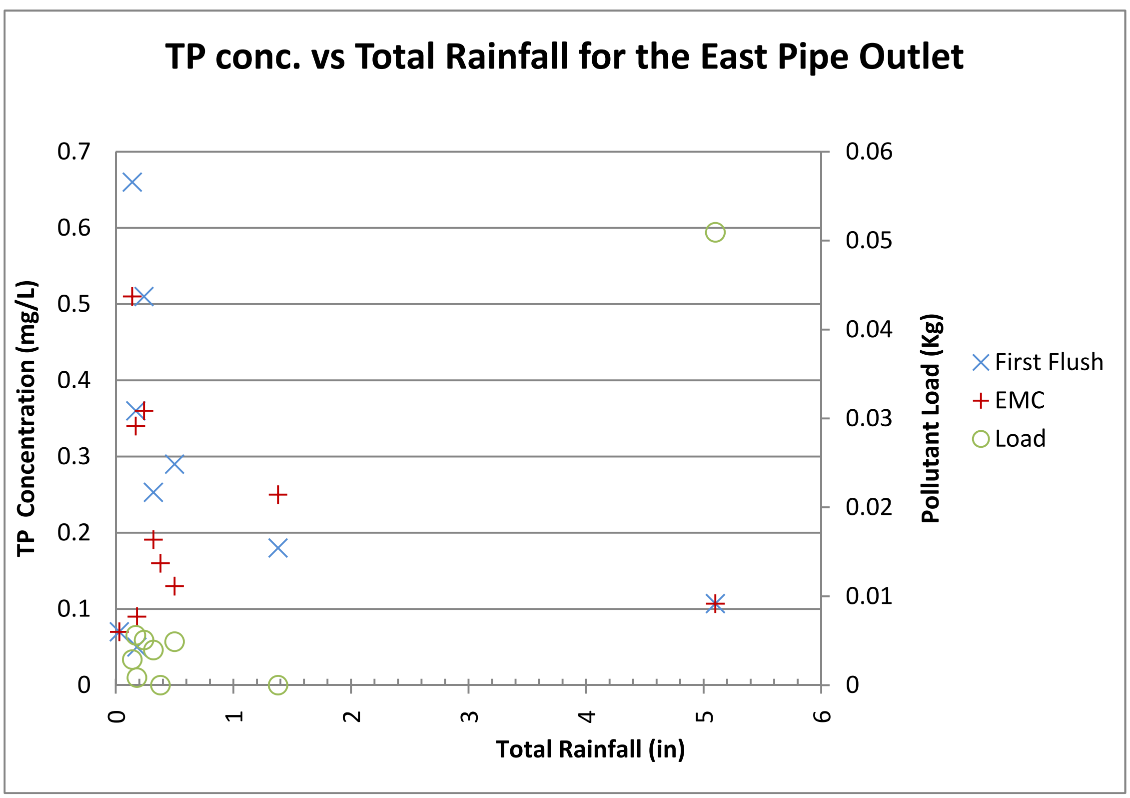

Figure 6-44 TP Concentration and Total Rainfall for the East Pipe Outlet

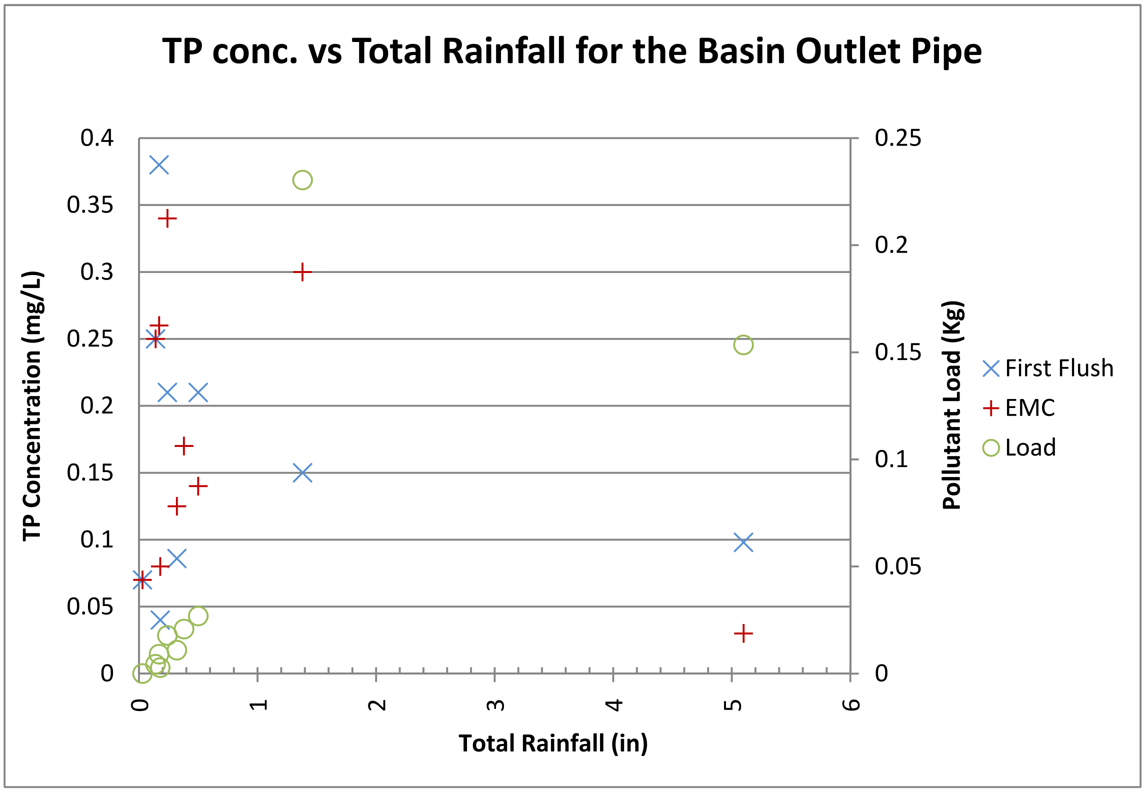

Figure 6-45 TP Concentration and Total Rainfall for the Basin Outlet Pipe

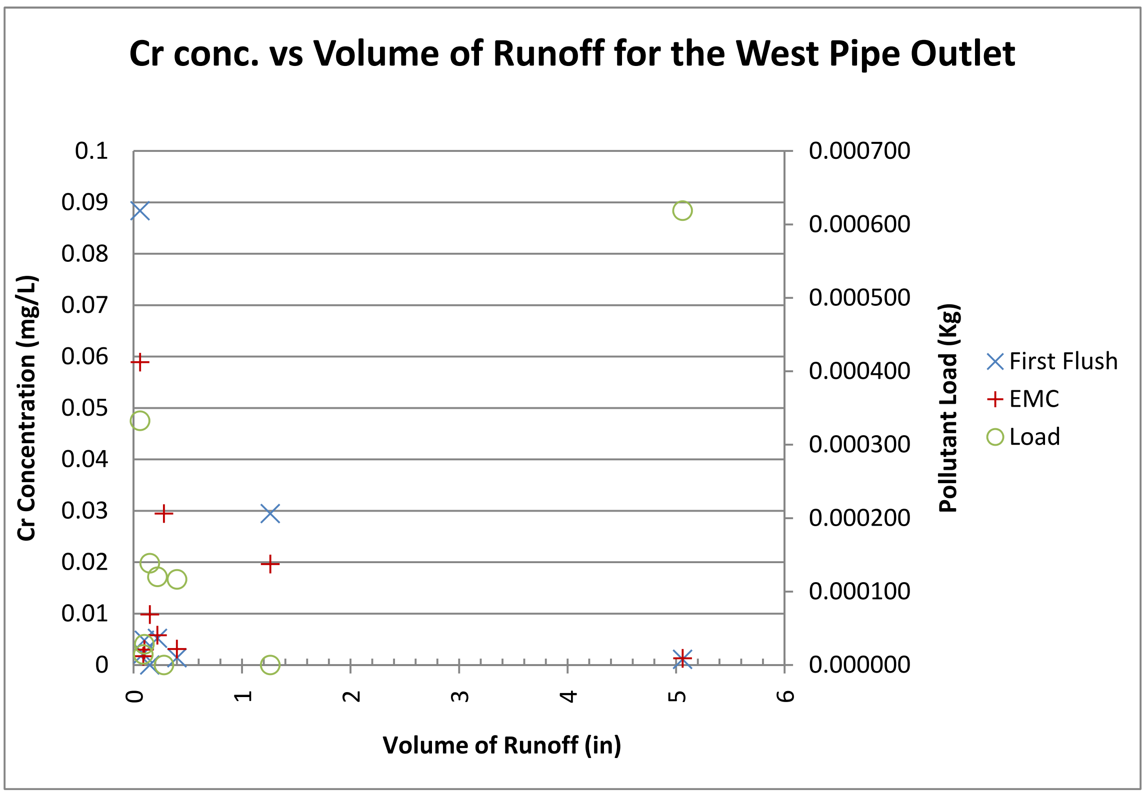

Figure 6-46 Cr Concentration and Volume of Runoff for the West Pipe Outlet

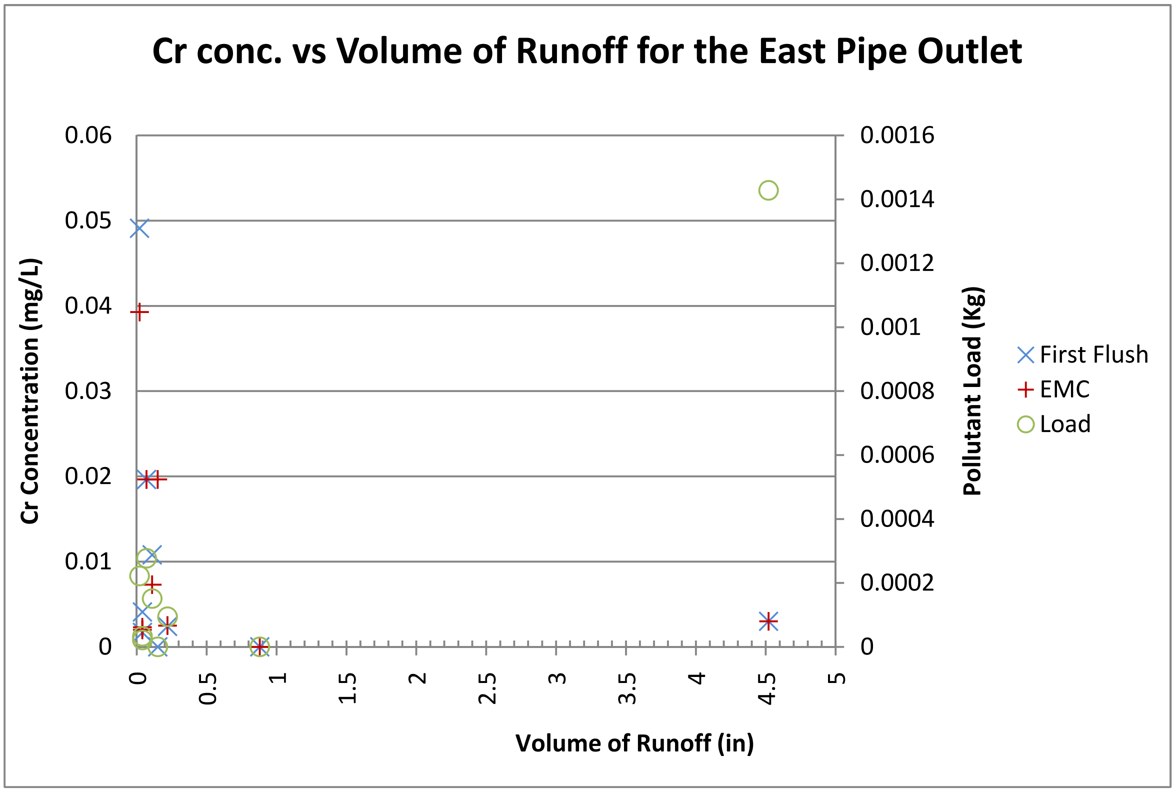

Figure 6-47 Cr Concentration and Volume of Runoff for the East Pipe Outlet

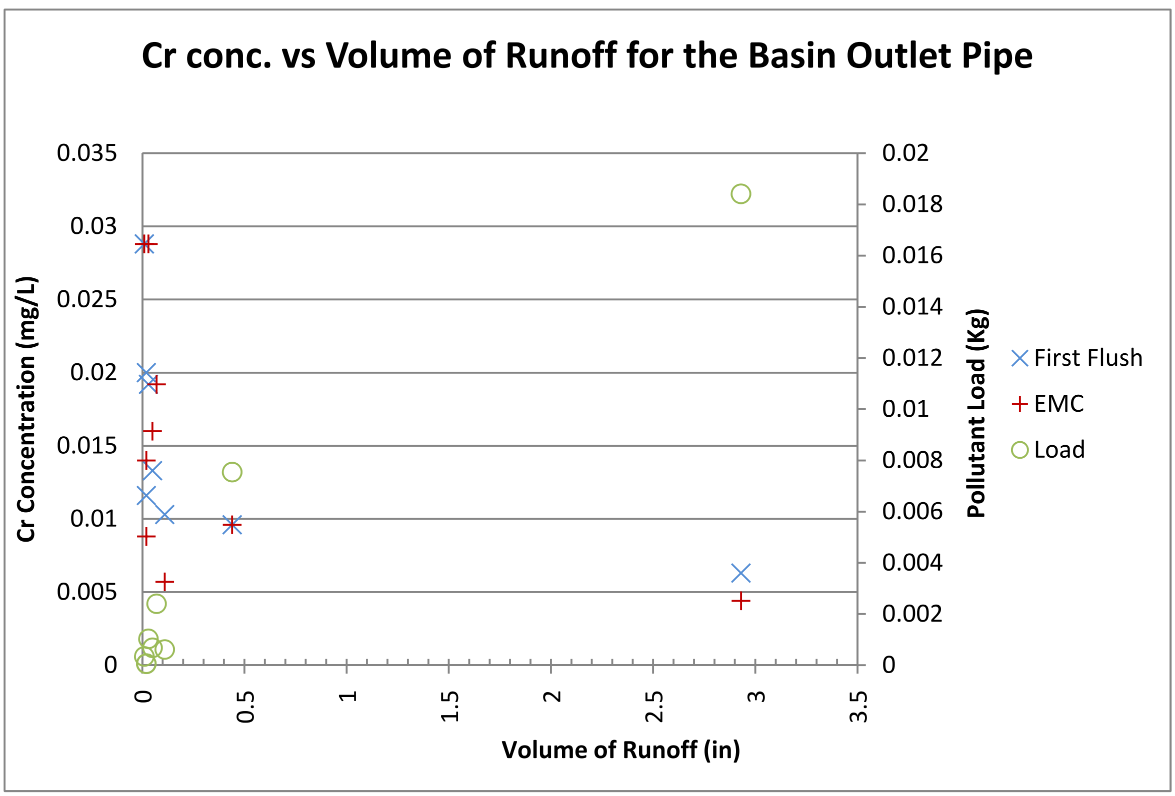

Figure 6-48 Cr Concentration and Volume of Runoff for the Basin Outlet Pipe

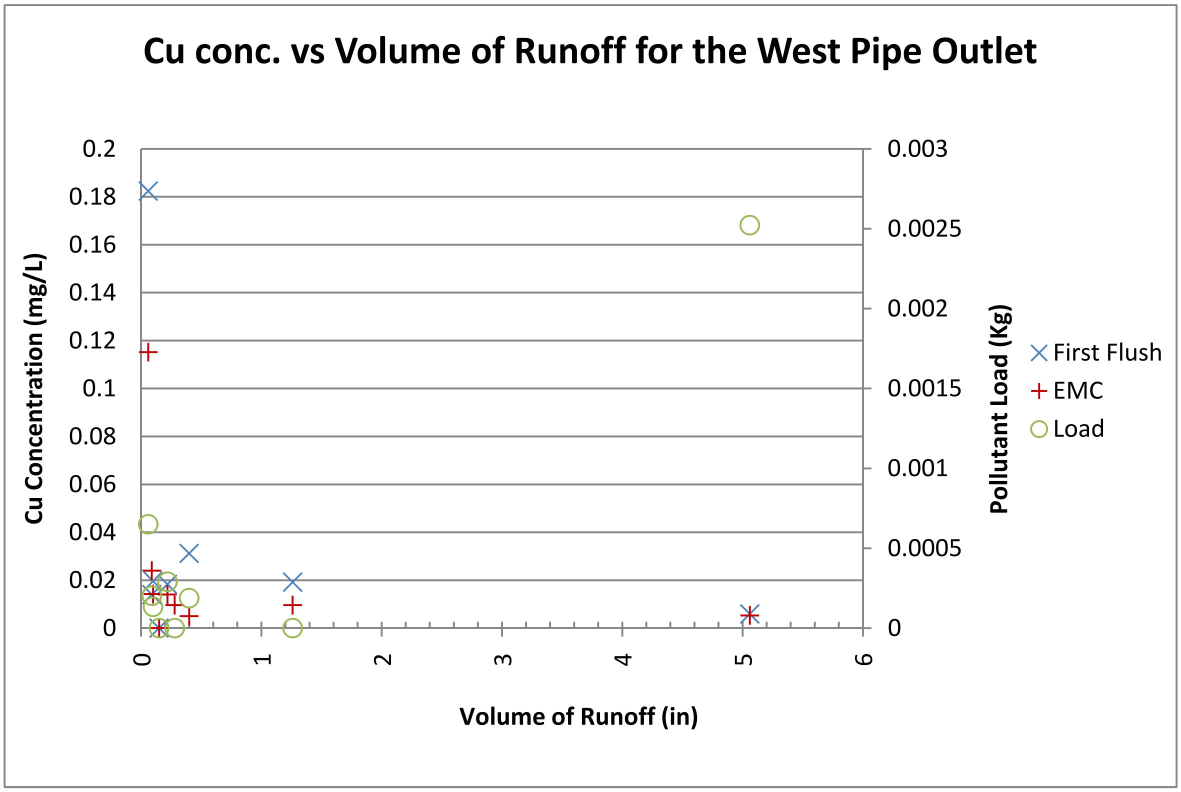

Figure 6-49 Cu Concentration and Volume of Runoff for the West Pipe Outlet

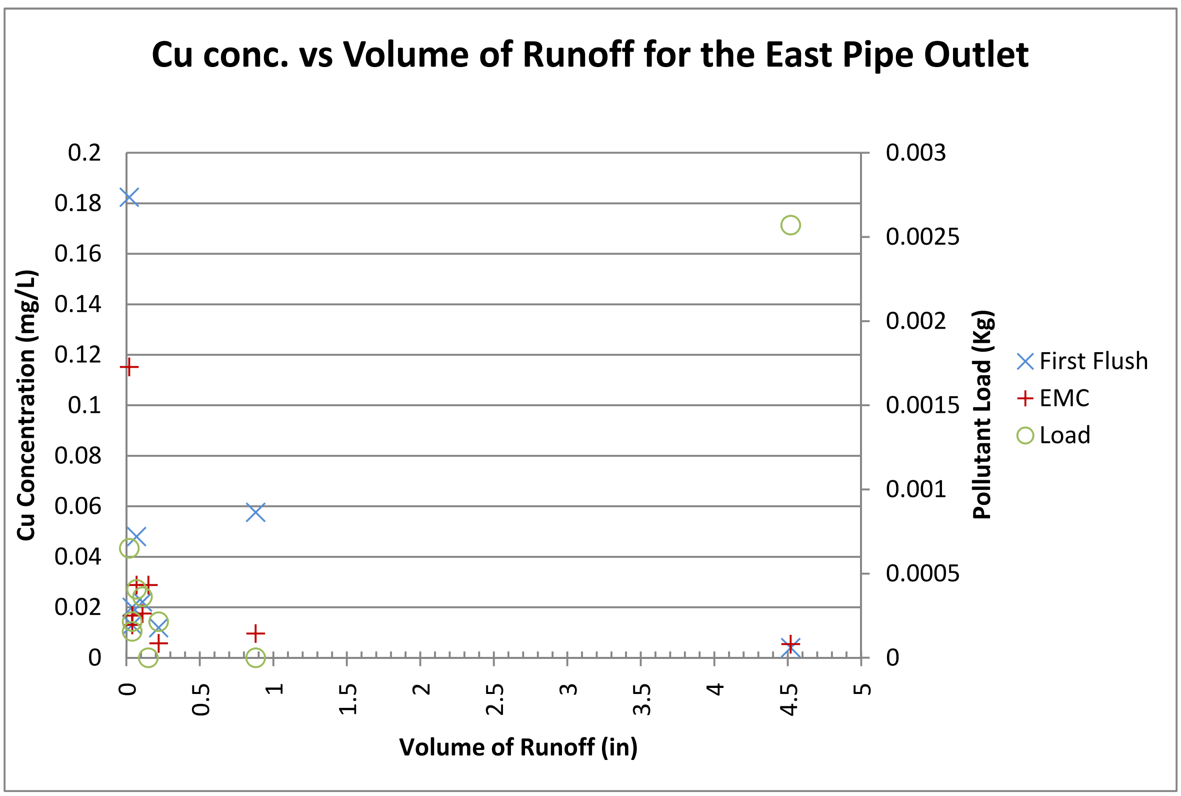

Figure 6-50 Cu Concentration and Volume of Runoff for the East Pipe Outlet

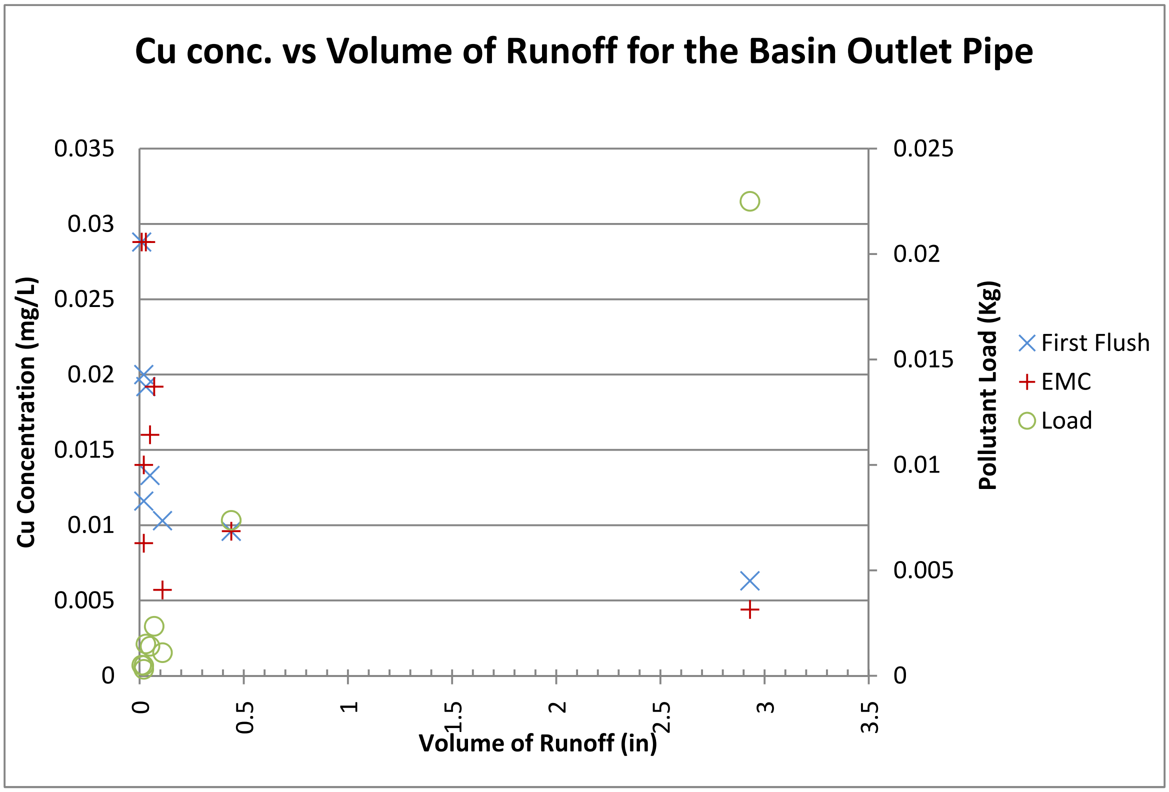

Figure 6-51 Cu Concentration and Volume of Runoff for the Basin Outlet Pipe

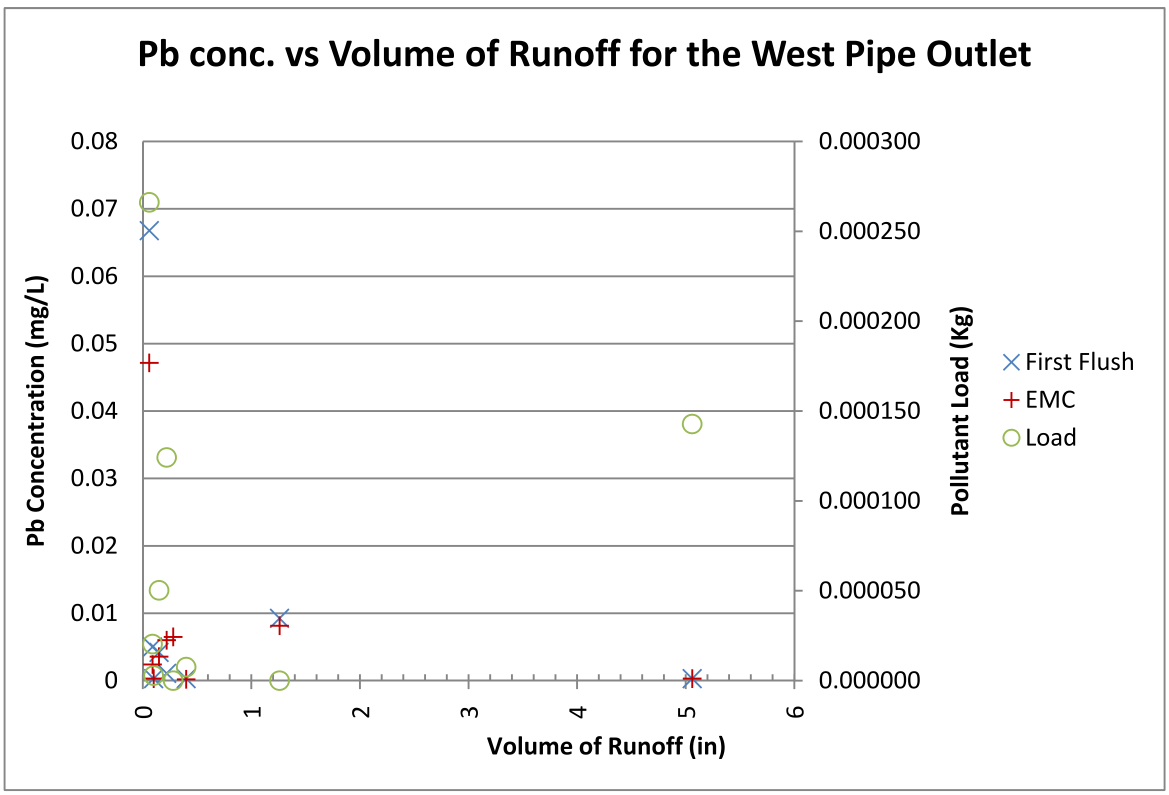

Figure 6-52 Pb Concentration and Volume of Runoff for the West Pipe Outlet

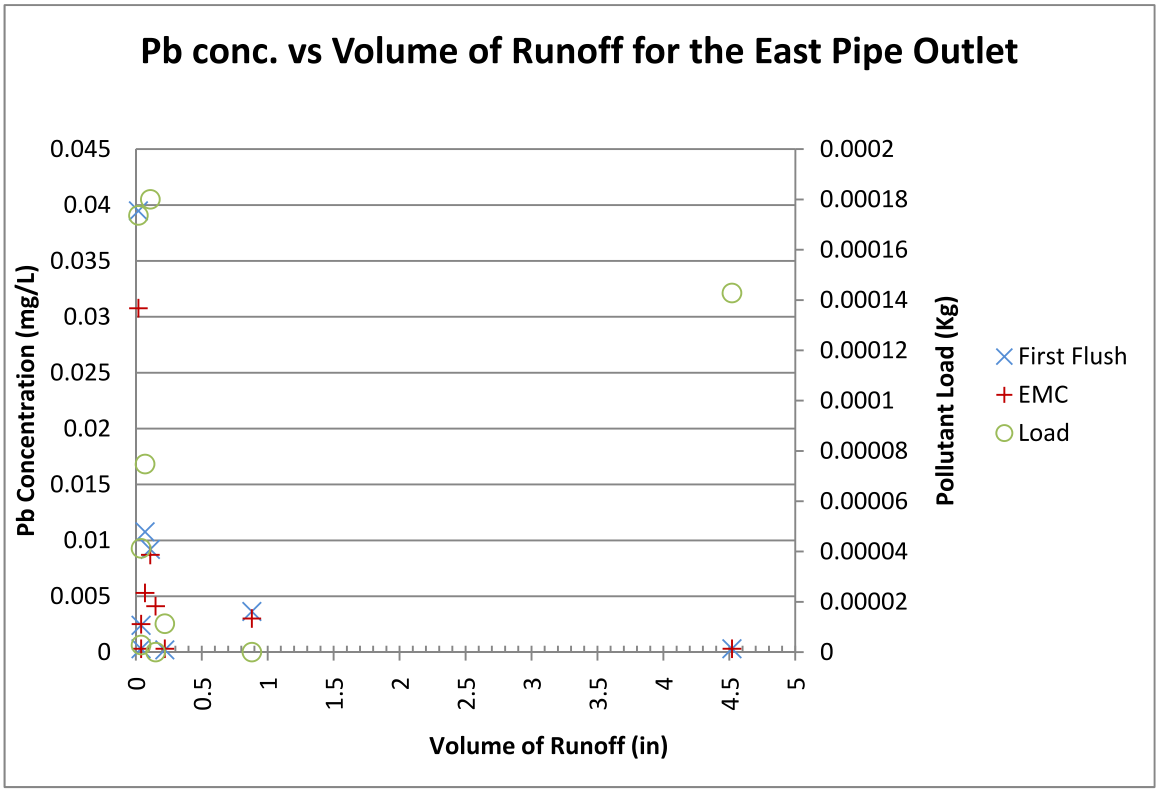

Figure 6-53 Pb Concentration and Volume of Runoff for the East Pipe Outlet

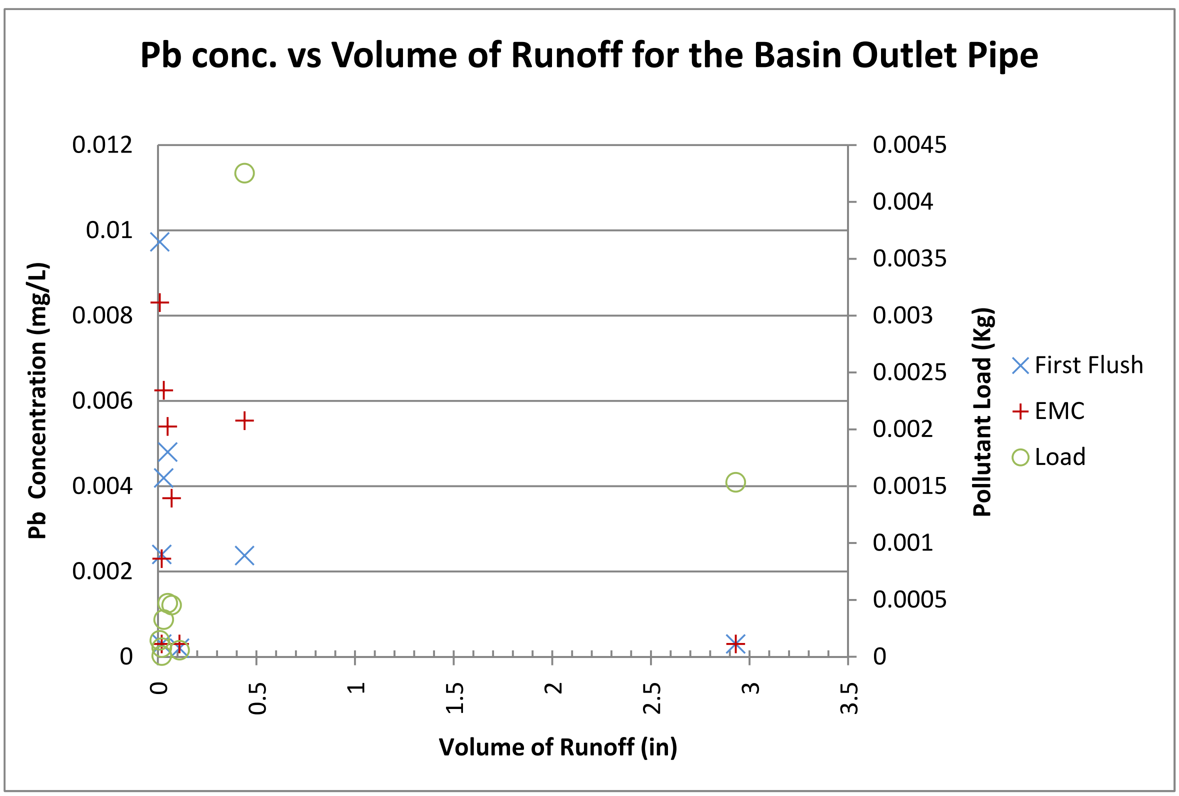

Figure 6-54 Pb Concentration and Volume of Runoff for the Basin Outlet Pipe

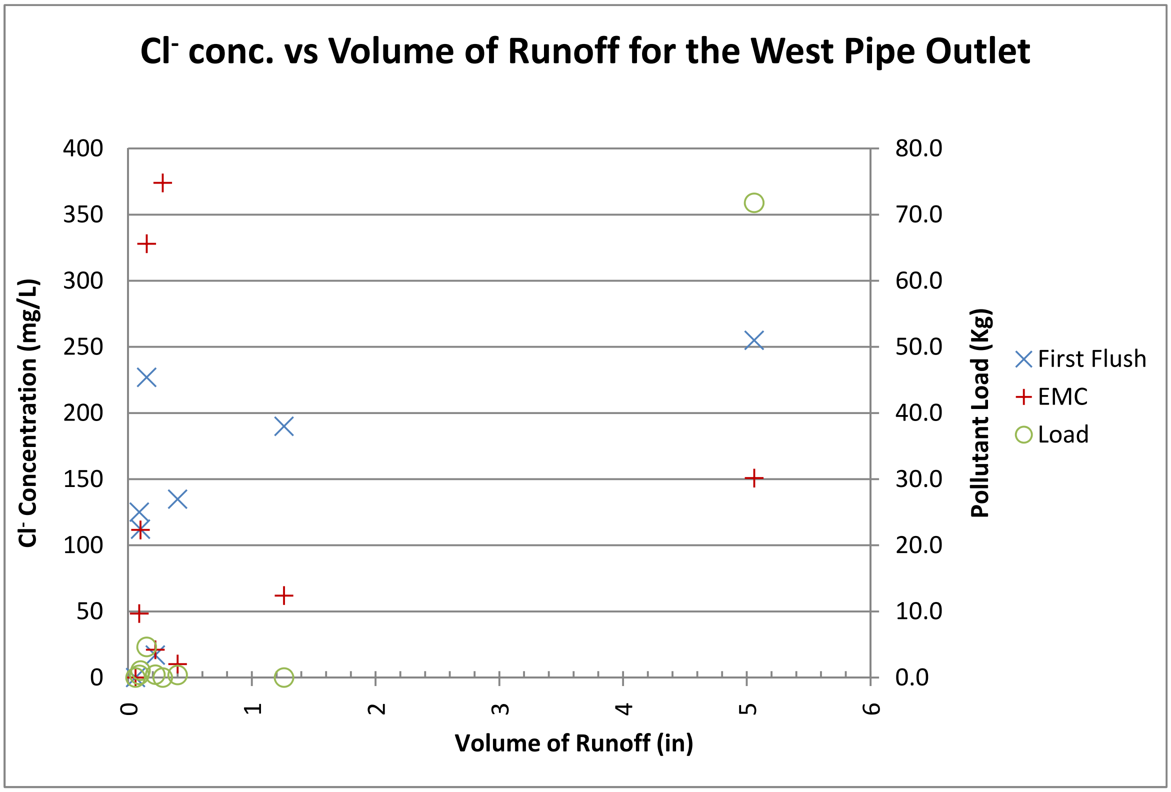

Figure 6-55 Cl$^-$ Concentration and Volume of Runoff for the West Pipe Outlet

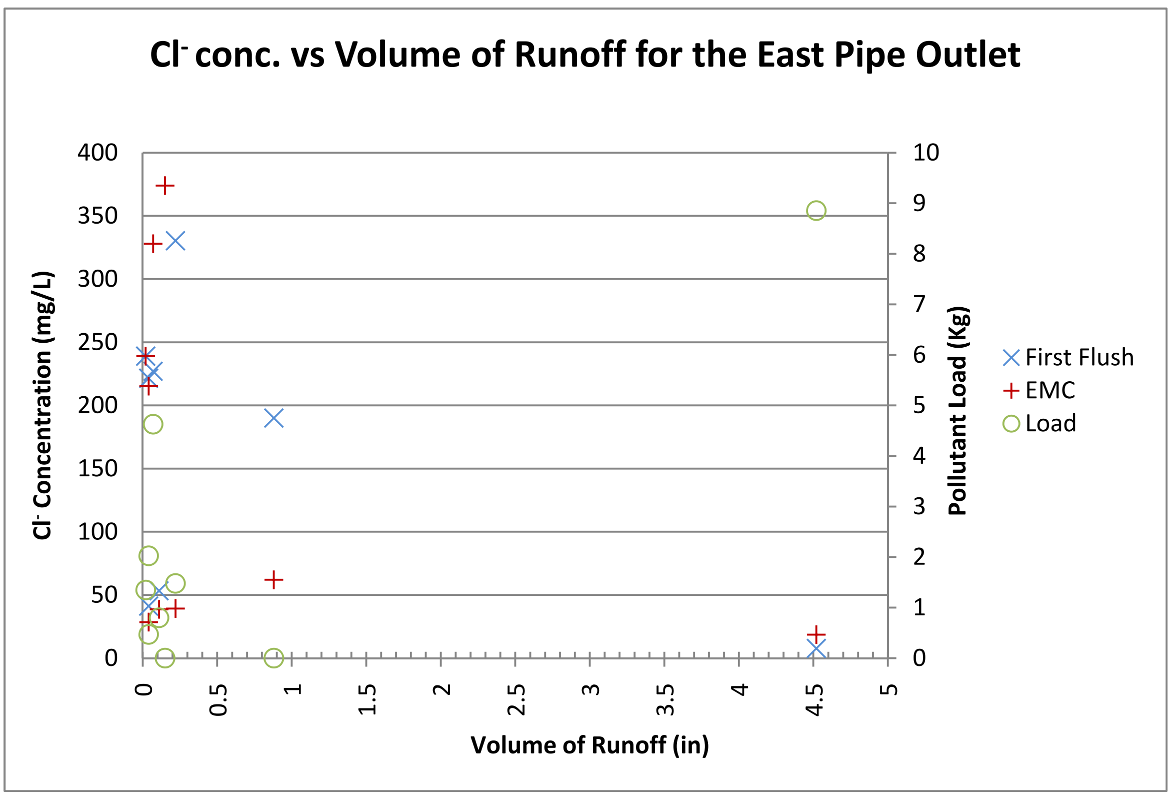

Figure 6-56 Cl$^-$ Concentration and Volume of Runoff for the East Pipe Outlet

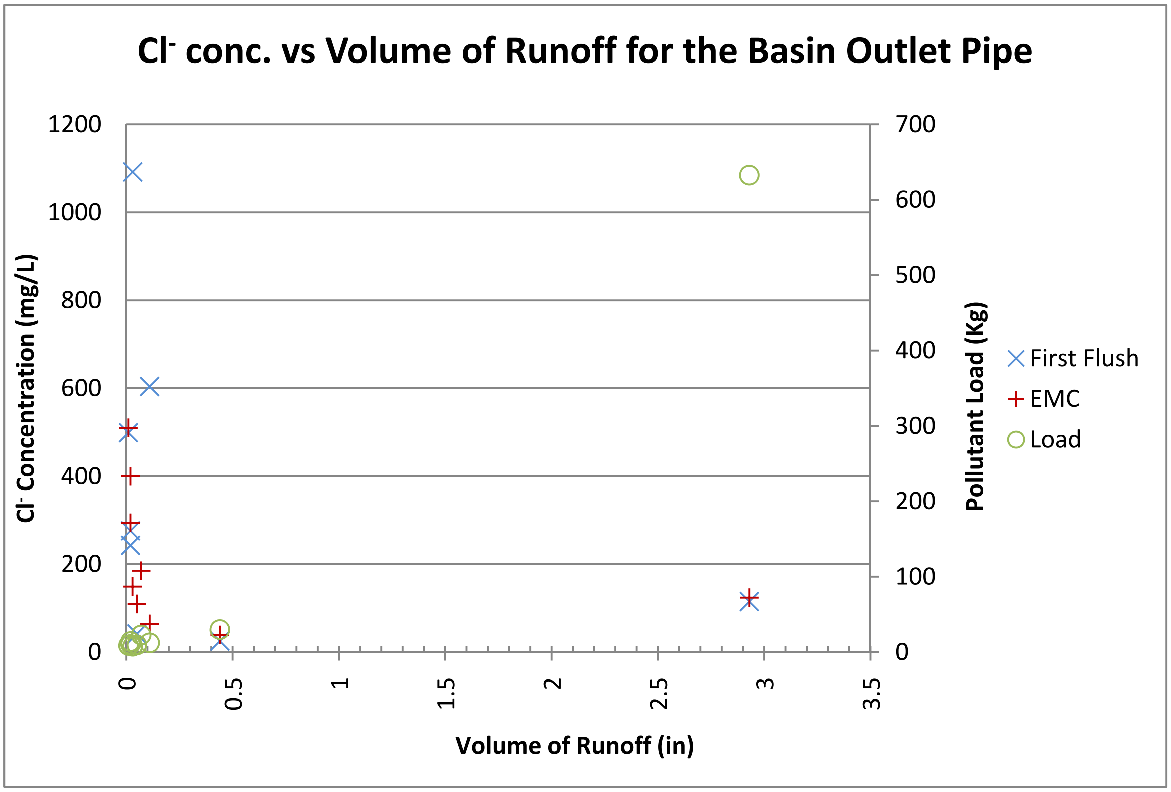

Figure 6-57 Cl^- Concentration and Volume of Runoff for the Basin Outlet Pipe

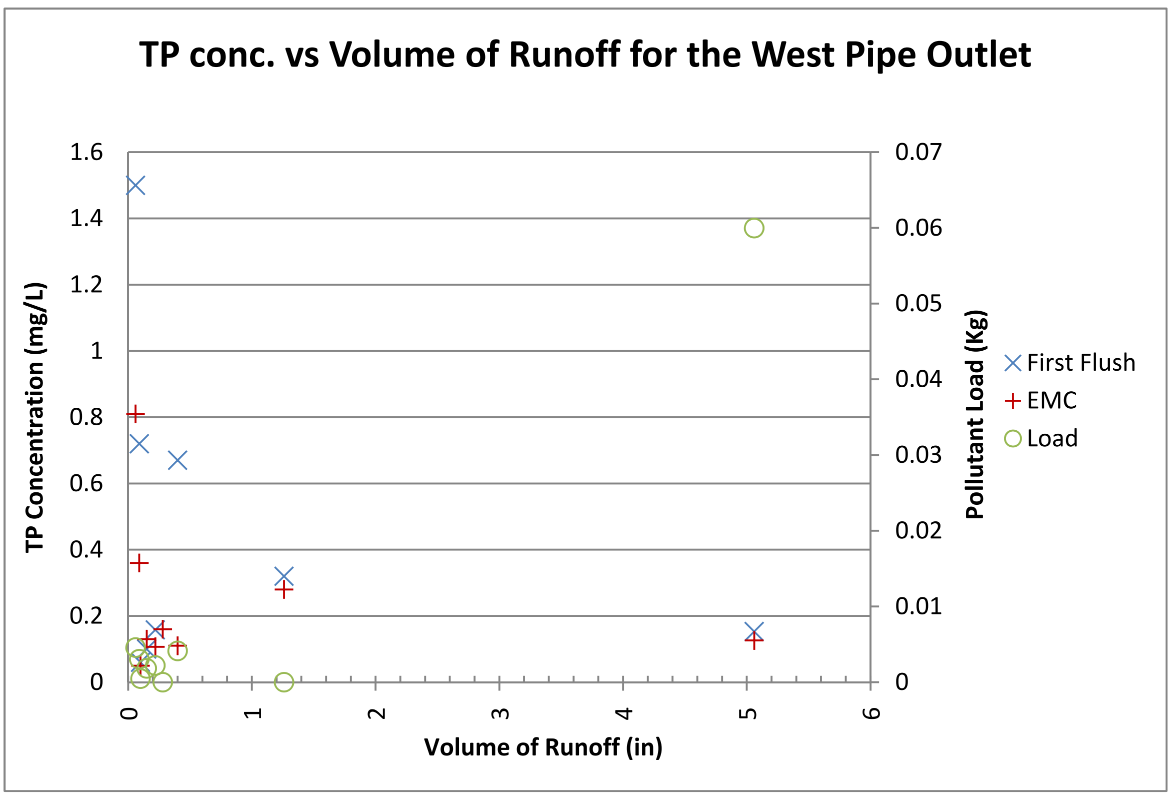

Figure 6-58 TP Concentration and Volume of Runoff for the West Pipe Outlet

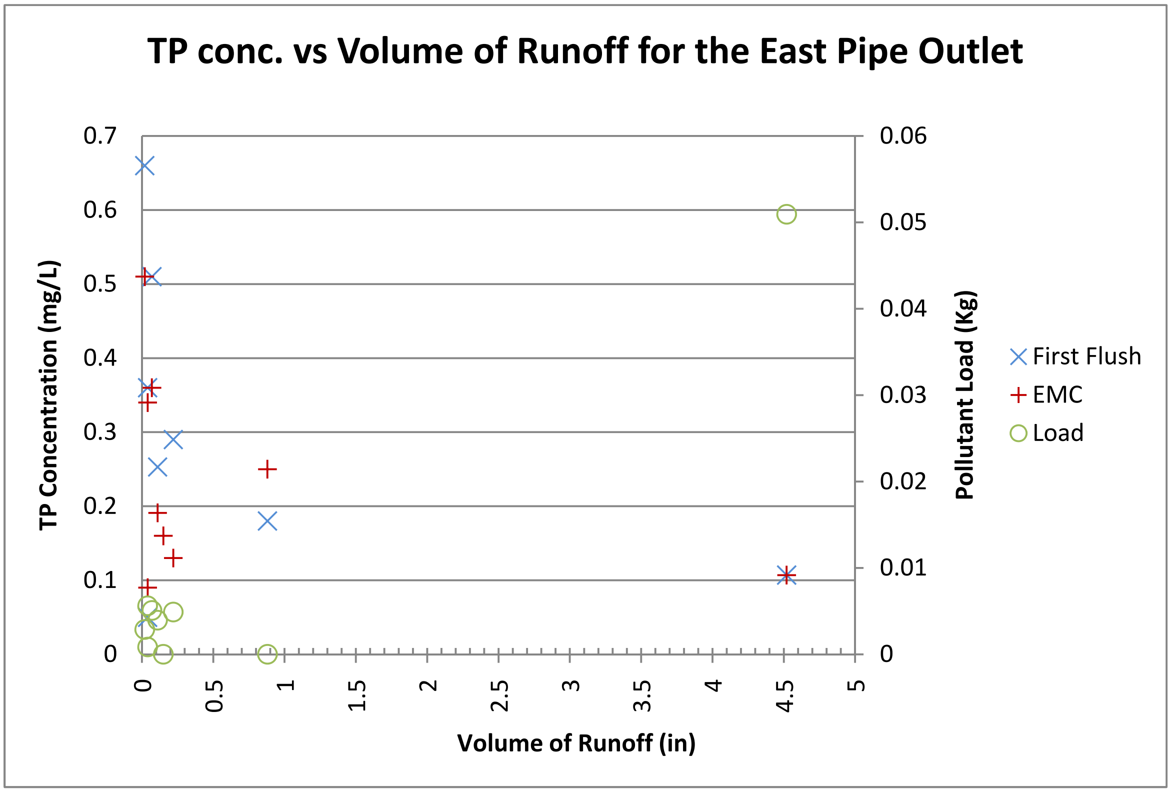

Figure 6-59 TP Concentration and Volume of Runoff for the East Pipe Outlet

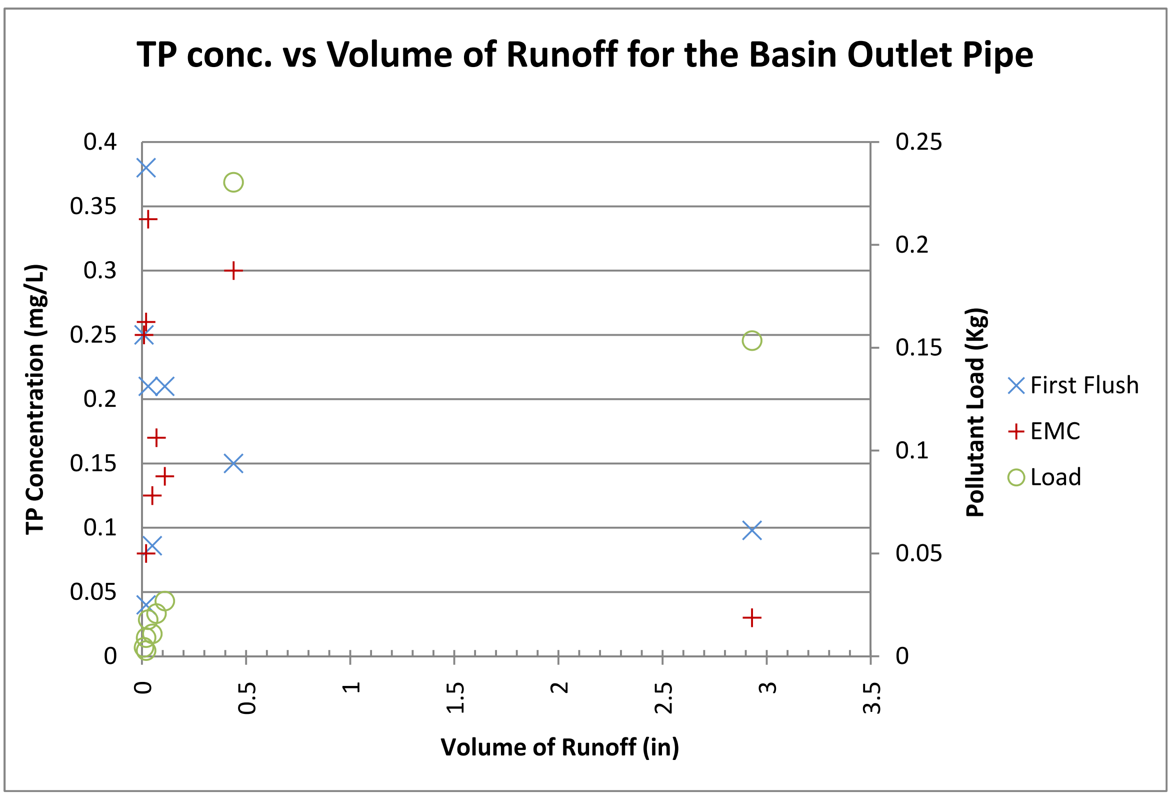

Figure 6-60 TP Concentration and Volume of Runoff for the Basin Outlet Pipe

6.2 Comparison with Similar Studies

As mentioned in the introduction, highway runoff pollution has been a study subject for the past 30 years. Table 6-1 shows a comparison between the EMC from the current study and other studies done in California (Kayhanian et al., 2007), North Carolina (Wu et al., 1998), Texas (Barret et al., 1998), and a summary of several studies done by the Federal Highway Administration (FHWA) (Driscoll et al., 1990b).

Kayhanian et al. (2007) obtained samples from 34 highway sites in California, covering different annual average daily traffic levels and environmental conditions. Table 6-2 shows the characteristics of the sampled sites by Kayhanian et al.

Wu et al. (1998) studied three highway sites located inside the city of Charlotte. The site used for comparison purposes is a section of the W.T. Harries Blvd. that carries an average traffic of 25,000 vehicles/day and is a major artery around the north and east sites of the city of Charlotte, extending from I-77 on the north to U.S. 74 on the southeast. The drainage area was 0.37 acres and the surrounding land use was 69 percent woods, 24 percent residential, and 6 percent heavy commercial.

Barret et al. (1998) monitored three sites along the MoPac Expressway in the Austin, Texas area. The site selected for comparison with this study was the MoPac at 35th Street which had an average daily traffic of 60,000 vehicles per day. The land use of the area adjacent to the highway was mixed residential and commercial and the catchment area was 1.32 acres.

Driscoll et al. (1990) compiled results from 31 sites around the United States. Table 6-3 show the location and characteristics of the sites compiled by Driscoll et al.

Table 6-1. Comparison with Similar Studies

Analyte		NDOR Study						Wu et al.[a]			Kayhanian et al.[b]			Barret et al.[c]			Driscoll et al.[d]		
		West Pipe (EMC)			East pipe (EMC)			Monitoring Site I (EMC)			Range	Median	Mean	35th Street (EMC)			National Highway Runoff Report		
		Range	Median	Mean	Range	Median	Mean	Range	Median	Mean				Range	Median	Mean	Range	Median	Mean
Cu	(µg/L)	5 - 115.2	14.2	24.5	5.1 - 76.8	14.9	18.8	9.0 - 52	15	24.2	1.1 - 130	14.9	10.2	2.0 – 120	34	38	5 - 155	52	39
Cd	(µg/L)	-	<DL	<DL	-	<DL	<DL	<DL	<DL	<DL	0.2 - 8.4	0.24	0.13	-	-	-	-	-	-
Cr	(µg/L)	1.3 - 58.9	3.10	13.9	1.1 - 39.3	3.0	10.8	5.0 - 20	6.5	8.1	1.0 - 23	3.3	2.2	-	-	-	-	-	-
Pb	(µg/L)	0.2 - 47.1	2.5	6.59	0.2 - 30.8	2.5	5.26	7.0 - 56	15	21	1.0 - 480	7.6	1.2	7 – 440	50	99	11 - 1457	525	234
Fe	(µg/L)	2.8 - 125	79.5	66.8	2.9 – 1233	7.5	271	-	-	-	32 - 3310	378	150	300 – 10000	2606	3537	-	-	-
Ni	(µg/L)	0.6 - 29.9	3.7	7.94	0.6 – 20.0	2.3	6.63	9.0 - 17	9	8.1	1.1 - 40	4.9	3.4	-	-	-	-	-	-
Zn	(µg/L)	4.5 – 802	83.1	165	0.7 - 645.5	92.9	150	-	-	-	3 - 1017	68.8	40.4	34 – 590	208	237	40 - 2892	368	217
TDS	(mg/L)	42 – 3226	122	509	10 - 1334	157	332	61 - 577	107	157	3.7 - 1800	87.3	60.3	-	-		-	-	-
TSS	(mg/L)	47 – 1040	116	240	10 - 419	70	120	32 - 771	215	283	1. - 2988	112.7	59.1	33 – 914	131	202	9 - 406	143	93
COD	(mg/L)	14.6 – 276	46	90	20.1 – 200	30.6	52.1	4 - 177	48	70	-	-	-	18 – 464	126	149	41 - 291	103	84
NO_3^- + N_2^-	(mg/L)	0.2 - 2.4	0.5	0.8	0.23 - 1.8	0.5	0.63	0.08 - 13.37	0.38	2.25	0.01 - 4.8	1.07	0.6	0.0 – 3.66	1.03	1.25	0.19 - 3.32	0.84	0.66
TKN	(mg/L)	0.64 - 9.04	1.62	2.40	0.49 - 3.86	1.2	1.71	0.76 - 2.45	1	1.42	0.1 - 17.7	2.06	1.4	-	-	-	0.38 - 3.51	1.79	1.48
Ortho P	(mg/L)	-	-	-	-	-	-	0.01 - 0.74	0.08	0.15	0.01 - 2.4	0.11	0.06	-	-	-	-	-	-
Total P	(mg/L)	0.05 - 0.81	0.22	0.248	0.07 - 0.51	0.2	0.215	0.04 - 1.54	0.2	0.43	0.03 - 4.69	0.29	0.18	0.07 - 1.09	0.33	0.42	-	-	-
O&G	(mg/L)	-	< DL	< DL	-	< DL	< DL	1.0 - 11-1	3.3	4.4	1. - 20	6.6	6	0.8 - 35.1	4.1	6.5	-	-	-

<DL: Below detection limit

[a] W.T. Harries Blvd, Charlotte, NC. ADT 25,000 vehicles/day. Drainage area 0.37 acres. Adjacent area: woods, residential, heavy commercial.

[b] 34 highway sites in California. Detailed information about the sites can be found in Table 6-2.

[c] MoPac at 35th Street, Austin, TX. ADT 60,000 vehicles/day. Catchment area 1.32 acres. Adjacent area: residential and commercial.

[d] 31 sites along the United States. Detailed information can be found in Table 6-3.

Table 6-2. Characteristics of the Sampled Sites by Kayhanian et al.

Monitoring site identification	Highway	Average annual rainfall (mm)	Catchments area (ha)	Average annual daily traffic	Surrounding land use[a]
1-34	299	1016	0.20	9100	Rural
1-35	36	1016	0.48	3300	Rural
1-36	101	1016	0.87	5800	Rural
1-39	175	914	0.35	1800	Rural
2-01	36	889	0.65	2150	Rural
2-02	5	889	0.65	29,000	Rural
3-05	99	381	0.08	47,500	Commercial
3-06	80	762	0.60	74,000	Commercial
3-07	50	533	0.70	127,000	Commercial
3-224	65	742	1.21	36,000	Commercial
4-35	680	635	0.65	53,000	Rural residential
4-38	680	635	0.14	13,200	Agricultural, rural
4-39	580	635	0.09	134,000	Rural
5-03	25	660	0.04	2250	Rural
5-04	46	558	1.30	23,000	Rural
5-05	227	584	0.01	15,000	Commercial
5-06	1	660	5.95	55,000	Rural
6-05	198	178	0.37	14200	Agricultural
6-06	99	178	0.25	43,000	Agricultural
6-205	180	279	0.75	7200	Residential, Commercial
6-209	41	279	0.18	127,000	Residential
7-201	101	226	1.28	328,000	Residential
7-202	405	209	1.69	260,000	Residential, commercial
7-203	405	228	0.39	322,000	Residential, commercial
8-07	10	260	1.20	18,300	Rural
8-08	10	381	0.48	63,000	Residential
8-10	91	279	1.21	231,000	Rural
9-01	395	152	0.82	5800	Rural
10-02	120	965	0.73	4950	Mixed use
10-03	5	330	0.48	70,000	Rural
10-04	132	787	0.65	2100	Commercial
11-98	805	254	0.77	177,000	Residential, commercial
11-100	805	254	1.13	212,000	Residential, Army
11-101	8	330	0.19	175,000	Rural

[a]Runoff from surrounding land use did not contribute to the monitored drainage area.

Table 6-3. Characteristics of Study Sites Compiled by Driscoll et al.

Site Location	Avg. Daily Traffic (1000 VDP)		Number of Traffic Lanes		Section Type	Surface Type	Curb	Land Use	Area (Acres)	Percentage Impervious	Annual Rainfall (in/yr)
	Total	Monitored Lanes	Total	Monitored Lanes							
Little Rock I-30	42	42	4	4	Bridge, fill	Asphalt	No	Urban – Residential	1.5	90	48.7
Los Angeles I-405	200	200	8	8	Fill	Concrete	Yes	Urban – Commercial/ residential	3.2	100	12.6
Sacramento Hwy 50	86	43	8	4	At grade	Concrete	Yes	Urban – Suburban	2.45	82	16.3
Walnut Creek I-680	70	70	6	6		Concrete	Yes	Urban – Residential	2.1	100	20.3
Denver I-25	149	149	10	10	At grade	Asphalt	Yes	Urban – Suburban	35.3	37	14.8
Broward CO Hwy 834	20	20	6	6	At grade	Asphalt	Both	Urban – Commercial/ residential	58.3	36	62
Miami I-95	140	70	6	3	Bridge	Asphalt	Yes	Urban - Undefined	1.43	100	59.8
Minneapolis I-94	80	80	10	10	Cut	Concrete	Yes	Urban – Commercial/ residential	21	55	24.8
St Paul I-94	65	65	6	6	Cut and fill	Concrete	Yes	Urban – Commercial/ residential	16.3	49	24.8
Efland I-85	26	26	4	3	At grade	Asphalt	No	Non-urban – Undefined	2.49	51	43.6
Harrisburg I-81 (Ph. 1)	24	24	6	6	At grade	Concrete	No	Urban – Suburban	18.5	27	37.7
Harrisburg I-81 (Ph. 2)	56	28	4	2	At grade	Concrete	No	Urban – Suburban	2.81	45	37.7
Nashville I-40	88	88	6	6	Cut – At grade	Concrete	Yes	Urban - Undefined	55.6	37	45.0
Montesano SR-12	7.3	7.3	2	2	At grade	Asphalt	Yes	Non-urban – Agricultural	0.28	100	84.0
Pasco SR-12	4.0	2.0	4	2	Cut	Concrete	Yes	Non-urban - Desert	1.25	100	7.5
Pullman SR-270E	5.0	2.5	2	1	At grade	Asphalt	Yes	Non-urban – Agricultural	0.25	100	18.0
Seattle I-5	106	53	8	4	At grade	Concrete	Yes	Urban – Residential	1.22	100	34.1
Seattle SR-520	84	42	4	2	Bridge	Concrete	Yes	Urban - Undefined	0.099	100	35.0
Snoq. Pass I-90	15	7.7	6	3	At grade	Concrete	Yes	Non-urban – Forest	0.18	100	97.0
Spokane I-90	35	17	6	3	Bridge	Concrete	Yes	Urban – Undefined	0.22	100	17.2
Vancouver I-205	17	8.6	6	3	At grade	Concrete	Yes	Urban – Suburban	0.28	100	39.0
Milwaukee Hwy 45	85	85	6	6	Cut – At grade	Concrete	Yes	Urban – Residential	106	31	27.6
Milwaukee I-794	53	53	8	8	Bridge	Concrete	Yes	Urban - Undefined	2.1	100	27.6
Milwaukee I-94	116	116	8	8		Asphalt	Yes	Urban – Residential	7.6	64	27.6

Comparing the data obtained in this study with similar studies, it is possible to see that the data from this study are comparable to those of other studies. Concentrations of lead, TDS, and TSS differ the most comparing the other studies.

Lead concentrations from other studies (e.g., Barret et al. and Driscoll et al.) are higher than the concentrations found in this study. The reason for this discrepancy is not clear, the values reported in our study are for dissolved lead, and some of the other studies may have included total lead results: however, this alone would not likely account for the large discrepancy.

6.3 Environmental Impact of Highway Pollutants

6.3.1 Surface Water Quality Standards

The Nebraska Department of Environmental Quality (NDEQ, 2009) established general criteria for aquatic life. Table 6-4 and Table 6-5 show the acute and chronic concentrations for Metals and Inorganics and Selected Organic Compounds, respectively.

Table 6-4. Comparison of NDEQ Criteria for Aquatic Life for Metals and Inorganics and Mean EMC for the West and East Outlet Pipes

Analyte	Acute (mg/L)	Chronic (mg/L)	Mean EMC for the West Pipe Outlet (mg/L)	Max. Concentration for the West Pipe Outlet (mg/L)	Mean EMC for the East Pipe Outlet (mg/L)	Max. Concentration for the East Pipe Outlet (mg/L)	Mean EMC for the Detention Basin Outlet Pipe (mg/L)	Max. Concentration for the Detention Basin Outlet Pipe (mg/L)
Antimony	0.088	0.030	0.0045	0.0098	0.0036	0.0068	0.00255	0.003
Arsenic	0.34	0.0167	0.005	0.008	0.0030	0.006	0.00280	0.003
Beryllium	0.130	0.0053	N.D	0.001	N.D	0.001	N.D	N.D
Cadmium	0.0017	0.0002	0.0015	**0.003**	**0.0022**	**0.00283**	**0.0023**	**0.0023**
Chromium (III)	0.489	0.064	0.0126	0.059	0.0108	0.03928	0.009	0.01964
Copper	0.011	0.008	**0.0224**	**0.115**	**0.0188**	**0.0768**	**0.014**	**0.0288**
Lead	0.053	0.002	0.0060	0.047	0.0053	0.0308	0.003	0.0083
Mercury	0.0014	0.00077	**0.0037**	**0.006**	**0.0033**	**0.005**	**0.003**	**0.0044**
Nickel	0.400	0.044	0.0068	0.030	0.0066	0.01996	0.004	0.014
Selenium	0.02	0.005	N.D	0.001	N.D	N.D	N.D	0.003
Silver	0.003	(Reserved)	N.D	N.D	N.D	N.D	N.D	N.D
Thallium	1.4	0.0063	N.D	N.D	N.D	N.D	N.D	N.D
Zinc	0.100	0.101	**0.147**	**0.802**	**0.150**	**0.645**	0.077	**0.166**
Chloride	Not to exceed 860 mg/l at any time or a four-day average concentration of 230 mg/l.		207.3	**1709**	139	690	207.3	510

Table 6-5. NDEQ Criteria for Aquatic Life for Selected Organic Compounds

Analyte	Acute (µg/L)	Chronic (µg/L)
Monocyclic Aromatics except Phenols, Cresols, and Phthalates		
Benzene	5300	712.8
Chlorinated benzenes	250	50
Dichlorobenzenes	1120	763
Ethylbenzene	32,000	29,000
Hexachlorobenzene	6.0	.0077
Nitrobenzene	27,000	1,900
Pentachlorobenzene	(Reserved)	41
1,2,4,5-tetrachlorobenzene	(Reserved)	29
1,2,4-trichlorobenzene	(Reserved)	940
Toluene	17,500	200,000
2,4-dinitrotoluene	330	91
Polycyclic Aromatic Hydrocarbons (PAHs)		
Acenaphthene	1,700	520
Anthracene	(Reserved)	110,000
Benzo(a)anthracene	(Reserved)	0.49
Benzo(a)pyrene	(Reserved)	0.49
Benzo(b)fluoranthene	(Reserved)	0.49
Benzo(k)fluoranthene	(Reserved)	0.49
Chrysene	(Reserved)	0.49
Dibenzo(a,h)anthracene	(Reserved)	0.49
Fluoranthene	3,980	370
Fluorene	(Reserved)	14,000
Ideno(1,2,3-cd)pyrene	(Reserved)	0.49
Naphthalene	2,300	620
2-chloronaphthalene	1,600	4,300
Phenanthrene	30	6.3
Pyrene	(Reserved)	11,000

Comparing the results obtained from the analyzed samples with the Nebraska surface water quality standards, Copper and Zinc have been found to be above the acute toxicity levels. Cadmium was found to be above the acute toxicity levels on two rainfall events; however, it was below the detection limits for the other storm events. Sodium was found to have high concentrations comparing to other metals. Sodium, calcium, and other salts are included in the NDEQ criteria for TDS and it should be less than 500 mg/L. For most of the rainfall events, the TDS criterion was exceeded.

The NDEQ criteria for aquatic life apply to streams rather than at a discharge point; therefore, pollutant concentrations may not exceed the NDEQ standards once the discharged water is diluted into the stream. Sampling the stream would be required to verify if the discharge from the study site would cause the stream to exceed the NDEQ criteria. However, dilution would reduce nearly all of the concentrations to below the acute criteria.

Another major pollutant found in this study was Total Extractable Hydrocarbons (TEH) as Diesel. Diesel fuels are similar to fuel oils used for heating (fuel oils no.1, no.2, and no. 4). Fuel oils consist of complex mixtures of aliphatic and aromatic hydrocarbons. The aliphatic alkanes (paraffins) and cycloalkanes (napthenes) are hydrogen saturated and make approximately 80-90 percent of the fuel oils. Aromatics (e.g., benzene) and olefins (e.g., styrene and indene) make 10-20 percent and 1 percent respectively, of the fuel oils. Diesel fuels predominately contain a mixture of C_{10} through C_{19} hydrocarbons, which include approximately 64 percent aliphatic hydrocarbons, 1-2 percent olefinic hydrocarbons, and 35 percent aromatic hydrocarbons (USDHHS, 1995). The compounds that were detected and reported as “diesel” are not generally included in the list of chemicals of environmental concern and are, therefore, not included in the list of VOCs and VOCs and SVOCs that are typically monitored in environmental studies. VOCs and

SVOCs analyzed in this study were mostly below the detection limit or were at very low concentrations because most of these analytes are not a significant diesel fuel constituent.

6.3.2 Impact of Highway Pollutants on Aquatic Life

Cadmium is a very toxic element and it can easily accumulate in the body. The salmonid species of fish are more sensitive to cadmium than the cyprinid varieties. An increase in water hardness reduces its toxicity (Dojlido and Best, 1993). Concentrations for cadmium were found to be slightly above the water quality criteria for the mean EMC at the east and detention basin outlet pipes, and the maximum EMC at the east, west, and detention basin outlet pipes. However, it does not appear that cadmium will pose a significant ecological problem in the receiving water body because expected dilution will reduce concentrations to the water quality criteria.

Small amounts of copper are essential to life; however, large doses are toxic, especially to plants (Dojlido and Best, 1993). According to Moore and Ramamoorthy (1984), copper restricts the growth of aquatic plants at concentrations greater than 100 µg/L (as cited in Dojlido and Best, 1993). Copper mean EMC concentrations were found to be slightly above the water quality criteria for the east, west, and detention basin outlet pipes; however, the maximum EMC were found to be 7, 10, and 2 times higher than the acute water quality criteria, respectively. These high concentrations may be of concern for potential ecological effects.

Mercury compounds are very toxic to aquatic organisms. At a concentration of a few µg/L, the growth of plants may be inhibited. The lethal levels for fish vary from 2 mg/L for shrimp (daphnia), to 2 mg/L for insects, and from 30 mg/L for guppies to 1 mg/L for tilapia (Dojlido and Best, 1993). Mercury mean EMC concentrations were found to be slightly above the water quality criteria for the east, west, and detention basin; however, EMC concentrations were found to be 5, 6, and 4 times higher that the acute water quality criteria, respectively. These high concentrations may be of concern for potential ecological effects.

Zinc in small concentrations is an essential element for living organisms. At higher concentrations, zinc is harmful to plants (Dojlido and Best, 1993). The toxicity of zinc for fish depends on several factors, primarily water hardness, pH, and temperature. Moore and Ramamoorthy (1984) found that toxicity as measured by the LC_{50} (48-96h) varied between 0.5 mg and 5 mg Zn/L (as cited in Dojlido and Best, 1993). Zinc mean EMC concentrations were found to be slightly above the water quality criteria for the east, west, and detention basin outlet pipes. The EMC concentrations for the east and west pipe outlet were higher 6 and 8 times higher than the acute water quality criteria, respectively. These high concentrations may be of concern for potential ecological effects.

6.3.3 Comparison Between BOD and COD

A comparison between BOD and COD gives information about the sources of the oxygen demanding constituents and their ability to biodegrade. Table 6-5 shows the BOD/COD ratio for the west and east outlet pipes for the sampled rainfall events where both indicators were analyzed.

Table 6-5. Comparison Between BOD and COD for Selected Sampled Events

Rainfall Event	BOD/COD ratio			
	West Pipe Outlet		East Pipe Outlet	
	First Flush	EMC	First Flush	EMC
11/10/2008	0.051	0.150	0.188	0.134
3/27/2010	0.071	0.052	0.105	0.070
5/7/2010	0.224	0.091	0.116	0.300
5/20/2010	-	0.234	-	0.196
7/4/2010	0.400	0.292	0.304	0.207
9/13/2010	0.205	0.205	0.225	0.225

The BOD/COD ratio ranges from 0.051 to 0.400. These values indicate that most of the oxygen demand comes from inorganic chemicals.

6.4 Effectiveness of the Detention Basin

The effectiveness of the current detention basin as a water quality BMP at the study site can be determined by comparing the calculate loads from the basin outlet with the loads from the west and east outlet pipes. Loads at the basin outlet correspond to the total load for the study site; therefore, in order to estimate the BMP effectiveness, it is necessary to subtract the loads from non-highway runoff sources. For this study, the only non-highway source monitored was the construction debris lot. Once the loads from this source were subtracted, the results were compared to the loads from the east and the west pipe outlets. Table 6-6 shows the loads entering and exiting the detention basin.

Table 6-6. Comparison Between Pollutant Loads Entering and Exiting the Detention Basin

Analyte	Rain Storm Event									
	11/10/2008		5/12/2009		7/3/2009		7/31/2009		9/3/2009	
	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)
Cadmium (dissolved)	4.17E-05	3.19E-05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium (dissolved)	0.49	1.12	0.32	0.58	0.61	1.37	0.58	-4.54[a]	11.8	89.2
Chromium (dissolved)	4.74E-05	1.86E-05	4.99E-05	-9.84E-05[a]	2.11E-04	4.32E-04	2.71E-04	1.55E-04	0.0020	0.0113
Copper (dissolved)	4.18E-04	3.23E-04	2.91E-04	1.99E-04	4.03E-04	-0.00110[a]	6.52E-04	1.22E-03	0.0051	0.0180
Iron (dissolved)	0.0028	0.0002	1.12E-04	1.82E-04	0.00052	0.00052	0.027	0.0117	0.0055	0.0176
Lead (dissolved)	6.16E-05	1.27E-05	5.64E-06	5.37E-06	1.881E-05	4.36E-05	3.04E-04	-1.76E-04[a]	2.86E-04	1.20E-03
Magnesium (dissolved)	0.048	0.496	0.020	0.063	0.023	0.023	0.019	-0.415[a]	0.67	19.35
Mercury (dissolved)	N/A	N/A	4.52E-05	4.94E-05	3.95E-04	1.30E-04	1.70E-04	1.75E-04	0.0021	0.0070
Nickel (dissolved)	N/A	N/A	3.29E-05	2.07E-05	5.27E-05	1.39E-04	4.74E-04	8.49E-04	6.19E-04	0.00491
Potassium (dissolved)	0.20	0.36	0.43	-0.262[a]	0.50	0.02	1.78	-1.95[a]	10.8	50.6
Sodium (dissolved)	0.63	5.77	1.89	0.74	1.95	4.97	1.24	-8.14[a]	14.5	296.3
Zinc (dissolved)	0.41	0.16	<0.10	<0.10	0.028	<0.10	7.20	14.31	<0.1	<0.1
Silica	0.18	0.26	0.060	0.045	0.15	0.40	0.097	-0.498[a]	<0.1	<0.1
Chloride	0.88	8.15	3.08	1.33	1.86	3.84	1.23	-10.7[a]	80.6	379
Fluoride	0.014	0.012	0.0092	0.014	0.017	0.022	0.012	0.019	0.10	0.45
Nitrate	<0.10	-0.00242[a]	0.013	-0.00292[a]	0.022	0.025	0.036	-0.00917[a]	0.77	1.09
Phosphate	<0.10	<0.10	0.0048	0.0099	0.021	0.037	0.018	0.033	0.25	1.01
Sulfate	0.32	1.47	0.75	-0.638[a]	0.62	1.20	0.57	-3.50[a]	6.61	146.9
Soluble Phosphate	0.0028	0.0010	0.0017	0.0025	0.0060	0.013	0.027	-0.00153[a]	0.080	0.140
Total Phosphorus	0.0087	0.0074	0.0013	0.0028	0.0090	0.0227	0.0062	0.0088	0.11	0.15
Total Kjeldahl Nitrogen	N/A	N/A	0.025	0.030	0.045	0.010	0.079	-0.117[a]	1.44	4.60
Total Dissolved Solids	1.71	0.00	7.38	-1.94[a]	8.43	90.50	4.43	-27.9[a]	78.1	1616.3
Total Suspended Solids	N/A	N/A	1.19	-1.15[a]	6.40	118.9	4.55	-26.5[a]	94.3	1235.2
Total Solids	15.7	15.6	8.47	-3.09[a]	14.8	209.4	8.98	-54.4[a]	172	2852
Volatile Dissolved Solids	1.71	<10	<10.0	<10.0	6.77	37.28	0.79	-8.78[a]	195	195
Volatile Suspended Solids	2.08	5.25	1.19	1.01	2.78	0.12	1.37	-0.674[a]	82.8	55.0
Total Volatile Solids	3.79	2.57	0.96	-0.459[a]	9.56	37.40	2.15	-9.46[a]	92.3	250.3
Alkalinity as $CaCO_3$	1.21	3.25	1.11	1.22	2.00	9.45	1.60	0.27	27.3	232.6
COD	0.73	2.24	0.48	-0.635[a]	4.08	7.34	0.718	-0.00595[a]	234	234

N/A: Not data available.

[a] Negative values indicates that loads at the construction debris lot are higher than loads at the detention basin outlet

Table 6-6. Comparison Between Pollutant Loads Entering and Exiting the Detention Basin (cont.)

Analyte	Rain Storm Event							
	3/27/2010		5/7/2010		5/20/2010		7/4/2010	
	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)	Loads Into the Basin (Kg)	Loads Out of the Basin (Kg)
Antimony (total)	9.37E-05	4.73E-05	3.528E-05	1.10E-04	1.176E-09	3.30E-04	<0.0010	<0.0010
Arsenic (total)	7.902E-05	2.05E-05	9.878E-05	1E-05	0.0003666	3.67E-04	8.82E-09	0.0023
Calcium (total)	1.04	1.00	2.00	0.49	3.95	3.95	5.58E-05	16.4
Chromium (dissolved)	5.54E-04	3.43E-04	4.16E-04	8.41E-04	1.37E-08	0.0024	0.0075	0.0075
Chromium (total)	5.64E-04	3.49E-04	4.23E-04	8.56E-04	1.4E-08	0.0024	0.0077	0.0077
Copper (dissolved)	0.0013	0.0005	0.0015	0.0015	1.08E-08	0.0023	2.42E-08	0.0074
Copper (total)	0.0014	0.0005	0.0016	0.0016	1.12E-08	0.0024	2.52E-08	0.0077
Lead (dissolved)	4.40E-04	1.37E-04	1.25E-04	2.59E-04	2.97E-09	4.54E-04	1.41E-08	0.0043
Lead (total)	5.56E-04	1.74E-04	1.58E-04	3.28E-04	3.75E-09	5.74E-04	1.78E-08	0.0054
Magnesium (total)	0.12	0.03	0.45	-0.43	4.52E-06	6.46E-01	8.59E-06	2.50
Nickel (dissolved)	2.82E-04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (total)	2.82E-04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (total)	2.14	4.93	10.4	-1.1[a]	9.67E-05	18.3	1.23E-04	31.0
Thallium (total)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (dissolved)	0.00817	0.00290	0.0022	0.0042	3.83E-08	8.37E-03	7.39E-08	0.023
Zinc (total)	0.00835	0.00296	0.00226	0.0043	3.92E-08	0.0086	7.56E-08	0.023
Chloride	1.56	7.38	9.26	1.53	2.09E-04	22.6	1.56E-04	30.0
Nitrate/Nitrite Nitrogen	0.0068	0.0070	0.040	0.075	4.48E-07	0.073	0.23	0.23
Phosphorus (dissolved ortho)	0.0010	<0.05	0.0042	0.0042	<0.05	<0.05	2.14E-07	0.100
Total Phosphorus	0.0075	0.0037	0.0069	0.0153	8.96E-08	0.021	6.68E-07	0.23
Total Kjeldahl Nitrogen	0.028	0.012	0.073	0.139	7.196E-07	0.12	3E-06	0.91
Total Dissolved Solids	6.08	15.7	38.6	-7.3	3.96E-04	63.5	3.30E-04	98.3
Total Suspended Solids	5.73	2.12	3.73	4.35	5.29E-05	8.31	3.91E-04	83.0
TEH as Diesel	0.0062	-2.16[a]	0.012	-2.24[a]	0.032	0.032	1.31E-07	0.055
BOD	0.16	0.20	0.47	1.19	4.76E-06	1.10	1.76E-05	5.38
COD	2.66	2.18	4.57	2.56	4.28E-05	7.33	9.45E-05	33.03

N/A: No data available.

[a] Negative values indicates that loads at the construction debris lot are higher than loads at the detention basin outlet

A reduction of some contaminants can be observed in low intensity rain events (11/10/2008, 5/12/2009, 7/31/2009, 3/27/2010, 5/07/2010). The total rainfall in these events ranges from 0.14 to 0.32 inches. The reduction was observed in heavy metals, chloride, COD, and TSS. This reduction may be due to the low flow generated during low intensity storms; therefore, more particulates are absorbed by the soil and grass cover in the detention basin. Conversely, during high-intensity events the higher flow conditions in the basin may not have allowed particulate settling, and indeed, some of the previously particulates may have been picked up, increasing the pollutant loads at the detention basin outlet.

Since the detention basin was not designed to reduce pollutant loads from the highway runoff, it is not surprising that little load reduction is observed. To improve pollutant removal, the basin should be re-designed to increase detention time, sedimentation rates, and biological activity.

6.5 Possible Measures to Reduce Pollutants

Heavy metals, COD, BOD, suspended solids, dissolved solids, and diesel fuel are the main concerns from the highway runoff at the study site. An option that can be considered to reduce the concentration and loads from these pollutants is the construction of an extended detention basin. This type of structure typically provides 68-90 percent removal of sediments, 42-90 percent removal of heavy metals, and 42-50 percent removal of COD (FHWA, 1996). The existent detention basin could be adapted by making changes in the outlet design. For an extended basin, the outlet would be much smaller, extending the detention time in the basin.

Section 7. Conclusions

Twelve highway runoff samples were collected from November 2008 through November 2010. For each sampled year, two rain events for each weather season (spring, summer, and fall) were sampled. Winter snowfalls were not sampled in this study. A first flush and a composite sample for each sampling location were analyzed for every rainfall event. Heavy metals, anions, nutrients, BOD, COD, SVOCs, and VOCs concentrations were obtained from the Water Science Laboratory at UNL and Midwest Laboratories for 2009 and 2010 respectively. The results of the samples show:

- Metals (especially copper, chromium, and sodium), BOD, COD, suspended solids, and dissolved solids are the primary contaminants found in the highway runoff.
- TEH as diesel was found in all 2010 samples (it was not analyzed for the 2009 samples). According to the laboratory, this result does not correspond specifically to diesel. Instead, the results correspond to a mixture of compounds with diesel-range molecular weights that cannot be classified as gasoline, diesel, oil, fuel additives, coolant fluid, or brake fluid.
- Chloride, total phosphorus, and TKN were found in all of the sampled events. However, the concentrations were low, having little or no apparent impact to the receiving stream.
- SVOCs and VOCs were found to be below the detection limits in most of the sampled events.
- Total suspended solids (TSS), antecedent dry period (ADP), total rainfall, and volume of runoff are typically believed to influence highway runoff pollutant

concentrations. However, no strong correlations between pollutant concentrations and these variables were found in this study.

- The existing detention basin has minimal effectiveness in reducing the pollutants from highway runoff.

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Appendix A: Additional Regulations Related to Stormwater Pollution

The National Environmental Policy Act

The main objective of National Environmental Policy Act (NEPA) was to create a way for considering environmental impacts consistent with other national needs, such as economic development. To accomplish this objective, NEPA established a policy that obligates all Administered Federal Programs to become more environmentally efficient, imposing environmental responsibilities on all agencies of the Federal Government. As part of NEPA, Federal Agencies are required to conduct a preliminary impact analysis in the early planning process and in all cases prior to the undertaking of any project or action.

The Coastal Zone Management Act

The Coastal Zone Management Act of 1972 (CZMA), was approved by Congress to "preserve, protect, develop, and where possible to restore and enhance the resources of the Nation's coastal zone for this and succeeding generations" (CZMA, 1972). This act encourages States and Territories to develop comprehensive programs to protect and manage coastal resources, including the Great Lakes. In 1990, the Coastal Zone Act Reauthorization Amendments (CZARA) mandate to all State Coastal Programs and State nonpoint sources programs (including highway programs) to work in the solution of nonpoint source pollution that may affect coastal water quality.

The Safe Drinking Water Act

The Safe Drinking Water Act of 1974 (SDWA) and its 1984 amendment has as its main objective the "protection of the Nation's sources of drinking water and the protection of public health to the maximum extent possible, using proper water treatment techniques" (SDWA, 1974). In the SDWA, underground sources of drinking water and aquifers were included to be protected. Therefore, in order to be in compliance with SDWA, highway projects required additional planning and analysis, and possible permitting if the project is located in the recharge area of a drinking water aquifer.

Appendix B: Modeling Runoff with HEC-HMS

The HEC-HMS model was used to estimate runoff from the sub-basins at the study site. The HEC-HMS incorporates several sub-models to compute runoff. To determine the cumulative losses, HEC-HMS offers the following sub-models: Initial and constant rate loss, deficit and constant-rate, SCS curve number (CN), and Green and Ampt loss. For Unit-Hydrograph (UH) models, HEC-HMS offers the following sub-models: Snyder's UH model, SCS UH model, Clark's UH model, ModClark model, and Kinematic-wave model. HEC-HMS also offers sub-models to determine the baseflow; however, in this model baseflow was estimated to be insignificant compared to runoff-event flows.

For this study, the model uses the SCS curve number method to determine the cumulative losses. This model was chosen because it requires a single variable (curve number) that is characterized by data that were available for the site; i.e., the type of soil, soil cover and antecedent moisture. Additionally, as this model was developed for agricultural watersheds in the Midwest, it is applicable for conditions in this study.

The unit-hydrograph model used for this basin model was the SCS UH model. This model was chosen because it requires a single variable (lag time) which could be estimated from the physical characteristics of the site and from the measured hydrographs from the site sub-basins. Additionally, some of the parameters required for other models are difficult to determine at a site like the NDOR site because the area is very heterogeneous and does not have open channels with constant characteristics.

The HEC-HMS model requires specification of the area for each subbasin. Areas for each subbasin were determined using drawings of the drainage system, highway vertical alignments, and section profiles of the site. Additionally, aerial photos obtained at the Geographic Information Systems for Douglas County website (DOGIS, 2009) were used to measure distances and areas inside of the NDOR site.

The model requires specification of the curve number (CN) which is used to determine the losses for each subbasin. The CN was obtained from Table 2.2a, 2.2b, 2.2c, and 2.2d contained in the Urban Hydrology for Small Watersheds, Technical Release 55 (U.S. Department of Agriculture, 1986). In addition, HEC-HMS requires specifications of the percentage of impervious area for each subbasin. The percent impervious area for each sub-basin was assumed to be 0.0. No impervious area was used because all of the surfaces (including pavement) have some permeability. Table B-1 shows the CN for each subbasin in the HEC-HMS basin model.

Table B-1: Curve Numbers for Each Subbasin

Subbasin	Description	CN
Subbasin-1A	Hard packed driveway in the construction debris lot.	98
Subbasin-1B	Construction material piles and soil in the construction debris lot.	60
Subbasin-2	Area along the fence, interstate shoulder, and some of I-80 Eastbound/D entrance lane.	69
Subbasin-3	Tributary area for the west pipe inlet. This area includes the two outside lanes of the I-80 East bound and interstate shoulder.	99
Subbasin-4	Grass and shoulder area that runoff directly into the detention basin and some pavement from the center lanes.	80
Subbasin-5A	Tributary area for the east pipe inlet. This area includes the two inside lanes of the I-80 Eastbound and the four lanes of the I-80 Westbound.	98
Subbasin-5B	Tributary area for the East pipe inlet. This area includes a segment of the two outside lanes of the I-80 Westbound and the grass area between I-80 Westbound and the Exit 445 ramp.	89
Subbasin-6	Detention basin.	69

As shown in Table 1.2, a value between 95 and 98 was assigned to the hard packed driveway in the construction debris lot and the highway pavement. The CN for subbasin 1B was more difficult to determine because there are different kinds of material piles with characteristics that differ from one to the other. As it was seen in the field, water running off the material piles was minimal comparing with water coming from the driveway. As a result, a small CN was assigned to this subbasin (representing the material piles) because most of the water infiltrates into the piles.

For subbasin 2 a CN of 69 was assigned, to reflect the low runoff from this subbasin. It was discovered late in the project (fall of 2010) that significant amounts of flows in the ditch were leaking through the berm separating the ditch site from the construction debris lot. Therefore, direct flow measurements (i.e., from the weir at sample site B) were not reliable. Consequently, flows from the ditch/shoulder site were estimated by the HEC-HMS model using typical input values for the properties at that site.

For subbasin 4 and 5A, the CN values correspond to typical values for an area covered with grass. The CN for subbasin 5B is smaller compared to the one for subbasin 4 because the area of subbasin 5B is not covered completely with grass and is apparently more compacted (based on runoff measurements).

For subbasin 6, a CN of 69 was assigned. During the sample period, negligible flow was observed coming from the detention basin floor (i.e., away from the central channel). This is likely because of the small slope in the detention basin, the permeability of the surface, and the low intensity storms.

The SCS unit hydrograph requires the lag time as an input. To calculate the initial lag time values, the time of concentration t_c was used as it was suggested by the NRCS (NRCS, 1986). Equation B-1 shows the relation between lag time and time of concentration.

$$t_{lag} = 0.6t_c \qquad \textbf{(B-1)}$$

In the Revised Technical Release (NRCS,1986), the NRCS published that water moves though a watershed sequentially as sheet flow, shallow concentrated flow, open channel flow, or a combination of the three before reaching an inlet of the sewer system (as cited in Gupta, 2001). Time of concentration is calculated as the sum of the travel time for sheet flow, shallow concentrated flow, and open channel flow. Equation B-2 is used to calculate the travel time for sheet flow.

$$t_{sheet} = \frac{0.42(nL)^{0.8}}{(P_2)^{0.5}S^{0.4}} \qquad \textbf{(B-2)}$$

Where: t_{sheet} = travel time for sheet flow, s.

n = Manning's roughness coefficient.

L = flow length, ft.

P_2 = 2-yr 24-hr rainfall, in. (3.2 in for Omaha)

S = land slope.

Equation B-3 is used to calculate the travel time for shallow concentrated flow.

$$t_{shallow} = \frac{L}{V} \times \frac{1}{60} \qquad \textbf{(B-3)}$$

Where: $t_{shallow}$ = travel time for shallow concentrated flow, s.

L = flow length, ft.
V = average velocity, ft/s

The average velocity can be obtained from standard references such as the Technical Release 55 (NRCS, 1986) and Hydrology and Hydraulic Systems (Gupta, 2008). The time in open channel flow can be calculated using Manning's equation. Equations B-4 show Manning's equation for open channels.

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \qquad \textbf{(B-4)}$$

Where: V = mean velocity of flow in an open channel, ft/s.

R = hydraulic radius, ft.

S = slope of energy line. Equal to channel bottom for uniform flow.

n = Manning's roughness coefficient.

The lag times obtained from these equations were the initial values used in the HEC-HMS basin model. Once data from the rain events were obtained, these values were adjusted to make the model match the measured data. Table B-2 shows the lag times used for the different subbasins in the HEC-HMS basin model. Lag times for subbasin 2 and 6 could not be adjusted due to lack of runoff measurements from these sites during the rain events. Therefore, the values used for these subbasins are the lag time obtained using the above equations (SCS method).

In the HEC-HMS basin model, junctions were created as the discharge point from one or more basins. The model included five junctions (see figure 4-6). Table B-3 shows the junctions with their connections upstream and downstream.

Table B-2: Lag times for each subbasin in the HEC-HMS Model

Subbasin	Surface Flow Material/ Condition	Length of Flow Path (ft)	Lag Time (min)
Subbasin-1A	Hard packed driveway	560	8.1
Subbasin-1B	Mixed construction material piles	270	37
Subbasin-2	Grass-fair condition	370	29.5
Subbasin-3	Pavement	550	5
Subbasin-4	Grass-fair condition	260	10.51
Subbasin-5A	Grass-fair condition	600	4.5
Subbasin-5B	Pavement	540	25
Subbasin-6	Grass-poor condition	290	20.7

Table B-3: Junctions and Connections in the HEC-HMS Model

Junction	Upstream Connections	Downstream Connection
Junction 1	Subbasin 1A Subbasin 1B	Junction 3
Junction 2	Subbasin 3	Reach 2
Junction 3	Subbasin 2 Reach 2	Reach 3
Junction 4	Subbasin 5A Subbasin 5B	Reach 5
Junction 5	Reach 3 Reach 4 Reach 5 Reach 6	None

Junction 1 represented the point where water coming from Site A entered the basin. Junction 2 represented where the west pipe entered the basin. Junction 4 represented the beginning of the channel that conducted water from the west side of the detention basin to the outlet pipe. Junction 5 represented the east pipe. Junction 5 represented the outlet pipe, where water from the detention basin, I-80 runoff, and construction debris lot were collected and discharge into the creek.

Reaches were created to connect subbasins with junctions or to connect one junction with another junction. The routing method used in the reaches was the lag method. This method was used because it required the lag times in the reach, and these had been calculated as described above. Other routing methods (e.g. kinematic wave, Muskingum, Modified puls) were not selected because the reaches had different types of surfaces, and the channels are not well defined. The initial lag times were calculated based on the topography and the distance between the subbasin or junction connected by the reach. Elevations and distances were obtained from DOGIS (DOGIS, 2009). Lag times values were adjusted to match as close as possible the data obtained from the measured hydrographs during rain events.

The model was calibrated using the rain and flow measurements obtained from an ISCO rain gauge and the flow measurement devices installed in each of the sampling sites respectively.

Appendix C: Complete List of Analytes

Table C-1: List of Inorganics and Anions Tested at the University of Nebraska – Lincoln Water Sciences Laboratory

Inorganics	Detection Limit (DL)	Method Used
Calcium (Ca)	0.1 mg/L	AA Spectrophotometry
Magnesium (Mg)	0.1 mg/L	AA Spectrophotometry
Potassium (K)	0.1 mg/L	AA Spectrophotometry
Sodium (Na)	0.1 mg/L	AA Spectrophotometry
Cadmium (Cd)	1.0 µg/L	ICPMS 6020A
Chromium (Cr)	1.0 µg/L	ICPMS 6020A
Copper (Cu)	0.5 µg/L	ICPMS 6020A
Iron (Fe)	1.0 µg/L	ICPMS 6020A
Lead (Pb)	0.2 µg/L	ICPMS 6020A
Mercury (Hg)	0.1 µg/L	ICPMS 6020A
Nickel (Ni)	0.1 µg/L	ICPMS 6020A
Zinc (Zn)	0.1 µg/L	ICPMS 6020A
Silica (SiO_2)	0.20 mg/L	EPA 370.1
Soluble phosphate	0.02 mg/L	EPA 365.1
Alkalinity as $CaCO_3$	10.0 mg/L	SM 2320
BOD – 5 day	0.5 mg/L	SM 5210
COD	5 mg/L	SM 5220
Total phosphorus (TP)	0.02 mgP/L	EPA 365.1
Total Kjeldahl Nitrogen (TKN)	0.20 mg/L	SM 4500
Total Solids (TS)	10 mg/L	SM 2540B
Total Suspended Solids (TSS)	10 mg/L	SM 2540D
Total Volatile Solids (TVS)	10 mg/L	SM 2540G
Volatile Dissolved Solids (VDS)	10 mg/L	SM 2540C
Volatile Suspended Solids (VSS)	10 mg/L	SM 2540E
Oil and Grease	5.0 mg/L	EPA 1664

Anions	Detection Limit (DL)	Method Used
Bromide	0.10 mg/L	EPA 300.0
Chloride	0.10 mg/L	EPA 300.0
Fluoride	0.10 mg/L	EPA 300.0
Nitrate	0.10 mg/L	EPA 300.0
Nitrite	0.10 mg/L	EPA 300.0
Phosphate	0.10 mg/L	EPA 300.0
Sulfate	0.10 mg/L	EPA 300.0

Table C-2: List of VOCs and SVOCs Tested at the University of Nebraska – Lincoln Water Sciences Laboratory

Volatile Organic Compounds (VOCs)	Detection Limit (DL)	Method Used	Semi-volatile Organic Compounds (SVOCs)	Detection Limit (DL)	Method Used
Benzene	0.05 µg/L	EPA 8260	1,2,4-Trichlorobenzene	0.10 µg/L	EPA 8270
Toluene	0.05 µg/L	EPA 8260	1,2-Dichlorobenzene	0.10 µg/L	EPA 8270
o-Xylene	0.05 µg/L	EPA 8260	1,3-Dichlorobenzene	0.10 µg/L	EPA 8270
m-Xylene + p-Xylene	0.20 µg/L	EPA 8260	1,4-Dichlorobenzene	0.10 µg/L	EPA 8270
Ethylbenzene	0.05 µg/L	EPA 8260	2-Chloronaphthalene	0.10 µg/L	EPA 8270
Isopropylbenzene	0.05 µg/L	EPA 8260	2-Methylnaphthalene	0.10 µg/L	EPA 8270
Propylbenzene	0.05 µg/L	EPA 8260	4-Chloroaniline	0.10 µg/L	EPA 8270
Butylbenzene	0.05 µg/L	EPA 8260	Acenaphthene	0.10 µg/L	EPA 8270
sec-Butylbenzene	0.05 µg/L	EPA 8260	Acenaphthylene	0.10 µg/L	EPA 8270
p-Isopropyltoluene	0.05 µg/L	EPA 8260	Anthracene	0.10 µg/L	EPA 8270
1,2,4-Trimethylbenzene	0.05 µg/L	EPA 8260	Benz[a]anthracene	0.10 µg/L	EPA 8270
Chlorobenzene	0.05 µg/L	EPA 8260	Benzo[a]pyrene	0.10 µg/L	EPA 8270
2-Chlorotoluene	0.05 µg/L	EPA 8260	Benzo[b]fluoranthene	0.10 µg/L	EPA 8270
4-Chlorotoluene	0.05 µg/L	EPA 8260	Benzo[ghi]perylene	0.10 µg/L	EPA 8270
1,2-Dichlorobenzene	0.05 µg/L	EPA 8260	Benzo[k]fluoranthene	0.10 µg/L	EPA 8270
1,3-Dichlorobenzene	0.05 µg/L	EPA 8260	Bis-(2-chloroethoxy) methane	0.10 µg/L	EPA 8270
1,4-Dichlorobenzene	0.05 µg/L	EPA 8260	Carbazole	0.40 µg/L	EPA 8270
1,2,3-Trichlorobenzene	0.05 µg/L	EPA 8260	Chrysene	0.10 µg/L	EPA 8270
1,2,4-Trichlorobenzene	0.05 µg/L	EPA 8260	Dibenz[a,h]anthracene	0.10 µg/L	EPA 8270
Bromobenzene	0.05 µg/L	EPA 8260	Dibenzofuran	0.10 µg/L	EPA 8270
Naphthalene	0.05 µg/L	EPA 8260	Fluoranthene	0.10 µg/L	EPA 8270
Styrene	0.05 µg/L	EPA 8260	Fluorene	0.10 µg/L	EPA 8270
Chloroform	0.05 µg/L	EPA 8260	Hexachloro-1,3-butadiene	0.10 µg/L	EPA 8270
1,1,1,2-Tetrachloroethane	0.05 µg/L	EPA 8260	Hexachlorobenzene	0.10 µg/L	EPA 8270
			Hexachlorocyclopentadiene	0.10 µg/L	EPA 8270
1,2,3-Trichloropropane	0.05 µg/L	EPA 8260	Hexachloroethane	0.10 µg/L	EPA 8270
			Indeno[1,2,3-cd]pyrene	0.10 µg/L	EPA 8270
cis-1,3-Dichloropropene	0.05 µg/L	EPA 8260	Isophorone	0.10 µg/L	EPA 8270
			Naphthalene	0.10 µg/L	EPA 8270
trans-1,3-Dichloropropene	0.05 µg/L	EPA 8260	Nitrobenzene	0.10 µg/L	EPA 8270
Hexachloro-1,3-butadiene	0.05 µg/L	EPA 8260	Phenanthrene	0.10 µg/L	EPA 8270
			Pyrene	0.10 µg/L	EPA 8270

Table C-3: List of Inorganics Tested at Midwest Laboratories

Inorganics	Detection Limit (DL)	Method Used
Antimony	0.0001 mg/L	EPA 200.8
Arsenic	0.001 mg/L	EPA 200.8
Beryllium	0.0005 mg/L	EPA 200.7
Cadmium (Cd)	0.002 mg/L	EPA 200.7
Calcium	0.01 mg/L	EPA 200.7
Chloride	50 mg/L	SM 4500-CL E
Chromium (Cr)	0.01 mg/L	EPA 200.7
Copper (Cu)	0.01 mg/L	EPA 200.7
Lead (Pb)	0.0005 mg/L	EPA 200.8
Magnesium (Mg)	0.01 mg/L	EPA 200.7
Mercury	0.0004 mg/L	EPA 245.1
Nitrate/Nitrite Nitrogen	0.2 mg/L	EPA 353.2
Nickel	0.01 mg/L	EPA 200.7
Phosphorus (dissolved ortho)	0.05 mg/L	SM 4500-P G
Phosphorus (total)	0.05 mg/L	SM 4500-P H
Sodium (Na)	0.01 mg/L	EPA 200.7
Selenium	0.001 mg/L	EPA 200.8
Silver	0.01 mg/L	EPA 200.7
Thallium	0.0005 mg/L	EPA 200.8
Zinc (Zn)	0.01 mg/L	EPA 200.7
Total Kjeldahl Nitrogen (TKN)	0.50 mg/L	PAI - DK 02
BOD	2 mg/L	SM 5210B
COD	5 mg/L	ASTM D 1252-95-B
Total dissolved solids	10 mg/L	SM 2540C
Total suspended solids	4 mg/L	SM 2540D

Table C-4: List of VOCs and SVOCs Tested at Midwest Laboratories

Compound	Detection Limit (DL)	Method Used	Compound	Detection Limit (DL)	Method Used
Benzene	1 µg/L	OA-1	bis(2-Chloroethyl) Ether	10 µg/L	EPA 625
Toluene	1 µg/L	OA-1	1,3-Dichlorobenzene	10 µg/L	EPA 625
Ethylbenzene	1 µg/L	OA-1	1,4-Dichlorobenzene	10 µg/L	EPA 625
Napthalene	1 µg/L	OA-1	1,2-Dichlorobenzene	10 µg/L	EPA 625
Total Xylenes	1 µg/L	OA-1	bis (2-Chloroisopropyl) Ether	10 µg/L	EPA 625
Total Purgeable Hydrocarbons	10 µg/L	OA-1	N-Nitrosodimethylamine	10 µg/L	EPA 625
TEH as Gasoline	50 µg/L	OA-2	N-Nitroso-di-n-propylamine	10 µg/L	EPA 625
TEH as Diesel	50 µg/L	OA-2	Hexachloroethane	10 µg/L	EPA 625
TEH as Waste Oil	50 µg/L	OA-2	Dibenz (a,h) Anthracene	10 µg/L	EPA 625
Isophorone	10 µg/L	EPA 625	1,2-Diphenylhydrazine	10 µg/L	EPA 625
bis (2-Chloroethoxy) Methane	10 µg/L	EPA 625	Hexachlorocyclopentadiene	10 µg/L	EPA 625
1,2,4-Trichlorobenzene	10 µg/L	EPA 625	Phenol	10 µg/L	EPA 625
Naphtalene	10 µg/L	EPA 625	2-Chlorophenol	10 µg/L	EPA 625
Diethyl Phthalate	10 µg/L	EPA 625	2-Nitrophenol	10 µg/L	EPA 625
N-Nitrosodiphenylamine	10 µg/L	EPA 625	2,4-Dichlorophenol	10 µg/L	EPA 625
4-Bromophenyl Phenyl Ether	10 µg/L	EPA 625	2,4-Dimethylphenol	10 µg/L	EPA 625
Hexachlorobenzene	10 µg/L	EPA 625	4-Chloro-3-methylphenol	10 µg/L	EPA 625
3,3'-Dicholorobenzidine	20 µg/L	EPA 625	2,4,6-Trichlorophenol	10 µg/L	EPA 625
Chrysene	10 µg/L	EPA 625	Benzo (g,h,i) Perylene	10 µg/L	EPA 625
Benzo (a) Anthracene	10 µg/L	EPA 625	Hexachlorobutadiene	10 µg/L	EPA 625
Benzo (k) Fluoranthene	10 µg/L	EPA 625	2-Chloronapthalene	10 µg/L	EPA 625
Indeno (1,2,3,-cd) Pyrene	10 µg/L	EPA 625	Dimethyl Phtalate	10 µg/L	EPA 625
Benzidine	50 µg/L	EPA 625	Acenaphthylene	10 µg/L	EPA 625
Acenaphthene	10 µg/L	EPA 625	2,6-Dinitrotoluene	10 µg/L	EPA 625
2,4-Dinitrotoluene	10 µg/L	EPA 625	2,4-Dinitrophenol	50 µg/L	EPA 625
Benzo (b) Fluoranthene	10 µg/L	EPA 625	4-Nitrophenol	10 µg/L	EPA 625
Benzo (a) Pyrene	10 µg/L	EPA 625	4,6-Dinitro-2-methylphenol	25 µg/L	EPA 625
4-Chlorophenyl Phenyl Ether	10 µg/L	EPA 625	Pentacholorophenol	10 µg/L	EPA 625
Fluorene	10 µg/L	EPA 625	Di-n-octyl Phthalate	10 µg/L	EPA 625
Nitrobenzene	10 µg/L	EPA 625	n-Hexane	1 µg/L	EPA 625
Butyl Benzyl Phthalate	10 µg/L	EPA 625	Methyl t-Butyl Ether	1 µg/L	EPA 625
Bis (2-ethylhexyl) Phthalate	10 µg/L	EPA 625	Anthracene	10 µg/L	EPA 625
Pyrene	10 µg/L	EPA 625	Di-n-butyl Phthalate	10 µg/L	EPA 625
Phenanthrene	10 µg/L	EPA 625	Fluoranthene	10 µg/L	EPA 625

Appendix D: Results from Each Sampled Site

Table D-1: Concentrations for Site A

Analyte[1]	Unit	Rainfall Event											
		11/10/2008		5/12/2009		7/3/2009		7/31/2009		9/3/2009		3/27/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0008	0.0008
Arsenic (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.005	0.005
Beryllium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.0005	<0.0005
Cadmium (dissolved)	(mg/L)	0.0032	0.0038	<0.001	<0.001	<0.001	<1.00	0.0013	<0.001	<0.001	<0.001	<0.002	<0.002
Cadmium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.002	<0.002
Calcium (dissolved)	(mg/L)	123	50.7	8.5	6	13.6	13.6	256	202	58.6	8.4	N/A	N/A
Calcium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	59.6	59.6
Chromium (dissolved)	(mg/L)	<0.001	0.0032	0.0161	0.0121	0.002	0.0026	0.0472	0.0165	0.0064	0.0042	<0.01	<0.01
Chromium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	<0.01
Copper (dissolved)	(mg/L)	0.0096	0.013	0.0119	0.0085	0.0074	0.0313	0.0221	0.0055	0.0038	0.0027	<0.01	<0.01
Copper (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	<0.01
Iron (dissolved)	(mg/L)	0.016	0.122	0.004	<0.001	0.0015	<0.001	2.978	2.138	0.0178	0.0023	N/A	N/A
Lead (dissolved)	(mg/L)	0.0023	0.0053	0.0004	0.0004	0.0002	0.0002	0.0211	0.0203	0.0003	0.0002	0.0011865	0.001187
Lead (total)	(mg/L)	-	-	-	-	-	-	-	-	-	-	0.0015	0.0015
Magnesium (dissolved)	(mg/L)	67.2	17.2	7.9	6.3	2.5	3.5	22.2	19.6	7.2	3.7	N/A	N/A
Magnesium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37.3	37.3
Mercury (dissolved)	(mg/L)	N/A	N/A	0.0027	0.0027	0.0538	0.0102	0.007	0.0052	0.0026	0.0025	N/A	N/A
Mercury (total)	(mg/L)	N/A	N/A	-	-	-	-	-	-	-	-	<0.0004	<0.0004
Nickel (dissolved)	(mg/L)	N/A	N/A	0.0076	0.0044	0.0022	0.0013	0.0442	0.0117	0.0016	0.001	<0.01	<0.01
Nickel (total)	(mg/L)	N/A	N/A	-	-	-	-	-	-	-	-	<0.01	<0.01
Potassium (dissolved)	(mg/L)	25.4	20.5	0.4	43	6.3	12.1	91.4	85.4	40	21.3	N/A	N/A
Selenium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.002	0.002
Silver (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	<0.01
Sodium (dissolved)	(mg/L)	301	183	16.2	353	67.3	100	561	491	252	140	N/A	N/A
Sodium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	292	292
Thallium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.0005	<0.0005
Zinc (dissolved)	(mg/L)	1.8	16	0.1	0.1	0.1	0.1	85.2	43.9	0.1	0.1		
Zinc (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.01	<0.01
Silica	(mg/L)	30.9	21.4	7.57	8.2	14	8.3	23.8	28.5	N/A	N/A	N/A	N/A
Bromide	(mg/L)	<0.10	<0.10	0.1	0.1	0.1	0.1	0.31	0.54	0.1	0.1	N/A	N/A

N/A: No data available.

Table D-1: Concentrations for Site A

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		7/3/2009		7/31/2009		9/3/2009		3/27/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Chloride	(mg/L)	438.1	456.7	675.2	700.6	111.8	120.7	386.2	634.2	255	150.8	239	239
Fluoride	(mg/L)	<0.10	<0.10	0.25	0.31	0.13	0.15	0.1	0.12	0.1	0.1	N/A	N/A
Nitrate	(mg/L)	<0.10	0.82	1.57	1.79	0.24	0.52	1.37	2.67	1.21	1.36	N/A	N/A
Nitrite	(mg/L)	<0.10	<0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Nitrate/Nitrite Nitrogen	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.2	<0.2
Phosphate	(mg/L)	<0.10	<0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	N/A	N/A
Sulfate	(mg/L)	158.4	170.2	274.6	273.8	82.2	72.1	98.3	201	101.2	58.3	N/A	N/A
Soluble Phosphate	(mg P/L)	<0.02	<0.02	0.02	0.02	0.02	0.03	0.02	0.415	0.706	0.02	N/A	N/A
Phosphorus (dissolved ortho)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.05	<0.05
Total Phosphorus	(mg N/L)	0.08	0.13	<0.02	<0.02	0.03	0.06	<0.02	0.067	0.021	<0.020	0.1	0.1
Total Kjeldahl Nitrogen	(mg/L)	N/A	N/A	2.79	3.18	1.89	1.37	8.71	5.32	1.34	<0.020	1.42	1.42
Total Dissolved Solids	(mg/L)	N/A	N/A	1,510	1,998	1,406	210	1,830	1,380	758	468	1178	1178
Total Suspended Solids	(mg/L)	N/A	N/A	732	638	1,994	380	1,758	1,352	228	196	35	35
Total Solids	(mg/L)	2506	1422	2,242	2,636	3,400	590	3,588	2,732	986	664	N/A	N/A
Volatile Dissolved Solids	(mg/L)	244	213	50	110	12	16	298	396	196	42	N/A	N/A
Volatile Suspended Solids	(mg/L)	136	51	174	156	342	64	40	54	30	22	N/A	N/A
Total Volatile Solids	(mg/L)	380	264	224	266	354	80	338	450	226	64	N/A	N/A
Alkalinity as $CaCO_3$	(mg/L)	241.9	177.6	146.1	146.3	95.5	51.5	137.1	142.2	90.2	64.8	N/A	N/A
Oil and Grease	(mg/L)	N/A	N/A	25.9	28.5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	N/A	N/A
TEH as Diesel	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	340	340
BOD	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	5
COD	(mg/L)	126.7	83.6	107.8	90.6	55.7	31.2	94.6	79.6	76	5	189	189
n-Hexane	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<1	<1
Methyl t-Butyl Ether	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<1	<1
Benzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1	<1
Toluene	(µg/L)	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1	<1
Ethylbenzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1	<1
Napthalene	(µg/L)	0.11	0.11	0.11	<0.05	0.09	<0.05	0.09	<0.05	0.17	0.09	<1	<1

N/A: No data available.

Table D-1: Concentrations For Site A (cont.)

Analyte	Unit	Rainfall Event							
		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	0.0006	0.0008	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.0014	<0.0010	<0.0010	0.0015	0.0015
Arsenic (total)	(mg/L)	0.006	0.006		0.008	0.008	0.005	0.013	0.013
Beryllium (total)	(mg/L)	<0.0005	<0.0005		<0.0005	0.001	0.001	0.001	0.001
Cadmium (dissolved)	(mg/L)	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (total)	(mg/L)	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Calcium (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Calcium (total)	(mg/L)	83.7	65.5		N/A	53.4	33.8	54.30	54.30
Chromium (dissolved)	(mg/L)	<0.01	0.00982		0.02946	0.02946	0.01964	0.02	0.02
Chromium (total)	(mg/L)	<0.01	0.01		0.03	0.03	0.02	0.02	0.02
Copper (dissolved)	(mg/L)	<0.01	<0.01		0.0096	0.0192	0.0096	0.019	0.019
Copper (total)	(mg/L)	<0.01	<0.01		0.01	0.02	0.01	0.02	0.02
Iron (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	(mg/L)	0.0041923	0.00356		0.006486	0.0092547	0.008147	0.0058	0.0058
Lead (total)	(mg/L)	0.0053	0.0045		0.0082	0.0117	0.0103	0.0073	0.0073
Magnesium (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Magnesium (total)	(mg/L)	36.9	29.5		15.1	7.26	4.99	19	19
Mercury (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Mercury (total)	(mg/L)	<0.0004	<0.0004		<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Nickel (dissolved)	(mg/L)	<0.01	<0.01		0.00998	0.00998	0.00998	0.01	0.01
Nickel (total)	(mg/L)	<0.01	<0.01		0.01	0.01	0.01	0.01	0.01
Potassium (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Selenium (total)	(mg/L)	0.001	<0.001		0.001	0.002	0.001	0.002	0.002
Silver (total)	(mg/L)	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (dissolved)	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sodium (total)	(mg/L)	278	353		298	205	73.2	439	439.00
Thallium (total)	(mg/L)	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (dissolved)	(mg/L)	0.02	0.02		0.029	0.029	0.029	0.039	0.039
Zinc (total)	(mg/L)	0.02	0.02		0.03	0.03	0.03	0.04	0.04
Silica	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Bromide	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Chloride	(mg/L)	227	328		374	190	62	403	403
Fluoride	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrate	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrite	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A

N/A: No data available.

Table D-1: Concentrations For Site A (cont.)

Analyte	Unit	Rainfall Event							
		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	<0.2	1	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	1.2	1.3	0.5	1.6	1.6
Phosphate	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sulfate	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	(mg P/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	(mg/L)	<0.05	<0.05		<0.05	<0.05	0.06	<0.05	<0.05
Total Phosphorus	(mg N/L)	0.1	0.13		0.16	0.32	0.28	0.46	0.46
Total Kjeldahl Nitrogen	(mg/L)	1.58	1.67		1.75	2.43	1.55	4.81	4.81
Total Dissolved Solids	(mg/L)	1246	1398		1246	668	228	1554	1554
Total Suspended Solids	(mg/L)	114	142		157	377	251	226	226
Total Solids	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Oil and Grease	(mg/L)	N/A	N/A		N/A	N/A	N/A	N/A	N/A
TEH as Diesel	(µg/L)	130	120		<50	155	50	462	462
BOD	(mg/L)	7	9		8	13	8	22	22
COD	(mg/L)	146	244		107	80	46	302	302
n-Hexane	(µg/L)	<1	<1		<1	<2	1	<1	<1
Methyl t-Butyl Ether	(µg/L)	<1	<1		<1	<1	<1	<1	<1
Benzene	(µg/L)	<1	<1		<1	<1	<1	<1	<1
Toluene	(µg/L)	<1	<1		<1	<1	<1	<1	<1
Ethylbenzene	(µg/L)	<1	<1		<1	<1	<1	<1	<1
Napthalene	(µg/L)	<1	<1		<1	<1	<1	<10	<10

N/A: No data available.

Table D-2: Concentrations For Site C

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium (dissolved)	(mg/L)	0.0033	0.0018	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0	<1.00	<1.00	<1.00	<1.00
Cadmium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium (dissolved)	(mg/L)	31.8	24.9	17.2	15.8	21.400	21.400	37.9	8.2	21.7	15.4	16.7	11.3
Calcium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium (dissolved)	(mg/L)	0.0022	0.0017	0.0048	0.003	0.00260	0.00260	0.0014	0.0031	0.0052	0.0058	0.0011	0.0013
Chromium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper (dissolved)	(mg/L)	14	24	19.6	14.2	5.00000	5.00000	31.2	5	18.3	14	5.9	5.3
Copper (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron (dissolved)	(mg/L)	0.116	0.121	0.0044	0.0028	0.1250	0.1250	0.026	<0.001	1.322	0.0795	0.0073	0.0057
Lead (dissolved)	(mg/L)	0.005	0.0024	0.0003	0.0003	0.0004	0.0004	0.0003	0.0002	0.00108	0.006	0.0003	0.0003
Lead (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium (dissolved)	(mg/L)	3.6	2.9	0.8	0.9	1.500	1.500	2.1	0.3	0.8	0.3	0.8	0.4
Magnesium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mercury (dissolved)	(mg/L)	N/A	N/A	0.0026	0.0025	0.003900	0.003900	0.0063	0.0055	0.0045	0.0042	0.0024	0.0023
Mercury (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel (dissolved)	(mg/L)	N/A	N/A	0.0025	0.0014	0.006000	0.006000	0.0056	0.0006	0.0089	0.009	0.001	0.0007
Nickel (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium (dissolved)	(mg/L)	25.4	20.5	0.4	43	6.5	6.5	6.3	12.1	91.4	85.4	40	21.3
Selenium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium (dissolved)	(mg/L)	50.5	36.1	81.7	87.7	61.8	61.8	85.9	17.1	15	18.4	22.9	12.6
Sodium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zinc (dissolved)	(mg/L)	16	21	0.05	0.05	4.500	4.500	16.3	0.05	168	162	3	0.05
Zinc (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silica	(mg/L)	7.4	6.9	2.51	3.44	1.280	1.280	8.3	1.8	1.6	2.6	N/A	N/A
Bromide	(mg/L)	<0.10	<0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	<0.10	<0.10	0.1	0.1
Chloride	(mg/L)	125.1	48.4	112.2	111.6	93.000	93.000	134.9	10.2	17	21	255	150.8
Fluoride	(mg/L)	0.58	0.66	0.51	0.51	0.230	0.230	0.99	0.23	0.35	0.32	0.1	0.1
Nitrate	(mg/L)	<0.10	<0.10	0.6	0.69	<0.10	<0.10	<0.10	0.36	1.19	1.11	1.21	1.36
Nitrite	(mg/L)	<0.10	<0.10	0	0	0.000	0.000	3.3	0	0	0	0.1	0.1

N/A: No data available.

Table D-2: Concentrations For Site C (cont.)

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phosphate	(mg/L)	<0.10	<0.10	0.45	0.3	0.830	0.830	1	0.35	0.41	0.38	0.49	0.3
Sulfate	(mg/L)	57.1	20.2	30.2	41.7	84.100	84.100	82.9	7.71	13.1	16.6	17.2	6.52
Soluble Phosphate	(mg P/L)	0.18	0.13	0.07	0.11	0.170	0.170	0.27	0.07	0.093	0.811	0.116	0.087
Phosphorus (dissolved ortho)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	(mg N/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen	(mg/L)	N/A	N/A	1.73	1.64	9.040	9.040	6.6	0.71	2.41	1.6	7.54	1.8
Total Dissolved Solids	(mg/L)	1.01	89	236	272	106.000	106.000	172	78	86	90	64	122
Total Suspended Solids	(mg/L)	N/A	N/A	198	116	1040.000	1040.000	380	124	246	116	552	118
Total Solids	(mg/L)	744	92	434	388	1146.000	1146.000	552	202	332	206	616	240
Volatile Dissolved Solids	(mg/L)	101	89	<10.0	<10.0	<10.0	<10.0	66	24	32	22	134	16
Volatile Suspended Solids	(mg/L)	167	51	104	54	324.000	324.000	40	34	32	30	38	114
Total Volatile Solids	(mg/L)	268	140	76	56	260.000	260.000	106	58	64	52	172	130
Alkalinity as $CaCO_3$	(mg/L)	131.7	63.1	71	68.2	84.800	84.800	106	25.1	46	39.8	40.5	27.4
Oil and Grease	(mg/L)	N/A	N/A	6.8	<5.0	14	14	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
TEH as Diesel	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BOD	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COD	(mg/L)	101.1	35.4	5.6	23.5	80.7	80.7	84	88.4	14	14.6	<5.0	<5.0
n-Hexane	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl t-Butyl Ether	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	0.12	0.12	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Toluene	(µg/L)	<0.05	<0.05	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05
Ethylbenzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Napthalene	(µg/L)	0.11	0.11	<0.05	<0.05	0.08	0.08	<0.05	<0.05	<0.05	<0.05	0.08	0.06

N/A: No data available.

Table D-2: Concentrations For Site C (cont.)

Analyte	Unit	Rainfall Event									
		3/27/2010		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	0.0108	0.0098	0.0006	0.0008	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.0014	<0.0010	<0.0010	0.0027	0.0027
Arsenic (total)	(mg/L)	0.011	0.008	0.006	0.006		0.008	0.008	0.005	<0.001	<0.001
Beryllium (total)	(mg/L)	0.001	0.001	<0.0005	<0.0005		<0.0005	0.001	0.001	<0.005	<0.005
Cadmium (dissolved)	(mg/L)	0.0038	0.0028	N/A	N/A		N/A	N/A	N/A	<0.002	<0.002
Cadmium (total)	(mg/L)	0.004	0.003	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Calcium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Calcium (total)	(mg/L)	153	97.2	83.7	65.5		N/A	53.4	33.8	16.20	16.20
Chromium (dissolved)	(mg/L)	0.08838	0.05892	<0.01	0.00982		0.02946	0.02946	0.01964	<0.01	<0.01
Chromium (total)	(mg/L)	0.09	0.06	<0.01	0.01		0.03	0.03	0.02	<0.01	<0.01
Copper (dissolved)	(mg/L)	0.1824	0.1152	<0.01	<0.01		0.0096	0.0192	0.0096	0.019	0.019
Copper (total)	(mg/L)	0.19	0.12	<0.01	<0.01		0.01	0.02	0.01	0.02	0.02
Iron (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	(mg/L)	0.0667604	0.047144	0.004192	0.00356		0.006486	0.009255	0.008147	0.0025	0.0025
Lead (total)	(mg/L)	0.0844	0.0596	0.0053	0.0045		0.0082	0.0117	0.0103	0.0032	0.0032
Magnesium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Magnesium (total)	(mg/L)	19.6	13	36.9	29.5		15.1	7.26	4.99	1.05	1.05
Mercury (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Mercury (total)	(mg/L)	<0.0004	<0.0004	<0.0004	<0.0004		<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Nickel (dissolved)	(mg/L)	0.0499	0.02994	<0.01	<0.01		0.00998	0.00998	0.00998	<0.01	<0.01
Nickel (total)	(mg/L)	0.05	0.03	<0.01	<0.01		0.01	0.01	0.01	<0.01	<0.01
Potassium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Selenium (total)	(mg/L)	0.001	<0.001	0.001	<0.001		0.001	0.002	0.001	<0.001	<0.001
Silver (total)	(mg/L)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sodium (total)	(mg/L)	159	170	278	353		298	205	73.2	17.8	17.8
Thallium (total)	(mg/L)	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (dissolved)	(mg/L)	1.22	0.80	0.02	0.02		0.029	0.029	0.029	0.068	0.068
Zinc (total)	(mg/L)	1.25	0.82	0.02	0.02		0.03	0.03	0.03	0.07	0.07
Silica	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Bromide	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Chloride	(mg/L)	<0.2	<0.2	227	328		374	190	62	13.0	13.0
Fluoride	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrite	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A

N/A: No data available.

Table D-2: Concentrations For Site C (cont.)

Analyte	Unit	Rainfall Event									
		3/27/2010		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	0.4	0.5	<0.2	1	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	1.2	1.3	0.5	1.0	1.0
Phosphate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sulfate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	(mg P/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	(mg/L)	0.1	0.09	<0.05	<0.05		<0.05	<0.05	0.06	0.11	0.11
Total Phosphorus	(mg N/L)	1.5	0.81	0.1	0.13		0.16	0.32	0.28	0.28	0.28
Total Kjeldahl Nitrogen	(mg/L)	4.97	3	1.58	1.67		1.75	2.43	1.55	1.27	1.27
Total Dissolved Solids	(mg/L)	428	490	1246	1398		1246	668	228	42	42
Total Suspended Solids	(mg/L)	1273	596	114	142		157	377	251	71	71
Total Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Oil and Grease	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
TEH as Diesel	(µg/L)	880	520	130	120		<50	155	50	407	407
BOD	(mg/L)	28	14	7	9		8	13	8	9	9
COD	(mg/L)	394	271	146	244		107	80	46	44	44
n-Hexane	(µg/L)	<1	<1	<1	<1		<1	<2	1	<1	<1
Methyl t-Butyl Ether	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Benzene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Toluene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Ethylbenzene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Napthalene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<10	<10

N/A: No data available.

Table D-3: Concentrations For Site D

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium (dissolved)	(mg/L)	0.0017	0.0016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium (dissolved)	(mg/L)	22.2	16.9	21.4	18.3	18.900	18.900	40.8	7.9	12.6	12.6	21.9	13.4
Calcium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium (dissolved)	(mg/L)	0.0017	0.002	0.0041	0.0023	0.00110	0.00110	0.0024	0.0025	0.0108	0.0073	0.003	0.003
Chromium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper (dissolved)	(mg/L)	0.013	0.013	0.02	0.0167	0.00510	0.00510	0.0119	0.0057	0.0221	0.0175	0.004	0.0054
Copper (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron (dissolved)	(mg/L)	0.083	0.106	0.0093	0.0091	0.0029	0.0029	0.0046	0.0032	2.692	1.233	0.0037	0.0059
Lead (dissolved)	(mg/L)	0.0024	0.0025	0.0003	0.0003	0.0002	0.0002	0.0002	0.0003	0.0092	0.0087	0.0003	0.0003
Lead (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium (dissolved)	(mg/L)	1.6	1.4	1.3	1.2	1.000	1.000	1.7	0.3	1	0.6	1.4	1
Magnesium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mercury (dissolved)	(mg/L)	N/A	N/A	0.0025	0.0023	0.003000	0.003000	0.0053	0.005	0.0041	0.004	0.0023	0.0022
Mercury (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel (dissolved)	(mg/L)	N/A	N/A	0.0032	0.0021	0.002400	0.002400	0.0022	0.0008	0.0278	0.0139	0.0006	0.0006
Nickel (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium (dissolved)	(mg/L)	2.2	1.9	3	2.8	3.400	3.400	7.5	1.3	4.6	0.7	1	1.3
Selenium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium (dissolved)	(mg/L)	25.7	19.5	88.3	113	75.700	75.700	184	34.8	43.3	41.5	8	17.8
Sodium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zinc (dissolved)	(mg/L)	19	14	<0.10	<0.10	<0.10	<0.10	1	0.7	197	186	2.3	<0.1
Zinc (total)	(mg/L)	N/A	N/A	-	-	-	-	-	-	-	-	-	-
Silica	(mg/L)	8.4	7.6	1.97	2.9	2.090	2.090	8.8	2.3	1.6	2.1	-	-
Bromide	(mg/L)	<0.10	<0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	<0.10	<0.10	<0.10	<0.10
Chloride	(mg/L)	41.2	28.5	221.5	215.3	156.500	156.500	330.3	39.3	53.3	38.6	7.72	18.6
Fluoride	(mg/L)	0.61	0.5	0.58	0.47	0.170	0.170	0.82	0.21	0.3	0.27	0.17	0.12
Nitrate	(mg/L)	0.38	0.31	0.63	0.71	0.420	0.420	0.15	0.23	0.64	0.65	0.25	0.26
Nitrite	(mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1.2	<0.10	<0.10	<0.10	<0.10	<0.10

N/A: No data available.

Table D-3: Concentrations For Site D (cont.)

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phosphate	(mg/L)	<0.10	<0.10	0.5	0.21	0.310	0.310	0.35	0.2	0.66	0.51	0.28	0.23
Sulfate	(mg/L)	10.5	8.74	40.7	38.1	69.800	69.800	36.7	8.83	17.9	11	4.83	7.36
Soluble Phosphate	(mg P/L)	0.09	0.1	0.05	0.07	0.060	0.060	0.11	0.09	0.188	0.517	0.043	0.081
Phosphorus (dissolved ortho)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	(mg N/L)	0.36	0.34	0.05	0.09	0.070	0.070	0.29	0.13	0.253	0.191	0.107	0.107
Total Kjeldahl Nitrogen	(mg/L)			1.26	1.04	3.860	3.860	2.85	0.49	2.63	2.2	<0.20	1.2
Total Dissolved Solids	(mg/L)	48	58	460	512	360.000	360.000	678	146	120	124	136	42
Total Suspended Solids	(mg/L)			154	<10.0	278.000	278.000	82	46	138	104	262	80
Total Solids	(mg/L)	506	904	614	512	638.000	638.000	760	192	258	228	398	122
Volatile Dissolved Solids	(mg/L)	48	58	<10.0	<10.0	10.000	10.000	26	156	58	16	94	<10.0
Volatile Suspended Solids	(mg/L)	114	100	74	72	128.000	128.000	24	40	16	36	52	60
Total Volatile Solids	(mg/L)	162	158	52	46	138.000	138.000	50	196	74	52	146	64
Alkalinity as $CaCO_3$	(mg/L)	51.5	41.2	60.1	50.2	76.800	76.800	86	28	38.1	37.5	36	30
Oil and Grease	(mg/L)	N/A	N/A	9.8	<5.0	9.6	9.6	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
TEH as Diesel	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BOD	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COD	(mg/L)	29.2	26.1	24.9	27.8	32.1	32.1	50.1	20.1	21.8	20.1	9.6	<5.0
n-Hexane	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl t-Butyl Ether	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	0.07	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Toluene	(µg/L)	<0.05	<0.05	<0.05	0.05	0.06	0.06	<0.05	<0.05	0.08	0.1	<0.05	<0.05
Ethylbenzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Napthalene	(µg/L)	0.11	0.11	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06

N/A: No data available.

Table D-3: Concentrations For Site D (cont.)

Analyte	Unit	Rainfall Event									
		3/27/2010		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	0.0076	0.0068	0.0024	0.0017	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.0028	<0.0010	<0.0010	0.003	0.003
Arsenic (total)	(mg/L)	0.007	0.006	0.003	0.001		<0.001	<0.001	0.002	<0.001	<0.001
Beryllium (total)	(mg/L)	0.001	0.001	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium (dissolved)	(mg/L)	0.0028	0.0028	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (total)	(mg/L)	0.003	0.003	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Calcium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Calcium (total)	(mg/L)	94.2	87.1	93.7	76.4		16.6	8.92	10.5	13.00	13.00
Chromium (dissolved)	(mg/L)	0.0491	0.03928	0.01964	0.01964		0.01964	<0.01	<0.01	<0.01	<0.01
Chromium (total)	(mg/L)	0.05	0.04	0.02	0.02		0.02	<0.01	<0.01	<0.01	<0.01
Copper (dissolved)	(mg/L)	0.1824	0.1152	0.048	0.0288		0.0288	0.0576	0.0096	0.0096	0.0096
Copper (total)	(mg/L)	0.19	0.12	0.05	0.03		0.03	0.06	0.01	0.01	0.01
Iron (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	(mg/L)	0.0394709	0.03077	0.010758	0.0053		0.004113	0.003639	0.003006	0.0024	0.0024
Lead (total)	(mg/L)	0.0499	0.0389	0.0136	0.0067		0.0052	0.0046	0.0038	0.003	0.003
Magnesium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Magnesium (total)	(mg/L)	10.9	9.02	4.03	2.49		1.06	0.89	1.83	0.83	0.83
Mercury (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Mercury (total)	(mg/L)	<0.0004	<0.0004	<0.0004	<0.0004		<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Nickel (dissolved)	(mg/L)	0.02994	0.01996	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (total)	(mg/L)	0.03	0.02	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Potassium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Selenium (total)	(mg/L)	0.003	<0.001	0.002	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
Silver (total)	(mg/L)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sodium (total)	(mg/L)	106	209	399	386		47.4	11	24.5	15.30	15.30
Thallium (total)	(mg/L)	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (dissolved)	(mg/L)	0.83	0.65	0.29	0.14		0.108	0.078	0.029	0.078	0.078
Zinc (total)	(mg/L)	0.85	0.66	0.3	0.14		0.11	0.08	0.03	0.08	0.08
Silica	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Bromide	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Chloride	(mg/L)	239	239	227	328		374	190	62	11.0	11.0
Fluoride	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrite	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A

N/A: No data available.

Table D-3: Concentrations For Site D (cont.)

Analyte	Unit	Rainfall Event 3/27/2010 First Flush	3/27/2010 EMC	5/7/2010 First Flush	5/7/2010 EMC	5/20/2010 First Flush	5/20/2010 EMC	7/4/2010 First Flush	7/4/2010 EMC	9/13/2010 First Flush	9/13/2010 EMC
Nitrate/Nitrite Nitrogen	(mg/L)	0.5	0.7	2.6	1.8	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.4	0.2	<0.2	0.8	0.8
Phosphate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sulfate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	(mg P/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	(mg/L)	0.1	0.09	0.14	0.09		0.09	0.08	0.11	0.06	0.06
Total Phosphorus	(mg N/L)	0.66	0.51	0.51	0.36		0.16	0.18	0.25	0.16	0.16
Total Kjeldahl Nitrogen	(mg/L)	2.44	1.91	4.32	3.53		0.82	1.07	0.83	1.24	1.24
Total Dissolved Solids	(mg/L)	296	588	1884	1334		168	<10	34	10	10
Total Suspended Solids	(mg/L)	622	419	241	122		32	71	59	51	51
Total Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Oil and Grease	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
TEH as Diesel	(µg/L)	260	570	1400	710		270	172	54	370	370
BOD	(mg/L)	18	14	34	24		9	7	6	9	9.0
COD	(mg/L)	172	200	292	80		46	23	29	40	40.0
n-Hexane	(µg/L)	<1	<1	1	1		<1	<1	<1	<1	<1
Methyl t-Butyl Ether	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Benzene	(µg/L)	<1	<1	<1	<1		1	<1	<1	<1	<1
Toluene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Ethylbenzene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1
Napthalene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	<1	<1

N/A: No data available.

Table D-4: Concentrations For Site E

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium (dissolved)	(mg/L)	0.002	0.0023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium (dissolved)	(mg/L)	45.8	50.5	19.4	18.9	23.9	23.9	42.2	12.1	12.1	21.7	22.8	20.2
Calcium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium (dissolved)	(mg/L)	0.0015	0.0017	0.0018	0.0016	0.002	0.002	0.0012	0.0032	0.0082	0.0078	0.0033	0.0036
Chromium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper (dissolved)	(mg/L)	0.02	0.014	0.0116	0.0088	0.0083	0.0083	0.0103	0.0057	0.0133	0.016	0.0063	0.0044
Copper (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron (dissolved)	(mg/L)	0.104	0.049	0.0016	0.0052	0.0173	0.0173	0.0021	0.0027	0.0874	0.0915	0.0019	0.0042
Lead (dissolved)	(mg/L)	0.0024	0.0023	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0048	0.0054	0.0003	0.0003
Lead (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium (dissolved)	(mg/L)	8.5	20.5	3.7	4.1	1.40	1.40	6.3	1.4	0.6	2.4	2.6	5
Magnesium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mercury (dissolved)	(mg/L)	N/A	N/A	0.0023	0.0024	0.0027	0.0027	0.0047	0.0044	0.0039	0.0039	0.0022	0.0022
Mercury (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel (dissolved)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel (total)	(mg/L)	N/A	N/A	0.0025	0.0022	0.0028	0.0028	0.0032	0.0012	0.0085	0.014	0.0013	0.0013
Potassium (dissolved)	(mg/L)	9.9	17.9	7.7	8.2	5.100	5.100	16.4	4.5	4.9	8.8	4	16.9
Selenium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium (dissolved)	(mg/L)	162	232	121	150	107	107	326	62.4	34.6	86	34.6	104
Sodium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zinc (dissolved)	(mg/L)	29	4.5	<0.10	<0.10	19.3	19.3	<0.10	<0.10	265	164	0.6	<0.1
Zinc (total)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silica	(mg/L)	14.5	15.3	2.34	4.28	2.0	2.0	15.9	5.1	1.5	4.7	N/A	N/A
Bromide	(mg/L)	<0.10	<0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	<0.10	<0.10	<0.10	<0.10
Chloride	(mg/L)	275.5	400.1	242.6	293.8	196.1	196.1	604	64.1	41.5	109.5	114.8	123.7
Fluoride	(mg/L)	0.7	0.33	0.51	0.51	0.180	0.180	0.49	0.17	0.27	0.26	0.2	0.12
Nitrate	(mg/L)	<0.10	0.23	0.32	0.57	0.690	0.690	0.47	0.32	0.67	0.87	0.94	0.66
Nitrite	(mg/L)	<0.10	<0.10	<0.10	<0.10	0.370	0.370	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

N/A: No data available.

Table D-4: Concentrations For Site E (cont.)

Analyte	Unit	Rainfall Event											
		11/10/2008		5/12/2009		6/1/2009		7/3/2009		7/31/2009		9/3/2009	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phosphate	(mg/L)	<0.10	<0.10	0.4	0.32	0.120	0.120	<0.10	0.23	0.4	0.41	0.35	0.23
Sulfate	(mg/L)	41.8	104.4	90.6	81.7	31.3	31.3	129.1	32.6	12.2	33.3	28.1	47.9
Soluble Phosphate	(mg P/L)	0.07	0.03	0.09	0.08	0.040	0.040	0.03	0.08	0.824	0.134	0.068	0.034
Phosphorus (dissolved ortho)	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Phosphorus	(mg N/L)	0.38	0.26	0.04	0.08	0.070	0.070	0.21	0.14	0.086	0.125	0.098	0.03
Total Kjeldahl Nitrogen	(mg/L)	N/A	N/A	2.33	2.03	2.79	2.79	1.89	0.55	0.66	0.6	1.64	0.9
Total Dissolved Solids	(mg/L)	N/A	N/A	650	674	424	424	1,168	548	118	184	50	470
Total Suspended Solids	(mg/L)	N/A	N/A	158	200	338	338	300	758	128	190	634	306
Total Solids	(mg/L)	1262	966	808	874	762	762	1,468	1,306	246	374	684	776
Volatile Dissolved Solids	(mg/L)	123	<10	<10.0	<10.0	<10.0	<10.0	50	200	40	44	26	52
Volatile Suspended Solids	(mg/L)	165	169	100	86	106	106	58	24	56	12	68	18
Total Volatile Solids	(mg/L)	288	170	84	84	98.0	98.0	108	224	96	56	94	70
Alkalinity as $CaCO_3$	(mg/L)	118	158	107	88.5	69.5	69.5	121.1	68	32.6	55	55	66.8
Oil and Grease	(mg/L)	N/A	N/A	13.1	7.8	9.8	9.8	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
TEH as Diesel	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BOD	(mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COD	(mg/L)	47.3	64.2	18.5	14.9	54.9	54.9	51.8	49.6	15.7	29	<5.0	47.4
n-Hexane	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl t-Butyl Ether	(µg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	(µg/L)	<0.05	<0.05	0.06	0.06	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Toluene	(µg/L)	<0.05	<0.05	<0.05	<0.05	0.06	0.06	<0.05	<0.05	0.17	0.1	0.1	0.08
Ethylbenzene	(µg/L)	<0.05	<0.05	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Napthalene	(µg/L)	0.11	0.11	<0.05	<0.05	< 0.05	< 0.05	<0.05	<0.05	<0.05	<0.05	0.1	0.05

N/A: No data available.

Table D-4: Concentrations For Site E (cont.)

Analyte	Unit	Rainfall Event									
		3/27/2010		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Antimony (total)	(mg/L)	0.003	0.003	0.0013	0.0024	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.0027	<0.0010	<0.0010	0.0021	0.0021
Arsenic (total)	(mg/L)	0.003	0.003	0.004	0.002		0.003	<0.001	0.003	0.003	0.003
Beryllium (total)	(mg/L)	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium (dissolved)	(mg/L)	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (total)	(mg/L)	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002
Calcium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Calcium (total)	(mg/L)	85.7	78.9	114	33.2		32.3	11.4	21.3	28.4	28.4
Chromium (dissolved)	(mg/L)	0.0196	0.01964	0.0196	0.0196		0.0196	<0.01	0.00982	<0.01	<0.01
Chromium (total)	(mg/L)	0.02	0.02	0.02	0.02		0.02	<0.01	0.01	<0.01	<0.01
Copper (dissolved)	(mg/L)	0.0288	0.0288	0.0192	0.0288		0.0192	0.0096	0.0096	0.0096	0.0096
Copper (total)	(mg/L)	0.03	0.03	0.02	0.03		0.02	0.01	0.01	0.01	0.010
Iron (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	(mg/L)	0.00973	0.00831	0.00419	0.00625		0.003718	0.002373	0.005537	0.0018	0.00182
Lead (total)	(mg/L)	0.0123	0.0105	0.0053	0.0079		0.0047	0.003	0.007	0.0023	0.00230
Magnesium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Magnesium (total)	(mg/L)	16.9	15.1	7.84	2.61		5.29	1.74	3.25	8.98	8.98
Mercury (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Mercury (total)	(mg/L)	<0.0004	<0.0004	<0.0004	<0.0004		<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Nickel (dissolved)	(mg/L)	0.00998	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (total)	(mg/L)	0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Potassium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Selenium (total)	(mg/L)	<0.001	<0.001	0.002	<0.001		<0.001	<0.001	0.03	<0.001	<0.001
Silver (total)	(mg/L)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (dissolved)	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sodium (total)	(mg/L)	380	389	621	107		150	30.6	40.4	111	111
Thallium (total)	(mg/L)	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (dissolved)	(mg/L)			0.07	0.09		0.068	0.049	0.029	0.039	0.039
Zinc (total)	(mg/L)	0.2	0.17	0.07	0.09		0.07	0.05	0.03	0.040	0.040
Silica	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Bromide	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Chloride	(mg/L)	499	510	1092	149		185	25	39	118	118
Fluoride	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Nitrite	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A

N/A: No data available.

Table D-4: Concentrations For Site E (cont.)

Analyte	Unit	Rainfall Event									
		3/27/2010		5/7/2010		5/20/2010		7/4/2010		9/13/2010	
		First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC	First Flush	EMC
Nitrate/Nitrite Nitrogen	(mg/L)	0.4	0.4	1.6	1.8	First flush sample could not be collected because a previous low intensity showers wash off the pollutants from the highway	0.6	0.2	0.3	0.900	0.900
Phosphate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Sulfate	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	(mg P/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	(mg/L)	<0.05	<0.05	0.05	0.08		<0.05	0.06	0.13	0.07	0.070
Total Phosphorus	(mg N/L)	0.25	0.25	0.21	0.34		0.17	0.15	0.3	0.21	0.21
Total Kjeldahl Nitrogen	(mg/L)	1.51	1.19	2.49	3.27		0.95	1.00	1.19	1.67	1.67
Total Dissolved Solids	(mg/L)	1262	1330	2054	372		520	16	128	512	512
Total Suspended Solids	(mg/L)	187	134	129	135		68	41	108	46	46.0
Total Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Oil and Grease	(mg/L)	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
TEH as Diesel	(µg/L)	200	290	610	1010		260	121	71	597	597
BOD	(mg/L)	11	13	16	26		9	6	7	15	15.0
COD	(mg/L)	166	194	157	138		60	23	43	101	101
n-Hexane	(µg/L)	<1	<1	<1	1		<1	<1	2	N/A	N/A
Methyl t-Butyl Ether	(µg/L)	<1	<1	<1	<1		<1	<1	<1	N/A	N/A
Benzene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	N/A	N/A
Toluene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	N/A	N/A
Ethylbenzene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	N/A	N/A
Napthalene	(µg/L)	<1	<1	<1	<1		<1	<1	<1	N/A	N/A

N/A: No data available.

Table D-5: Pollutant Loads For Site A

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Antimony (total)	N/A	N/A	N/A	N/A	N/A	5.78E-06	1.59E-05	5.17E-11	N.D	1.54E-04
Arsenic (total)	N/A	N/A	N/A	N/A	N/A	3.61E-05	1.19E-04	2.95E-10	1.04E-09	0.00134
Beryllium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	2.08E-10	1.03E-04
Cadmium (dissolved)	4.24E-05	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N.D
Cadmium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Calcium (dissolved)	0.565	0.0749	0.964	6.74	14.15	N/A	N/A	N/A	N/A	N/A
Calcium (total)	N/A	N/A	N/A	N/A	N/A	0.431	1.30	N/A	7.03E-06	5.59
Chromium (dissolved)	3.57E-05	1.51E-04	1.84E-04	5.51E-04	0.00707	N.D	1.95E-04	1.09E-09	4.09E-09	0.00202
Chromium (total)	N/A	N/A	N/A	N/A	N/A	N.D	1.99E-04	1.11E-09	4.16E-09	0.00206
Copper (dissolved)	1.45E-04	1.06E-04	0.00222	1.84E-04	0.00455	N.D	N.D	3.55E-10	2E-09	0.00198
Copper (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	3.69E-10	2.08E-09	0.00206
Iron (dissolved)	0.00136	N.D	N.D	0.0714	0.00387	N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	5.91E-05	4.99E-06	1.42E-05	6.78E-04	3.37E-04	8.58E-06	7.07E-05	2.4E-10	1.7E-09	5.95E-04
Lead (total)	N/A	N/A	N/A	N/A	N/A	1.08E-05	8.94E-05	3.03E-10	2.14E-09	7.52E-04
Magnesium (dissolved)	0.192	0.0786	0.248	0.654	6.23	N/A	N/A	N/A	N/A	N/A
Magnesium (total)	N/A	N/A	N/A	N/A	N/A	0.270	0.586	5.58E-07	1.04E-06	1.96
Mercury (dissolved)	N/A	3.37E-05	7.23E-04	1.74E-04	0.00421	N/A	N/A	N/A	N/A	N/A
Mercury (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)	N/A	5.49E-05	9.22E-05	3.91E-04	0.00168	N.D	N.D	3.69E-10	2.08E-09	0.00103
Nickel (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	3.69E-10	2.08E-09	0.00103
Potassium (dissolved)	0.229	0.537	0.858	2.85	35.9	N/A	N/A	N/A	N/A	N/A
Selenium (total)	N/A	N/A	N/A	N/A	N/A	1.45E-05	N.D	3.69E-11	2.08E-10	2.06E-04
Silver (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)	2.04	4.41	7.09	16.4	236	N/A	N/A	N/A	N/A	N/A
Sodium (total)	N/A	N/A	N/A	N/A	N/A	2.11	7.01	1.10E-05	1.52E-05	45.2
Thallium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)	1.78E-04	1.25E-06	7.09E-06	0.00147	N.D	N.D	3.88E-04	1.08E-09	6.11E-09	0.00403
Zinc (total)	N/A	N/A	N/A	N/A	N/A	N.D	3.97E-04	1.11E-09	6.24E-09	0.00412
Silica	0.239	0.102	0.588	0.952	N.D	N/A	N/A	N/A	N/A	N/A
Bromide	N.D	0.00125	0.00709	0.0180	0.168	N/A	N/A	N/A	N/A	N/A
Chloride	5.09	8.75	8.56	21.2	254	1.73	6.51	1.38E-05	1.29E-05	41.5
Fluoride	N.D	0.00387	0.0106	0.00401	0.168	N/A	N/A	N/A	N/A	N/A
Nitrate	0.00914	0.0223	0.0369	0.0892	2.29	N/A	N/A	N/A	N/A	N/A
Nitrite	N.D	0.00125	0.00709	0.00334	0.168	N/A	N/A	N/A	N/A	N/A

N/A: No data available.
N.D: Non-detected

Table D-5: Pollutant Loads For Site A

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Nitrate/Nitrite Nitrogen	N/A	N/A	N/A	N/A	N/A	N.D	0.0199	4.43E-08	1.04E-07	0.165
Phosphate	N.D	0.00125	0.00709	0.00334	0.168	N/A	N/A	N/A	N/A	N/A
Sulfate	1.90	3.42	5.11	6.71	98.2	N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	N.D	2.50E-04	0.00213	0.0139	0.0337	N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	1.25E-08	N.D
Total Phosphorus	0.00145	N.D	0.00425	0.00224	N.D	7.23E-04	0.00258	5.91E-09	5.83E-08	0.0474
Total Kjeldahl Nitrogen	N/A	0.0397	0.0971	0.178	N.D	0.0103	0.0332	6.46E-08	3.23E-07	0.495
Total Dissolved Solids	N/A	24.9	14.9	46.1	788	8.51	27.8	4.60E-05	4.75E-05	160
Total Suspended Solids	N/A	7.96	26.9	45.1	330	0.253	2.82	5.80E-06	5.22E-05	23.3
Total Solids	15.9	32.9	41.8	91.2	1118	N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	2.38	1.37	1.13	13.2	70.7	N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	0.569	1.95	4.54	1.80	37.1	N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	2.94	3.32	5.67	15.0	108	N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	1.98	1.83	3.65	4.75	109	N/A	N/A	N/A	N/A	N/A
Oil and Grease	N/A	0.356	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
TEH as Diesel	N/A	N/A	N/A	N/A	N/A	2.46	2.38	N.D	1.04E-05	47.6
BOD	0.00781	N/A	N/A	N/A	N/A	0.0361	0.179	2.95E-07	1.66E-06	2.27
COD	9.32E-04	1.131	2.21	2.66	8.42	1.37	4.85	3.95E-06	9.57E-06	31.1
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	2.08E-07	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Toluene	N.D	9.99E-07	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	1.52E-04	N.D	N.D	N.D	N.D	N.D

N/A: No data available.
N.D: Non-detected

Table D-6: Pollutant Loads For Site C

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Antimony (total)	N/A	N/A	N/A	N/A	N/A	6.00E-05	2.46E-05	7.8E-11	N.D	4.02E-05
Arsenic (total)	N/A	N/A	N/A	N/A	N/A	4.89E-05	2.73E-05	N.D	N.D	N.D
Beryllium (total)	N/A	N/A	N/A	N/A	N/A	6.12E-06	N.D	N.D	N.D	N.D
Cadmium (dissolved)	1.51E-05	N.D	N.D	N.D	N.D	1.73E-05	N/A	N/A	N/A	N.D
Cadmium (total)	N/A	N/A	N/A	N/A	N/A	1.84E-05	N.D	N.D	N.D	N.D
Calcium (dissolved)	0.209	0.145	0.306	0.313	5.38	N/A	N/A	N/A	N/A	N/A
Calcium (total)	N/A	N/A	N/A	N/A	N/A	0.595	2.54	3.84E-07	7.84E-07	0.241
Chromium (dissolved)	1.43E-05	2.76E-05	1.16E-04	1.18E-04	6.19E-04	3.60E-04	4.02E-04	4.14E-10	N.D	N.D
Chromium (total)	N/A	N/A	N/A	N/A	N/A	3.67E-04	4.09E-04	4.22E-10	N.D	N.D
Copper (dissolved)	2.02E-04	1.31E-04	1.86E-04	2.85E-04	0.00252	7.05E-04	3.93E-04	6.07E-10	9.20E-10	2.86E-04
Copper (total)	N/A	N/A	N/A	N/A	N/A	7.34E-04	4.09E-04	6.33E-10	9.59E-10	2.98E-04
Iron (dissolved)	0.00102	2.58E-05	<0.001	0.00162	0.00271	N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	2.02E-05	2.76E-06	7.46E-06	1.22E-04	1.43E-04	2.88E-04	7.66E-05	9.84E-11	2.81E-10	3.77E-05
Lead (total)	N/A	N/A	N/A	N/A	N/A	3.65E-04	9.69E-05	1.24E-10	3.55E-10	4.76E-05
Magnesium (dissolved)	0.0244	0.00828	0.0112	0.00611	0.190	N/A	N/A	N/A	N/A	N/A
Magnesium (total)	N/A	N/A	N/A	N/A	N/A	0.0795	0.071	2.51E-08	7.57E-08	0.0156
Mercury (dissolved)	N.D	2.30E-05	2.05E-04	8.55E-05	0.00109	N/A	N/A	N/A	N/A	N/A
Mercury (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)	0	1.29E-05	2.24E-05	1.83E-04	3.33E-04	1.83E-04	N.D	N.D	N.D	N.D
Nickel (total)	N/A	N/A	N/A	N/A	N/A	1.84E-04	N.D	N.D	N.D	N.D
Potassium (dissolved)	0.0446	0.0221	0.0298	0.00407	0.666	N/A	N/A	N/A	N/A	N/A
Selenium (total)	N/A	N/A	N/A	N/A	N/A	N.D	1.36E-05	N.D	N.D	N.D
Silver (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)	0.304	0.807	0.638	0.374	6.00	N/A	N/A	N/A	N/A	N/A
Sodium (total)	N/A	N/A	N/A	N/A	N/A	1.04	12.9	7.59E-07	6.40E-07	0.265
Thallium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)	1.77E-04	N.D	N.D	0.00330	N.D	0.00491	0.00173	2.06E-09	3.75E-09	0.00102
Zinc (total)	N/A	N/A	N/A	N/A	N/A	0.00502	0.00177	2.11E-09	3.84E-09	0.00104
Silica	0.0580	0.0317	0.0671	0.0529	N.D	N/A	N/A	N/A	N/A	N/A
Bromide	N.D	N.D	N.D	N.D	0.0476	N/A	N/A	N/A	N/A	N/A
Chloride	0.4	1.03	0.380	0.427	6.47	1.26	23.3	1.03E-06	5.75E-07	0.193
Fluoride	0.00555	0.00469	0.00858	0.00651	0.0714	N/A	N/A	N/A	N/A	N/A
Nitrate	N.D	0.00635	0.0134	0.0226	0.200	N/A	N/A	N/A	N/A	N/A
Nitrite	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A

N/A: No data available.
N.D: Non-detected

Table D-6: Pollutant Loads For Site C (cont.)

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Nitrate/Nitrite Nitrogen	N/A	N/A	N/A	N/A	N/A	0.00306	0.0327	1.05E-08	1.92E-08	0.0149
Phosphate	N.D	0.00276	0.0131	0.00773	0.143	N/A	N/A	N/A	N/A	N/A
Sulfate	0.170	0.384	0.287	0.338	3.10	N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	0.00109	0.00101	0.00261	0.0165	0.0414	N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	N/A	N/A	N/A	N/A	N/A	5.51E-04	0.00123	1.9E-09	1.05E-08	0.00164
Total Phosphorus	0.00303	4.60E-04	0.00410	0.00218	0.0600	0.00496	0.00409	5.06E-09	2.11E-08	0.00417
Total Kjeldahl Nitrogen	N/A	0.0151	0.0265	0.0326	0.875	0.0184	0.0423	2.51E-08	6.14E-08	0.0189
Total Dissolved Solids	N/A	2.50	2.91	1.83	58.0	3.00	44.0	3.29E-06	N.D	0.625
Total Suspended Solids	N/A	1.07	4.62	2.36	56.1	3.65	1.50	9.91E-07	5.75E-06	1.06
Total Solids	N/A	3.57	7.53	4.19	114	N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	0.749	N.D	0.895	0.448	7.61	N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	0.429	0.497	1.27	0.611	54.2	N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	1.18	0.515	2.16	1.06	61.9	N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	0.531	0.628	0.94	0.81	13.0	N/A	N/A	N/A	N/A	N/A
Oil and Grease	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
TEH as Diesel	N/A	N/A	N/A	N/A	N/A	0.00318	0.0089	8.23E-09	8.15E-09	6.05
BOD	0.0446	N/A	N/A	N/A	N/A	0.0857	0.341	2.32E-07	6.71E-07	0.134
COD	0.298	0.216	3.30	0.297	N.D	1.66	3.77	9.91E-07	2.30E-06	0.655
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	9.59E-11	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	2.11E-11	N.D	N.D
Toluene	N.D	N.D	N.D	1.22E-06	N.D	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	2.85E-05	N.D	N.D	N.D	N.D	N.D

N/A: No data available.
N.D: Non-detected

Table D-7: Pollutant Loads For Site D

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Antimony (total)	N/A	N/A	N/A	N/A	N/A	4.16E-05	2.32E-05	5.91E-11	<0.0010	4.46E-05
Arsenic (total)	N/A	N/A	N/A	N/A	N/A	3.67E-05	1.36E-05	N.D	1.92E-10	N.D
Beryllium (total)	N/A	N/A	N/A	N/A	N/A	6.12E-06	N.D	N.D	N.D	N.D
Cadmium (dissolved)	2.32E-05	N.D	N.D	N.D	N.D	1.73E-05	N/A	N/A	N/A	N.D
Cadmium (total)	N/A	N/A	N/A	N/A	N/A	1.84E-05	N.D	N.D	N.D	N.D
Calcium (dissolved)	0.246	0.168	0.295	0.256	6.38	N/A	N/A	N/A	N/A	N/A
Calcium (total)	N/A	N/A	N/A	N/A	N/A	0.533	1.04	3.5E-07	1.01E-06	0.19
Chromium (dissolved)	2.91E-05	2.12E-05	9.32E-05	1.49E-04	0.00143	2.40E-04	2.68E-04	4.14E-10	N.D	N.D
Chromium (total)	N/A	N/A	N/A	N/A	N/A	2.45E-04	2.73E-04	4.22E-10	N.D	N.D
Copper (dissolved)	1.89E-04	1.54E-04	2.13E-04	3.56E-04	0.00257	4.70E-04	2.62E-04	4.05E-10	N.D	1.43E-04
Copper (total)	N/A	N/A	N/A	N/A	N/A	4.89E-04	2.73E-04	4.22E-10	N.D	1.49E-04
Iron (dissolved)	0.00154	8.37E-05	1.19E-04	0.025	0.00281	N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	3.63E-05	2.76E-06	1.12E-05	1.77E-04	1.43E-04	1.88E-04	7.23E-05	8.67E-11	2.88E-10	3.53E-05
Lead (total)	N/A	N/A	N/A	N/A	N/A	2.38E-04	9.14E-05	1.1E-10	3.64E-10	4.46E-05
Magnesium (dissolved)	0.0203	0.0110	0.0112	0.0122	0.476	N/A	N/A	N/A	N/A	N/A
Magnesium (total)	N/A	N/A	N/A	N/A	N/A	0.06	0.0340	2.24E-08	1.75E-07	0.0123
Mercury (dissolved)	N/A	2.12E-05	1.86E-04	8.14E-05	0.00105	N/A	N/A	N/A	N/A	N/A
Mercury (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)	N/A	1.93E-05	2.98E-05	0.0003	2.85E-04	1.22E-04	N.D	N.D	N.D	N.D
Nickel (total)	N/A	N/A	N/A	N/A	N/A	1.22E-04	N.D	N.D	N.D	N.D
Potassium (dissolved)	0.0276	0.0258	0.0485	0.0142	0.619	N/A	N/A	N/A	N/A	N/A
Selenium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Silver (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)	0.283	1.04	1.30	0.845	8.47	N/A	N/A	N/A	N/A	N/A
Sodium (total)	N/A	N/A	N/A	N/A	N/A	1.28	5.27	1.00E-06	0.00	0.228
Thallium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)	2.03E-04	N.D	N.D	N.D	N.D	0.00395	0.00187	2.27E-09	2.81E-09	1.16E-03
Zinc (total)	N/A	N/A	N/A	N/A	N/A	0.00404	0.00191	2.32E-09	2.88E-09	1.19E-03
Silica	0.110	0.0267	0.086	0.0427	N.D	N/A	N/A	N/A	N/A	N/A
Bromide	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
Chloride	0.414	1.98	1.47	0.786	8.85	1.55	9.41	1.39E-06	1.44E-06	1.64E-01
Fluoride	0.00727	0.00432	0.00783	0.00550	0.0571	N/A	N/A	N/A	N/A	N/A
Nitrate	0.00450	0.00653	0.00858	0.0132	0.124	N/A	N/A	N/A	N/A	N/A
Nitrite	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A

N/A: No data available.
N.D: Non-detected

Table D-7: Pollutant Loads For Site D (cont.)

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Nitrate/Nitrite Nitrogen	N/A	N/A	N/A	N/A	N/A	0.00428	0.0246	8.44E-09	N.D	1.19E-02
Phosphate	N.D	0.00193	0.00746	0.0104	0.109	N/A	N/A	N/A	N/A	N/A
Sulfate	0.127	0.351	0.329	0.22	3.50	N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	0.00145	6.44E-04	0.00336	0.0105	0.0385	N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	N/A	N/A	N/A	N/A	N/A	5.51E-04	0.00109	N.D	1.15E-08	8.93E-04
Total Phosphorus	0.00494	8.28E-04	0.00485	0.00389	0.0509	0.00312	0.00491	3.37E-09	2.40E-08	0.00238
Total Kjeldahl Nitrogen	N/A	0.00957	0.0183	0.0442	0.561	0.0117	0.0482	1.73E-08	7.96E-08	0.0184
Total Dissolved Solids	N/A	4.71	5.44	2.52	20.0	3.60	18.2	3.54E-06	3.26E-06	0.149
Total Suspended Solids	N/A	0.0920	1.72	2.12	38.1	2.56	1.66	6.75E-07	5.66E-06	7.59E-01
Total Solids	13.1	4.71	7.16	4.64	58.0	N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	0.843	N.D	5.82	0.326	<10.0	N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	1.45	0.663	1.49	0.733	28.5	N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	2.30	0.423	7.31	1.06	30.5	N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	0.599	0.462	1.04	0.763	14.3	N/A	N/A	N/A	N/A	N/A
Oil and Grease	0	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
TEH as Diesel	N/A	N/A	N/A	N/A	N/A	0.00349	0.0097	5.69E-09	5.18E-09	5.50
BOD	0.0509	N/A	N/A	N/A	N/A	0.0857	0.327	1.90E-07	5.75E-07	1.34E-01
COD	0.379	0.256	0.749	0.409	N.D	1.22	1.09	9.70E-07	2.78E-06	5.95E-01
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D	1.36E-05	N.D	N.D	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Toluene	N.D	4.60E-07	N.D	2.04E-06	N.D	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	2.85E-05	N.D	N.D	N.D	N.D	N.D

N/A: No data available.
N.D: Non-detected

Table D-8: Pollutant Loads For Site E

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Antimony (total)	N/A	N/A	N/A	N/A	N/A	6.81E-06	1.24E-04	3.37E-04	N.D	3.12E-05
Arsenic (total)	N/A	N/A	N/A	N/A	N/A	6.81E-06	1.03E-04	3.74E-04	0.00228	4.46E-05
Beryllium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Cadmium (dissolved)	7.66E-05	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Cadmium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Calcium (dissolved)	1.68	0.681	2.42	1.86	103	N/A	N/A	N/A	N/A	N/A
Calcium (total)	N/A	N/A	N/A	N/A	N/A	0.179	1.72	4.03	16.2	0.422
Chromium (dissolved)	5.66E-05	5.76E-05	6.39E-04	6.68E-04	0.0184	4.46E-05	0.00101	0.00245	0.00747	N.D
Chromium (total)	N/A	N/A	N/A	N/A	N/A	4.54E-05	0.00103	0.00249	0.00761	N.D
Copper (dissolved)	4.66E-04	3.17E-04	1.14E-03	0.00137	0.0225	6.54E-05	0.00149	0.00239	0.00730	1.43E-04
Copper (total)	N/A	N/A	N/A	N/A	N/A	6.81E-05	0.00155	0.00249	0.00761	1.49E-04
Iron (dissolved)	0.00163	1.87E-04	5.39E-04	0.0783	0.0215	N/A	N/A	N/A	N/A	N/A
Lead (dissolved)	7.66E-05	1.08E-05	5.99E-05	4.62E-04	0.00153	1.89E-05	3.23E-04	4.64E-04	0.00421	2.71E-05
Lead (total)	N/A	N/A	N/A	N/A	N/A	2.38E-05	4.08E-04	5.86E-04	0.00533	3.42E-05
Magnesium (dissolved)	0.682	0.148	0.280	0.205	25.6	N/A	N/A	N/A	N/A	N/A
Magnesium (total)	N/A	N/A	N/A	N/A	N/A	0.0343	0.135	0.660	2.47	0.134
Mercury (dissolved)	N/A	8.64E-05	8.79E-04	3.34E-04	0.0112	N/A	N/A	N/A	N/A	N/A
Mercury (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Nickel (dissolved)	N/A	7.92E-05	2.40E-04	0.00120	0.00665	N.D	N.D	N.D	N.D	N.D
Nickel (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Potassium (dissolved)	0.596	0.295	0.899	0.753	86.4	N/A	N/A	N/A	N/A	N/A
Selenium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Silver (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Sodium (dissolved)	7.72	5.40	12.5	7.36	532	N/A	N/A	N/A	N/A	N/A
Sodium (total)	N/A	N/A	N/A	N/A	N/A	0.883	5.53	18.7	30.7	1.65
Thallium (total)	N/A	N/A	N/A	N/A	N/A	N.D	N.D	N.D	N.D	N.D
Zinc (dissolved)	1.50E-04	N.D	N.D	0.0140	N.D	3.77E-04	0.00455	0.00854	0.0223	5.82E-04
Zinc (total)	N/A	N/A	N/A	N/A	N/A	3.86E-04	0.00465	0.00873	0.0228	5.95E-04
Silica	0.509	0.154	1.02	0.40	N.D	N/A	N/A	N/A	N/A	N/A
Bromide	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
Chloride	13.3	10.6	12.8	9.37	632	1.16	7.70	23.1	29.7	1.76
Fluoride	0.0110	0.0184	0.0339	0.0223	0.613	N/A	N/A	N/A	N/A	N/A
Nitrate	0.00766	0.0205	0.0639	0.0745	3.37	N/A	N/A	N/A	N/A	N/A
Nitrite	N.D	N.D	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A

N/A: No data available.
N.D: Non-detected

Table D-8: Pollutant Loads For Site E (cont.)

Analyte	Pollutant Load (Kg/event)									
	11/10/2008	5/12/2009	7/3/2009	7/31/2009	9/3/2009	3/27/2010	5/7/2010	5/20/2010	7/4/2010	9/13/2010
Nitrate/Nitrite Nitrogen	N/A	N/A	N/A	N/A	N/A	9.08E-04	0.0930	0.0748	0.228	0.0134
Phosphate	N.D	0.0115	0.0459	0.0351	1.18	N/A	N/A	N/A	N/A	N/A
Sulfate	3.48	2.94	6.51	2.85	245	N/A	N/A	N/A	N/A	N/A
Soluble Phosphate	9.99E-04	0.00288	0.0160	0.0115	0.174	N/A	N/A	N/A	N/A	N/A
Phosphorus (dissolved ortho)	N/A	N/A	N/A	N/A	N/A	N.D	0.00413	N.D	0.099	0.00104
Total Phosphorus	0.00866	0.00288	0.0280	0.0107	0.153	5.67E-04	0.0176	0.0212	0.228	0.00312
Total Kjeldahl Nitrogen	N/A	0.0731	0.110	0.0513	4.6	0.0027	0.169	0.118	0.905	0.0248
Total Dissolved Solids	N/A	24.3	109	15.7	2403	3.0	19.2	64.9	97.4	7.62
Total Suspended Solids	N/A	7.20	151	16.3	1564	0.30	6.98	8.48	82.2	0.684
Total Solids	32.2	31.5	261	32.0	3967	N/A	N/A	N/A	N/A	N/A
Volatile Dissolved Solids	N.D	N.D	39.9	3.77	266	N/A	N/A	N/A	N/A	N/A
Volatile Suspended Solids	5.63	3.10	4.79	1.03	92.0	N/A	N/A	N/A	N/A	N/A
Total Volatile Solids	5.66	3.02	44.7	4.79	358	N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	5.26	3.186	13.6	4.71	341	N/A	N/A	N/A	N/A	N/A
Oil and Grease	N.D	0.281	N.D	N.D	N.D	N/A	N/A	N/A	N/A	N/A
TEH as Diesel	N/A	N/A	N/A	N/A	N/A	6.58E-04	0.0522	0.0324	0.0540	8.88
BOD	0.190	N/A	N/A	N/A	N/A	0.0295	1.34	1.12	5.33	0.22
COD	2.14	0.536	9.91	2.48	242	0.440	7.13	7.48	32.7	1.50
n-Hexane	N.D	N.D	N.D	N.D	N.D	N.D	5.17E-05	N.D	0.00152	N.D
Methyl t-Butyl Ether	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Toluene	N.D	N.D	N.D	8.56E-06	4.09E-04	N.D	N.D	N.D	N.D	N.D
Ethylbenzene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Napthalene	N.D	N.D	N.D	N.D	2.56E-04	N.D	N.D	N.D	N.D	N.D

N/A: No data available.
N.D: Non-detected.