Winter 12-1-2011

WATER QUALITY MONITORING OF AN URBAN STREAM FOR TOTAL MAXIMUM DAILY LOAD ASSESSMENT

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Mihulka, Jeffrey K., "WATER QUALITY MONITORING OF AN URBAN STREAM FOR TOTAL MAXIMUM DAILY LOAD ASSESSMENT" (2011). *Civil Engineering Theses, Dissertations, and Student Research*. 34.
http://digitalcommons.unl.edu/civilengdiss/34

WATER QUALITY MONITORING OF AN URBAN STREAM FOR TOTAL MAXIMUM DAILY LOAD ASSESSMENT

By

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Civil Engineering

Under the Supervision of Professor John Stansbury

Lincoln, Nebraska

December 2011

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University of Nebraska, 2011

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The purpose of this research project was to assess the water quality of an urban stream for total maximum daily load assessment in Omaha, Nebraska. This was accomplished by sampling the water quality at four different sites. These sites included sampling upstream, within, and downstream of the city. These samples were conducted throughout 2010 and 2011.

The results showed that concentrations of Escherichia coli (E. coli) are routinely above established criteria for the state of Nebraska. Concentrations of E. coli that exist in the Papillion Creek Watershed upstream of the City of Omaha have also been shown to be above established criteria. Therefore reduction of sources of E. coli within the city will not achieve compliance. Current data cannot discern specific sources of E. coli pollution in the Papillion Creek Watershed. Concentrations of total nitrogen and total phosphorus have been shown to be above recommended criteria for the Western Cornbelt Plains Ecoregion. Total nitrogen and nitrite plus nitrate were shown to be derived more from upstream sources above the City of Omaha.

Acknowledgements

The author wishes to express sincere appreciation to all who assisted with this project. I owe a debt of gratitude to my advisor Dr. John Stansbury who continued to motivate me through my research and writing. I would also like to thank Dr. Tian Zhang and Dr. Shannon Bartelt-Hunt for their support and helpful comments. I wish to convey a special thanks to Ben Vacha, Camilo Torres, Dan Jones, Lauren Swadener, and Charles Quigley who helped with the sampling for this project.

A very special acknowledgement goes to the sponsor for this project, the City of Omaha Public Works Department. I wish to thank the Nebraska Department of Environmental Quality, United States Geological Survey, and the United States Army Corps of Engineers for their cooperation in sharing data for this project.

I would like to also share my appreciation to Mr. Lyle Christensen for his shared knowledge of water quality and the Papillion Creek.

Lastly, I would like to thank my family and friends who helped motivate me and keep me on tract throughout this project.

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Acronyms, Abbreviations, and Short Forms

µS/cm	Microsiemens per centimeter
BOD	Biochemical oxygen demand
CEQ	Council of Environmental Quality
cfs	Cubic feet per second
cfu/100mL	Colony forming unit (bacteria counts) per 100 milliliters
cfu/s	Colony forming unit (bacteria counts) per second
City of Omaha	City of Omaha Public Works Environmental Quality Department
COD	Chemical oxygen demand
CSOs	Combined Sewer Overflows
CWA	Clean Water Act
DO	Dissolved oxygen
DP	Dissolved phosphorus
E. coli	Escherichia coli
FC	Fecal coliforms
FWPCA	Federal Water Pollution Control Act
g/s	Grams per second
HDR	HDR, Inc.
kcfu/yr	Kilocolony forming unit (bacteria counts) per year
kg/yr	Kilograms per year
LID	Low Impact Development
mg/L	Milligrams per liter
mi	Miles
mi^2	Square miles
MS4s	Municipal Separate Storm Sewer Systems
NDEQ	Nebraska Department of Environmental Quality
NDPES	National Discharge Pollution Elimination System
NEPA	National Environmental Policy Act
NH_3	Ammonia
NO_2	Nitrite
$NO_2 + NO_3$	Nitrite plus nitrate
NO_3	Nitrate
NTUs	Nephelometric turbidity units
NURP	Nationwide Urban Runoff Program
PCWP	Papillion Creek Watershed Partnership
pH	Negative logarithm of the molar concentration of dissolved hydrogen ion
SC	Specific conductance
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen

TMDL	Total Maximum Daily Load
TP	Total phosphorus
TS	Total solids
TSS	Total suspended solids
Turb	Turbidity
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQA	Water Quality Act
WQIA	Water Quality Improvement Act
WT	Water temperature

Chapter 1. Introduction

1.1 Project Overview

In accordance with the Clean Water Act, states, municipalities, and other agencies have undertaken programs to examine and address point and nonpoint source pollution in their waterways (Sullivan 2009). This project, “Water Quality Monitoring of an Urban Stream for TMDL Assessment” is funded by the City of Omaha to partially fulfill requirements of the City’s Combined Sewer Overflow and Municipal Separate Storm Sewer Systems permits. This project is a part of a monitoring program that “has been established for evaluating stormwater impacts to local waterways, effectiveness of pollution control measures, sources of pollution, and overall health of the local waterways.” (Kee 2011a). This thesis outlines just one of the facets of the overall monitoring program that the City has undertaken.

1.2 Project Goals and Objectives

Within the Papillion Creek system four stream segments have been listed as category 5 and four segments have been listed as category 4a category waterbodies. A category 5 is assigned to waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants and not all of the TMDLs have been developed. A category 4a is assigned to waterbodies in which assessments indicate the waterbody is impaired, but all of the required TMDLs have been completed (NDEQ 2010). These listings were made for these stream segments because of the unacceptably high concentrations of Escherichia coli (E. coli) from point and nonpoint source pollution. In addition to E. coli, other pollutants of interest are nutrients and suspended solids that are also likely from stormwater runoff from the agricultural and urban constituents. Because of these listings the City of Omaha must take steps to determine the source of the pollution and to diminish its effects. To do this the Papillion Creek system must be examined to determine the contributions from both the urban and rural constituents. Therefore, the overall objectives of this study are to monitor the stormwater pollutants in the Papillion Creek Watershed by sampling and to evaluate the impacts and potential sources of those pollutants. The specific objectives are to:

- Monitor the Papillion Creek system to identify where the pollutants exist
- Analyze and evaluate all of the available data
- Determine pollutant loadings for the stream reaches
- Evaluate the respective pollutant contributions between the urban and agricultural landscapes
- Examine the impacts from these pollutants to human and ecological communities

1.3 Thesis Outline

This thesis is divided into eight chapters and five appendices. Chapter 1 introduces the project. This chapter describes the overview and objectives of this project. Chapter 2 describes the characteristics, the hydrology, and the water quality of the Papillion Creek Watershed. Chapter 3 provides a literature review for the project. This chapter describes the background of stormwater regulations, the Papillion Creek Watershed regulations, and stormwater pollutants. Chapter 3 also provides summaries of previous studies completed that relate to this project. Chapter 4 describes the methods that were used in this project. Chapter 5 shows the results from the data collected from sampling. Chapter 6 provides the data analysis and a discussion of results completed for this project. Chapter 7 provides the conclusions. Chapter 8 provides the references.

Chapter 2. The Papillion Creek Watershed

2.1 Background of the Papillion Creek Watershed

The Papillion Creek Watershed, known locally as the Papio Watershed, is located in eastern Nebraska near Omaha, NE (Figure 2-1). The watershed covers an area of 402 square miles (1,041 square kilometers) or 257,280 acres. The basin receives 30.5 inches (77.5 centimeters) of precipitation annually (HPRCC 2011). Roughly one third of Nebraska’s population exists within the basin (NDEQ 2009c). The watershed covers parts of Washington, Douglas, and Sarpy counties. The Papillion Creek discharges into the Missouri River near river mile marker 597, located 4 miles south of Bellevue, NE.

The land of the Papillion Watershed is classified as part of the Western Corn Belt Plains Level III ecoregion (Chapman et al. 2000). The watershed is characterized by dissected hills with deep, silty, well drained soils supported by a potential natural vegetation of tallgrass prairie with scattered oak-hickory forests along the stream valleys. In general, the soils on the upland are deep, well-drained silt loam to silty clay loam formed in loess. Upland soils have moderate permeability with a high available water capacity. Bottomland soils consist of poorly drained silty clay to fine sand loam. Bottomland soils also have moderate permeability with a low available water capacity (HDR 2004).

The majority of the Papillion Creek Watershed basin is urbanized with the headwater reaches remaining as agricultural land. In 2003, 40 percent of the watershed was classified as being developed (HDR 2003a). Anticipated build out in Douglas and

Sarpy counties of the watershed is expected by 2040. Currently three to four square miles of rural land are urbanized each year (NDEQ 2009c). A variety of land uses exist within the watershed including commercial, industrial, high density residential, medium density residential, low density residential, residential estate, public, park, agriculture, pavement, and water (HDR 2003a). The increasing non-agricultural land development and related encroachments on drainage ways and other waterbodies, has led to increased environmental stressors (HDR 2003a). The change from the agricultural landscape to an urban landscape has altered the streams within the watershed. These alterations have been consistent with the Urban Stream Syndrome, which includes the characteristics of: a flashier hydrograph, higher concentration of nutrients and contaminants, altered channel morphology, altered stability, reduced biotic richness, and increased dominance of tolerant species (Walsh et al. 2005).

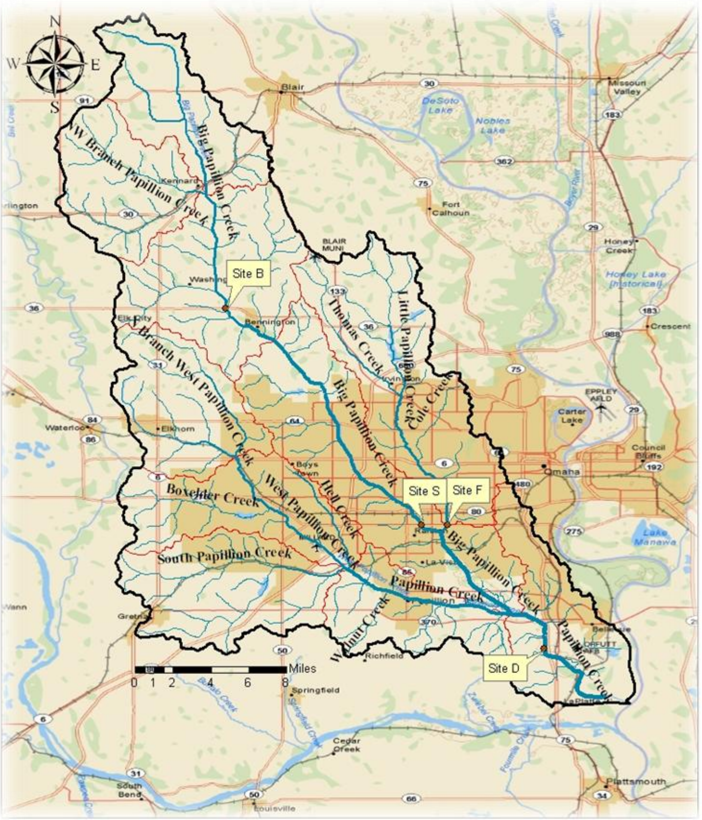

Figure 2-1 Papillion Creek Watershed

2.2 Hydrology of the Papillion Creek Watershed

The Papillion Creek Watershed receives an average 30.5 inches (77.5 centimeters) of precipitation annually. The basin receives an average 27.6 inches (70.1 centimeters) of snowfall annually. The month of May has the highest precipitation total with 4.5 inches (11.4 centimeters) of rain (HPRCC 2011). This precipitation falls onto a terrain that is characterized by relatively narrow flat floodplain surrounded by steeply sloping and rolling hills. As the precipitation is converted to runoff it flows into the streams of the Papillion Creek system. Streamflow progresses from the northwest to the southeast within the watershed. The Big Papillion Creek has the longest stream length (39.5 miles, 63.6 kilometers) and the largest watershed area (173 square miles, 447.9 square kilometers); while the South Papillion Creek has the shortest stream length (10.1 miles, 16.3 kilometers) and the smallest watershed area (39 square miles, 101.0 square kilometers). These descriptions were calculated from an ArcGIS representation of the Papillion Creek Watershed.

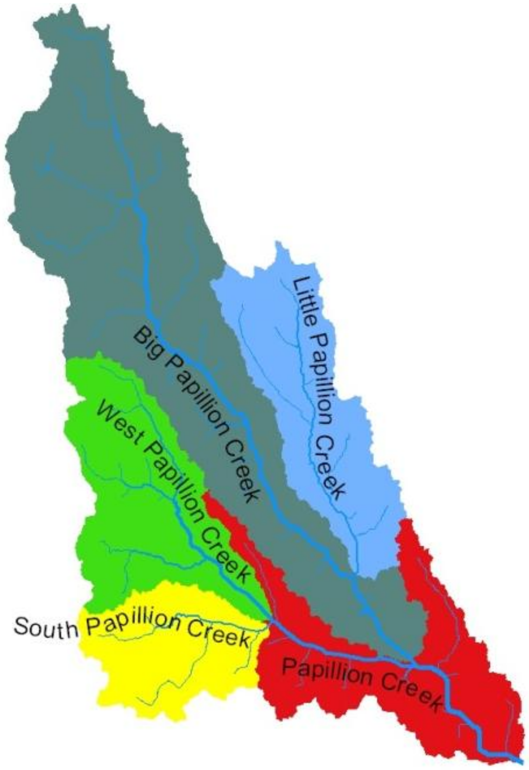

Figure 2-2 Papillion Creek Tributary Basins

Table 2-1 Papillion Creek Tributaries Watershed Characteristics

	Stream Length	Watershed Area	Mean Annual Flow
Tributary	(mi)	(mi^2)	(cfs)
Big Papillion Creek	39.5	173	34.4
Little Papillion Creek	16.6	60	11.1
Papillion Creek	15.8	65	57.1
West Papillion Creek	14.5	63	9.7
South Papillion Creek	10.1	39	4.4

Additional information about the other subbasins is listed in Table 2-1. Figure 2-1 shows the watershed as it exists today. Figure 2-2 displays the watershed broken down by its subbasins. Figure 2-3 displays a map of the land use for the Papillion Creek Watershed. The land use data (USDA 2011) represents the land use classification for 2006. The watershed was classified as 43.7 percent of urban development, 12.8 percent rural open land, and 43.5 percent rural cultivated crops in 2006.

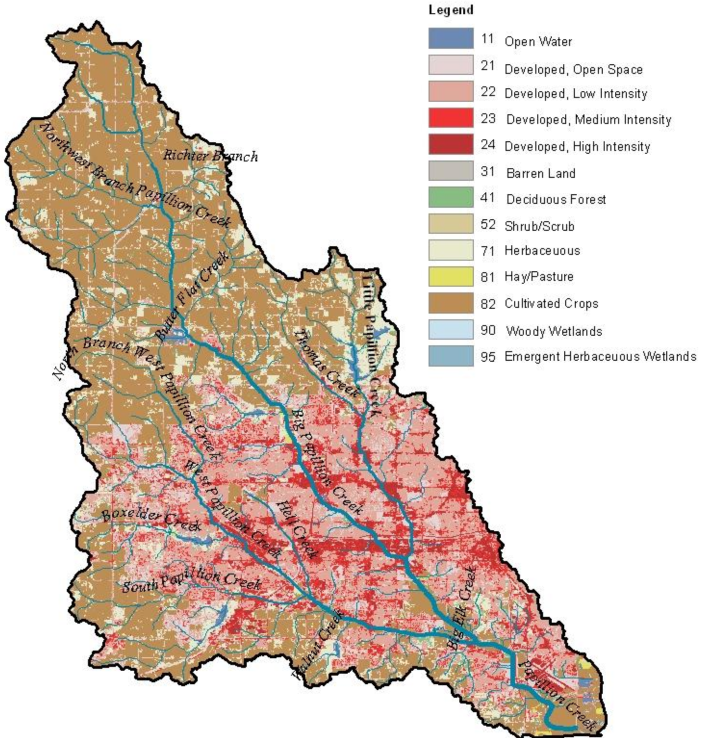

Figure 2-3 Land Use of the Papillion Creek Watershed

The streams of the Papillion Creek Watershed have been altered greatly. Historical accounts and records from the Nebraska State Historical Society indicate that much of the Papillion, Big Papillion, and West Papillion Creeks were straightened between 1910 and 1913(Rus et al. 2003). After the flood of 1959 the United States Army Corps of Engineers (USACE) began several projects in the 1960s aimed at preventing flooding in the basin. These projects included widening the stream channels, excavating the streams, and constructing levees (Rus et al. 2003). Also, four major dams were constructed including Papio 11, 16, 18, and 20. Papio 11 (Glenn Cunningham Lake) was closed in 1974, Papio 16 (Standing Bear Lake) was closed in 1972, Papio 18 (Ed Zorinisky Lake) was closed in 1984, and Papio 20 (Wehrspann Lake) was closed in September 1982 (USACE 2009).

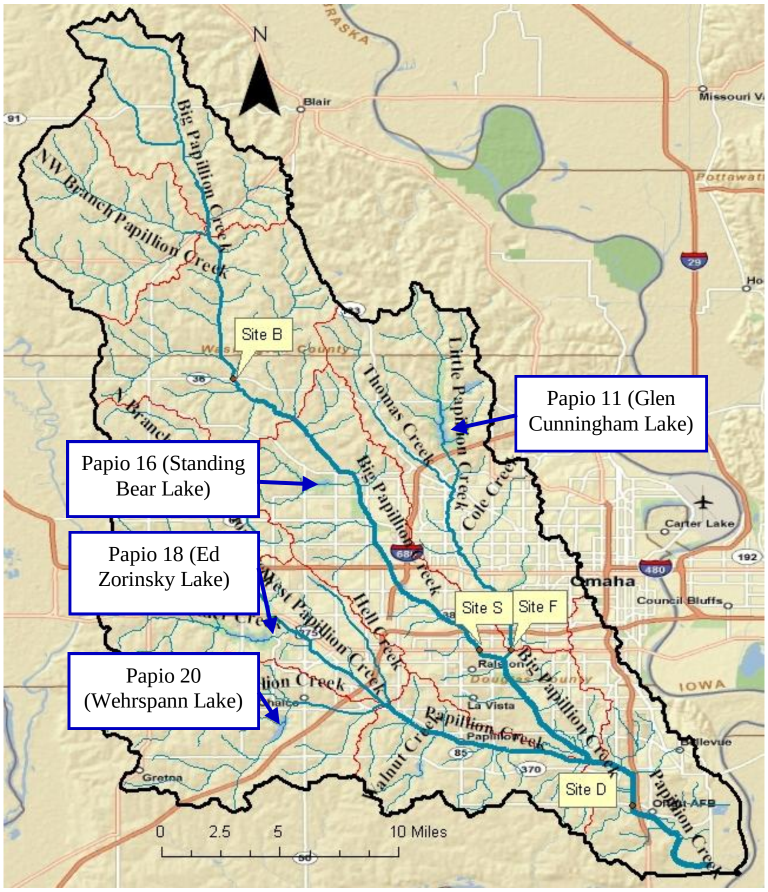

Figure 2-4 Reservoirs of the Papillion Creek Watershed

Stream characteristics have dramatically changed throughout the watershed through channel straightening and subsequent degradation and lateral erosion. The original channels of the watershed were sinuous. These streams had relatively narrow bottoms, sloping wooded backs, and limited discharge capacity (HDR 2004). Predevelopment flooding was characterized as frequent for the basin but for relatively short duration. Currently, the rural stream channels are characterized by incised channels with small tributary slopes averaging from 50 to 200 feet per mile (9.47 to 37.9 meters per kilometer) (HDR 2004). Main channel slopes range from 2 to 30 feet per mile (0.48 to 5.68 meters per kilometer). The stream channels that exist in the urbanized portion of the basin are characterized as incised channels with improved channel sections and levees that are continually maintained (HDR 2004).

Streamflow in the Papillion Creek basin can be characterized by looking at the records of gaging stations. The United States Geological Survey (USGS) currently operates three gages within the watershed, which include: the Big Papillion Creek at Fort Street (station number 06610732), the Little Papillion Creek near Irvington (station number 06610750), and the Papillion Creek at Fort Crook (station number 06610795). The City of Omaha also installed flow meters at four locations within the watershed, which include: the Big Papillion Creek at 168th Street and Highway 36; the Big Papillion Creek at 76th and L Street; the Little Papillion Creek 64th and L Street; and the Papillion Creek at Capehart Road and highway 75. Streamflow within the Papillion Creek basin can be described by these gages.

The gage on the Big Papillion Creek at Fort Street has been operating since October 2003. This gage represents 75 percent of the Big Papillion Creek Watershed. The total flow for 2010 was 83,560 acre-feet. Baseflow for this site is approximately 50 cubic feet per second (1.42 cubic meters per second) corresponding to a water depth of 3 feet (0.91 meters). The maximum flow for 2010 was 6,900 cubic feet per second (195 cubic meters per second) corresponding to a water depth of 23.9 feet (7.29 meters) (USGS 2010a).

The gage on the Little Papillion Creek near Irvington is highly dependent upon the release of water from Glen Cunningham Lake. For this reason the Little Papillion Creek Watershed will be characterized by the City of Omaha flow meters. The flow meter installed on the Little Papillion Creek at 64th and L streets has been operating since July 2009. This meter represents 98 percent of the Little Papillion Creek Watershed. The total flow for 2010 was 27,113 acre-feet. Baseflow for this site is approximately 25 cubic feet per second (0.71 cubic meters per second) corresponding to a water depth of 1.7 feet (0.52 meters). The maximum flow for 2010 was 3,766 cubic feet per second (106.6 cubic meters per second) corresponding to a water depth of 13.7 feet (4.18 meters).

The gage on the Papillion Creek at Fort Crook has been operating since 2004. This gage represents 95 percent of the Papillion Creek Watershed. The total flow for 2010 was 265,573 acre-feet. Baseflow for this site is approximately 200 cubic feet per second (5.66 cubic meters per second) corresponding to a water depth of 5 feet (1.52 meters). The maximum flow for 2010 was 12,700 cubic feet per second (359.7 cubic meters per second) (USGS 2010b). The City of Omaha has installed a flow meter at the Fort Crook site, but stormflows proved problematic for the equipment. High stormflows devastated the equipment and the City of Omaha decided to remove their meter and use the USGS gaging data.

Unfortunately flow data for the West and South Papillion Creeks could not be obtained for 2010. All of the streams in the Papillion Creek Watershed experience a flashy hydrograph. These stormflows move quickly through the watershed.

2.3 Water Quality of the Papillion Creek Watershed

The Nebraska Department of Environmental Quality (NDEQ) has set the designated uses for the Papillion Creek Watershed. Table 2-2 shows the stream segment names, creek names, and designated uses (NDEQ 2006). The recreation classification is defined as the use of the waterbody such that prolonged or intimate exposure occurs with the water. This exposure could cause accidental ingestion and/or contact to sensitive body organs (such as eyes, ears, etc.) with the water. Recreation is supported by meeting the criteria for the water quality parameter of Escherichia coli. The aquatic life classification states what type of aquatic life the stream is supposed to support such as Coldwater A, Coldwater B, Warmwater A, or Warmwater B biota. Aquatic life is supported by meeting the criteria for the water quality parameters of dissolved oxygen, total ammonia, and toxic substances. Segments MTI-10100, 10110, 10120, and 10200 (the Big Papillion Creek and Papillion Creek) are classified as Warmwater A. Segments MTI-10111 and 10111.1 (the Little Papillion Creek and Cole Creek) are classified as Warmwater B. The water supply classification states the current or future use for which the water in the stream is designated. Stream segments can be classified as water supply for public drinking water, agriculture, or industrial. Water supply is supported by meeting the criteria for the water quality parameters of conductivity, nitrate and nitrite, and selenium. The aesthetics classification is defined as the nature or beauty of the stream. The key aquatic species classification states any aquatic species that the stream is determined to support (NDEQ 2009b). Figure 2-5 displays the stream segments of the watershed listed by their Waterbody ID.

Table 2-2 Papillion Creek Watershed Stream Classifications

Waterbody ID (MT1-)	Waterbody Name (Creek)	Recreation	Aquatic Life	Public Drinking Water	Agriculture Water Supply	Industrial Water Supply	Aesthetics	Overall Assessment	Category
10100	Papillion	I	I		S		S	I	5
10110	Big Papillion	I	S		S		S	I	4a
10111	Little Papillion	I	S		S		S	I	4a
10111.1	Cole	I	I		S		S	I	5
10111.2	Thomas		NA		NA		NA		3
10112	Little Papillion		S		S		S	S	1
10120	Big Papillion	I	S		S		S	I	4a
10121	Butter Flat		NA		NA		NA		3
10130	Big Papillion		NA		NA		NA		3
10131	Unnamed		NA		NA		NA		3
10132	Northwest Branch		NA		NA		NA		3
10140	Big Papillion		NA		NA		NA		3
10200	Papillion	I	NA		NA		NA	I	4a
10210	Walnut		I		S		S	I	5
10220	Hell		NA		NA		NA		3
10230	South Papillion		NA		NA		NA		3
10231	Unnamed		S		S		S	S	2
10240	South Papillion		I		NA		NA	I	5
10250	West Papillion		I		NA		NA	I	5
10251	Boxelder		S		S		S	S	1
10252	North Branch West Papillion		NA		NA		NA		3
10260	West Papillion		NA		NA		NA		3

From the NDEQ (2010).
S = Supported beneficial use
I = Impaired beneficial use
NA = Not assessed
Blank cell indicates the beneficial use was not assigned
Category 1 - Waterbodies where all designated uses are met.
Category 2 - Waterbodies where some of the designated uses are met but there is insufficient information to determine if all uses are being met.
Category 3 - Waterbodies where there is insufficient data to determine if any beneficial uses are being met.
Category 4 - Waterbody is impaired, but a TMDL is not needed. Sub-categories 4A, 4B, 4C and 4R outline the rationale for the waters not needing a TMDL.
Category 4a – Waterbody assessment indicates the waterbody is impaired, but all of the required TMDLs have been completed.
Category 4b – Waterbody is impaired, but “other pollution control requirements” are expected to address the water quality impairment(s) within a reasonable period of time. Other pollution control requirements include but are not limited to, National Pollutant Discharge Elimination practices System (NPDES) permits and best management practices.
Category 4c – Waterbody is impaired but the impairment is not caused by a pollutant. This category also includes waters where natural causes/sources have been determined to be the cause of the impairment. In general, natural causes/sources shall refer to those pollutants that originate from landscape geology and climactic conditions. It should be noted; this general description does not exclude parameters and can be utilized when appropriate justification is provided.

Category 4r – Waterbody data exceeds the impairment threshold, however a TMDL may not be needed. The category will only be used for nutrient assessments in new or renovated lakes and reservoirs. Newly filled reservoirs usually go through a period of trophic instability – a trophic upsurge followed by the trophic decline. Erroneous or non-representative water quality assessments are likely to occur during this period. To account for this, all new or renovated reservoirs will be placed in this category for a period not to exceed eight years following the fill or re-fill process. After the eighth year monitoring data will be assessed and the waterbody will be appropriately placed into category 1, 2, or 5.

Category 5 – Waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the TMDLs have not been developed. Category 5 waters constitute the Section 303(d) list subject to USEPA approval/disapproval.

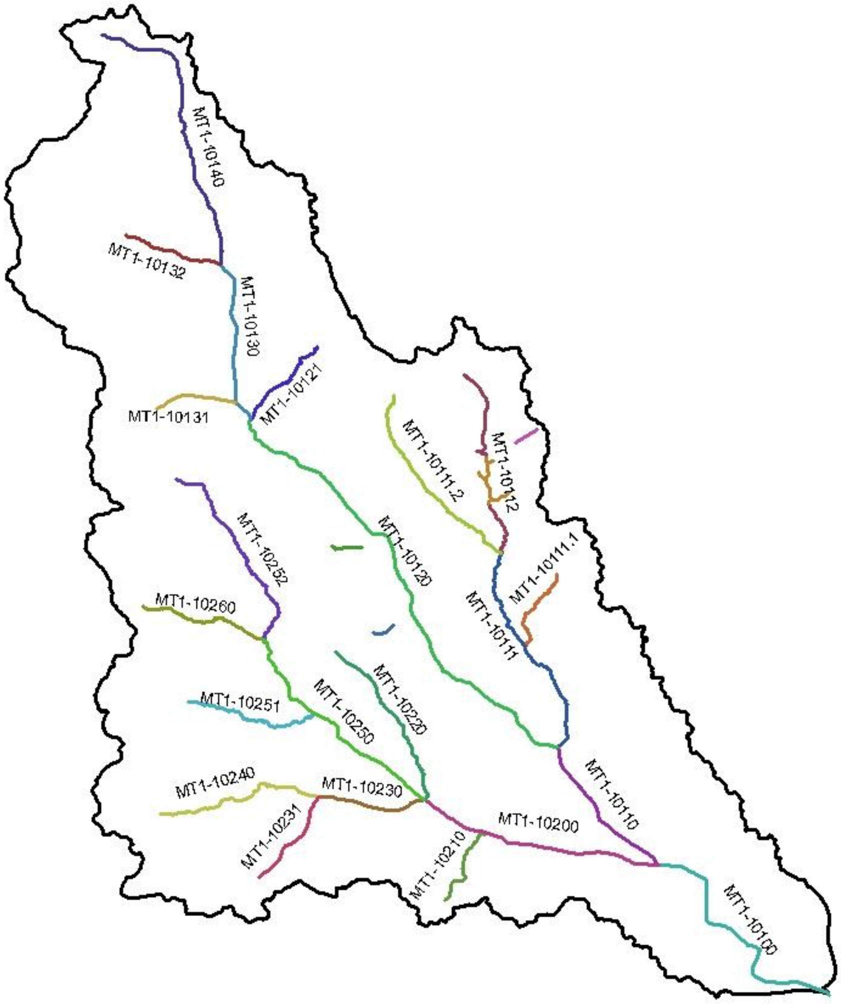

Figure 2-5 Stream Segments of the Papillion Creek Watershed

Table 2-2 displays the beneficial uses for the stream segments in the Papillion Creek Watershed. In 2010 five stream segments of the Papillion Creek system were listed as category 5, and four segments were listed as category 4a impaired waterbodies. Category 5 is assigned to waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants. Category 4a is assigned to waterbodies that are impaired but all of the required TMDLs have been completed (NDEQ 2010).

Table 2-3 displays the impaired waterbodies for the watershed according to their impairments, parameters of concern, and comments/action that were taken. E. coli is listed as an impairment for six stream segments in the Papillion Creek Watershed. In 2009, the NDEQ released TMDL reports (NDEQ 2009b) for the Papillion Creek Watershed. Within the TMDL report the NDEQ assigned the applicable water quality criterion for E. coli to be a geometric mean concentration of 126 cfu/100mL for the recreational season. The recreational season is defined as May 1 through September 30. These criteria concentrations, parameters, and sampling techniques will be discussed later in this report. Figure 2-6 displays the impaired waterbodies (highlighted in red) within the Papillion Creek Watershed.

Table 2-3 Papillion Creeks Impairments

Waterbody ID (MT1-)	Waterbody Name (Creek)	Impairments	Parameters of Concern	Comments/Action
10100	Papillion	E. coli, Selenium, Fish consumption advisory	E. coli, Selenium, Cancer Risk and HIC	E. coli TMDL approved 9/09, Fish consumption assessment
10110	Big Papillion	E. coli	E. coli	E. coli TMDL approved 9/09, Fish consumption assessment
10111	Little Papillion	E. coli	E. coli	E. coli TMDL approved 9/09
10111.1	Cole	E. coli, Low DO	E. coli, Unknown	E. coli TMDL approved 9/10
10120	Big Papillion	E. coli	E. coli	E. coli TMDL approved 9/09, Aquatic community assessment
10200	Papillion	E. coli	E. coli	E. coli TMDL approved 9/10
10210	Walnut	Impaired aquatic community	Unknown	Aquatic community assessment
10240	South Papillion	Impaired aquatic community	Unknown	Aquatic community assessment
10250	West Papillion	Fish consumption advisory	Cancer Risk and HIC	Fish consumption assessment

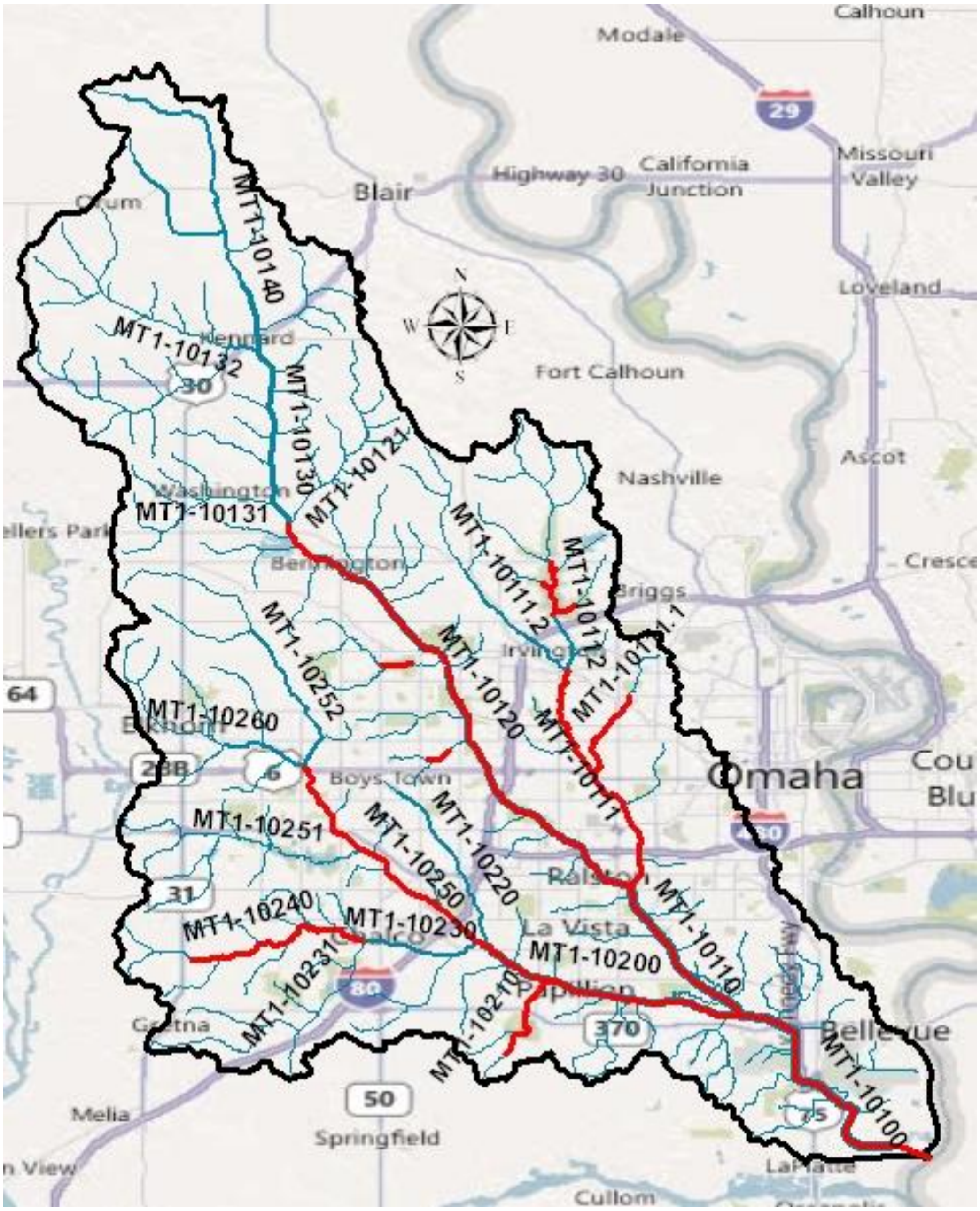

Figure 2-6 Impaired Waterbodies (Highlighted in Red) of the Papillion Creek Watershed

Chapter 3. Literature Review

3.1 Background of Stormwater Regulations

Concerns about surface water quality have been addressed for over 60 years. Up until the 1990s the majority of the regulations were aimed at addressing point sources (specific identifiable discharges) to waterways. Now that the majority of point sources have been addressed, attention is being turned to nonpoint sources of pollution. Current regulation requires municipalities to manage both point and nonpoint sources of pollution of waterways within the United States.

The first regulation passed addressing water resources was the River and Harbor Act of 1886 (USEPA 2011e). This act focused on promoting commerce through navigable waters. The goal of this act was to ensure that obstacles would not block the use of waterways because of human negligence. The Federal Water Pollution Control Act (FWPCA) of 1948 (USEPA 2011e) was the next regulation passed. The goal of the FWPCA was to enhance the quality and value of our water resources and to establish a national policy for the prevention, control, and abatement of water pollution. In 1965, Congress passed the Water Quality Act (WQA) (USEPA 2011e). The WQA established water quality standards which were State and Federally enforceable, these were known as Interstate Water Quality Standards. Congress strengthened the regulation in 1966 with the passage of the Clean Water Restoration Act (CWA) (USEPA 2011e) .

In 1969 the National Environmental Policy Act (NEPA) was passed (Sullivan 2009). NEPA requires federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions (USEPA 2011b). This law applies to all projects with federal involvement. NEPA also formed the Council of Environmental Quality (CEQ) to coordinate Federal environmental efforts and to work closely with agencies and other White House Offices in the development of environmental policies and initiatives (Sutley 2011). In 1970, President Nixon created the Environmental Protection Agency or USEPA as it is known. The new agency was pieced together from the National Air Pollution Control Administration; Water Hygiene and Solid Waste Management; Department of Health, Education, and Welfare; Bureau of Radiological Health; and the Food and Drug Administration (Lewis 2011). The EPA objectives were to establish and enforce environmental protection standards, conduct environmental research, provide assistance for addressing environmental pollution, and to assist the CEQ in developing and recommending to the President new policies for environmental protection. Congress then enacted the Water Quality Improvement Act (WQIA) of 1970 (USEPA 2011e). The WQIA established a State Certification procedure to prevent degradation of water below applicable standards (USEPA 2011e).

At this point in history water quality legislation was a hodgepodge of laws. Therefore Congress enacted the Federal Water Pollution Control Amendments of 1972 (USEPA 2011e). The objective of this new law was to “restore and maintain the chemical, physical, and biological integrity of the nation’s waters” (Sullivan 2009). The first national goal of this law was to eliminate the discharge of all pollutants into navigable waters of the United States by 1985. This goal was to be achieved by implementing the National Pollutant Discharge Elimination System (NDPES) (Sullivan

2009). The second national goal was to establish by July 1, 1983, the interim level of water quality that provides for the protection of fish, shellfish, wildlife, and recreation (USEPA 2011e). The amendments of 1977 contained the Flannery Decree which represented a new approach to toxics. These amendments also changed the name of the law to the Clean Water Act, which is what it is known as today. Through the 1980s, it became apparent by a number of studies, including the Nationwide Urban Runoff Program (NURP) (USEPA 1983), that the management of point source pollutants would not complete the goal of restoring the nation's waters (USEPA 2011e). In 1987 Congress amended the Clean Water Act which created new programs for toxic control, established a timetable for regulation of stormwater, strengthened requirements related to water quality, tightened requirements for certain variances, established a revolving loan fund for construction of sewage treatment plants, and expanded the USEPA's enforceable tools (Sullivan 2009).

The Clean Water Act uses the following major elements to meet its goals: prohibition of discharges except as in compliance with the act; a permit program to authorize and regulate discharges in compliance with the act; a system for determining the limitations to be imposed on authorized and regulated discharges; a permit program governing the discharge or placement of dredged fill material in the nation's waters; a procedure for cooperative federal/state implementation of the act; and strong enforcement mechanisms (Sullivan 2009). The main tool of the CWA is the NPDES program to authorize and regulate discharges in compliance with the act. The NPDES program currently controls water pollution by regulating both point and nonpoint sources. Point sources are defined by the act as "any discernable, confined and discrete conveyance from which pollutants are or may be discharged." Point sources are usually referred to as pipe discharges because the source is a specific place from which it flows. Nonpoint sources are not defined by a specific discrete location. These sources usually exist as incremental sources that enter receiving waterbodies over varying distances.

The amendments of 1987 mandated that measures must be taken to control pollutants in stormwater runoff. This was accomplished by a phased approach to stormwater management under the NPDES program. Phase I regulated medium and large municipal separate storm sewer systems (MS4s) with a population greater than 100,000 people, construction activities disturbing more than five acres, and ten categories of industrial activity. USEPA established Phase I in 1990, but it did not take effect in Nebraska until August 1997 (Krause 2005). Phase II regulated MS4s of smaller cities with populations of 10,000 or greater and construction activities of one acre or larger. Phase II was established in 1999 by the USEPA, but it did not take effect in Nebraska until March 2003 (Krause 2005).

3.2 Regulation of the Papillion Creek Watershed

The municipalities within the Papillion Creek Watershed collaborated to form a unique governing body called the Papillion Creek Watershed Partnership (PCWP). The PCWP was formed in August 2001 by the seven cities of Bellevue, Boys Town, Gretna, La Vista, Omaha, Papillion, and Ralston plus the Papio-Missouri River Natural Resources District and Sarpy County (PCWP 2009). The partnership has approved the third interlocal agreement which is effective through June 30, 2014. The partnership was formed to accomplish the following goals: compliance with the Clean Water Act, reduction of existing and future flood impacts, improvement of water quality in the Watershed’s streams and reservoirs, increase water-based recreational opportunities and associated improvement in quality of life, standardization of the construction sites soil erosion and sediment control, assessment and characterization of current water quality and quantity conditions for the watershed, and the creation of the Watershed Master Plan (PCWP 2009). The PCWP formed to pro-actively address Phase II of the NPDES program. Omaha is classified as a Phase I community, but the other municipalities are classified as Phase II communities in the NPDES program. Omaha has both a Phase I MS4 stormwater NPDES permit and a combined sewer overflow (CSO) permit.

The regulating authority for the Papillion Creek Watershed is the Nebraska Department of Environmental Quality (NDEQ). The NDEQ has the authority for environmental regulations for the state of Nebraska as directed by the USEPA. NDEQ’s approach for nonpoint source pollution control is to first establish designated uses of the waterbodies contained in the state of Nebraska. Then water quality sampling is completed to determine if designated uses are being supported. If the waterbody’s designated uses are not being supported, the waterbody is termed impaired and listed in the agency’s Water Quality Integrated Report (NDEQ 2010). Next, water quality management plans are developed and implemented to remediate or protect the listed waters and to bring them into compliance. These plans usually include the introduction of Best Management Practices (BMPs). If the BMPs are still unable to remediate the degradation, Total Maximum Daily Loads (TMDLs) for the waterbody are developed. The TMDL process is the last step of this control. TMDLs go through an in-depth analysis of the waterbody to examine sources and to determine the allowable total maximum daily loads of a pollutant that can be discharged to the waterbody for the waterbody to still support its designated uses (USEPA 2011f) .

3.3 Previous Studies Completed for the Papillion Creek Watershed

3.3.1 "Water Quality of Combined Sewer Overflows, Stormwater, and Streams, Omaha, Nebraska, 2006-07" by USGS

The United States Geological Survey (USGS) in cooperation with the City of Omaha investigated the water quality of the combined sewer overflows, stormwater, and streams in the Omaha, Nebraska area by collecting and analyzing 1,175 water samples from August 2006 through October 2007 (Jason et al. 2009). The study area encompassed the southern and eastern part of the Papillion Creek basin and the Missouri River adjacent to the Papillion Creek basin. This part of the watershed experiences the combined effects of stormwater and combined sewer overflow discharges to the streams. The study was undertaken to provide a detailed assessment and analysis of the water quality within the combined sewer overflows (CSOs), stormwater overflows (SWOs), and receiving streams in the Omaha area from August 2006 through October 2007. This was accomplished by measuring concentrations and calculating loads of nutrients, metals, organic compounds, bacteria, and other water quality constituents of concern during storm events and during scheduled sampling. Table 3-1 displays the water quality parameters used for analysis of the samples taken from the streams.

Table 3-1 Wastewater Method Compound Names, Endocrine-disrupting Potency, Parameter/method codes, and Possible Compound Uses (Jason et al. 2009)

[EDP, endocrine-disrupting potency; CAS, Chemical Abstracts Service; S, suspected; -, not a suspected endocrine disruptor; K, known; CP, combustion product; PAH, polycyclic aromatic hydrocarbon; FR, flame retardant; H, herbicide; GUP, general-use pesticide; I, insecticide; F, fungicide; UV, ultraviolet; WW, wastewater]

Compound name	EDP[1]	CAS Registry Number[2]	Parameter/ method codes[3]	Possible compound uses or sources[4]
1,4-Dichlorobenzene	S	106-46-7	34571Y	Moth repellent, fumigant, and deodorant.
1-Methylnaphthalene	-	90-12-0	81696Z	2 to 5 percent of gasoline, diesel fuel, or crude oil
2,2',4,4'-Tetrabromodiphenyl ether (BDE congener 47)	-	5436-43-1	63147A	Widely used brominated flame retardant
2,6-Dimethylnaphthalene	-	581-42-0	62805Z	Present in diesel/kerosene (trace in gasoline)
2-Methylnaphthalene	-	91-57-6	30194Z	2 to 5 percent of gasoline, diesel fuel, or crude oil
3,4-Dichlorophenyl isocyanate	-	102-36-3	63145A	Degradate of diuron, a noncrop herbicide
3-*beta*-Coprostanol	-	360-68-9	62806Z	Carnivore fecal indicator
3-Methyl-1H-indole (skatol)	-	83-34-1	62807Z	Fragrance, stench in feces and coal tar
3-*tert*-Butyl-4-hydroxyanisole (BHA)	K	25013-16-5	61702Z	Antioxidant, general preservative
4-Cumylphenol	K	599-64-4	62808Z	Nonionic detergent metabolite
4-*n*-Octylphenol	K	1806-26-4	62809Z	Nonionic detergent metabolite
para-nonylphenol (total)	K	84852-15-3	62829Z	Nonionic detergent metabolite
4-*tert*-Octylphenol	K	140-66-9	62810Z	Nonionic detergent metabolite
5-Methyl-1H-benzotriazole	-	136-85-6	61944Z	Antioxidant found in antifreeze and deicers
Acetophenone	-	98-86-2	62811Z	Fragrance in detergent and tobacco, flavor in beverages
Acetyl-hexamethyl-tetrahydronaphthalene (AHTN)	-	21145-77-7	62812Z	Musk fragrance (widespread use) persistent in groundwater
Anthracene	-	120-12-7	34220Z	Component of tar, diesel, or crude oil; CP
Anthraquinone	-	84-65-1	62813Z	Manufacture of dyes and textiles, seed treatment, bird repellent
Atrazine	K	1912-24-9	39630C	Selective triazine herbicide
Benzo[*a*]pyrene	K	50-32-8	34247Z	Regulated PAH, used in asphalt and in cancer research; CP
Benzophenone	S	119-61-9	62814Z	Fixative for perfumes and soaps
beta-Sitosterol	-	83-46-5	62815Z	Plant sterol
beta-Stigmastanol	-	19466-47-8	61948Z	Herbivore fecal indicator (digestion of sitosterol)
Bis(2-ethylhexyl) phthalate	K	117-81-7	39100C	Plasticizer for polymers and resins, pesticide inert ingredient
Bisphenol A	K	80-05-7	62816Z	Manufacture of polycarbonate resins, antioxidant; FR
Bromacil	-	314-40-9	30234Z	H (GUP); greater than 80 percent noncrop usage on grass/brush
Caffeine	-	58-08-2	81436Z	Beverages, diuretic, very mobile/biodegradable
Camphor	-	76-22-2	62817Z	Flavor, odorant, ointments
Carbaryl	K	63-25-2	39750Z	I; crop and garden uses, low persistence
Carbazole	-	86-74-8	77571Z	I; manufacture of dyes, explosives, and lubricants
Chlorpyrifos	K	2921-88-2	38932Z	I; domestic pest and termite control (domestic use restricted as of 2001)
Cholesterol	-	57-88-5	62818Z	Often a fecal indicator, also a plant sterol
Cotinine	-	486-56-6	61945Z	Primary nicotine metabolite
Diazinon	K	333-41-5	39570Y	I; greater than 40 percent nonagricultural usage, ants, flies.
Dichlorvos	S	62-73-7	30218Z	I; pet collars
Diethyl phthalate (DEP)	K	84-66-2	34336B	Plasticizer for polymers and resins
d-Limonene	-	5989-27-5	62819Z	F; antimicrobial, antiviral, fragrance in aerosols

[EDP, endocrine-disrupting potency; CAS, Chemical Abstracts Service; S, suspected; -, not a suspected endocrine disruptor; K, known; CP, combustion product; PAH, polycyclic aromatic hydrocarbon; FR, flame retardant; H, herbicide; GUP, general-use pesticide; I, insecticide; F, fungicide; UV, ultraviolet; WW, wastewater]

Compound name	**EDP**[1]	**CAS Registry Number**[2]	**Parameter/ method codes**[3]	**Possible compound uses or sources**[4]
Fluoranthene	-	206-44-0	34376Z	Component of coal tar and asphalt (only traces in gasoline or diesel fuel); CP
Hexahydrohexamethyl cyclopentabenzopyran (HHCB, Galaxolide)	-	1222-05-5	62823Z	Musk fragrance, persistent, widespread in groundwater, concern for bioaccumulation and toxicity
Indole	-	120-72-9	62824Z	Pesticide inert ingredient, fragrance in coffee
Isoborneol	-	124-76-5	62825Z	Fragrance in perfumery, in disinfectants
Isophorone	-	78-59-1	34008Z	Solvent for lacquer, plastic, oil, silicon, and resin
Isopropylbenzene (cumene)	-	98-82-8	77223Y	Manufacture of phenol/acetone, fuels and paint thinner
Isoquinoline	-	119-65-3	62826Z	Flavors and fragrance
Menthol	-	89-78-1	62827Z	Cigarettes, cough drops, liniment, and mouthwash
Metalaxyl	-	57837-19-1	04254Z	H, F (GUP); mildew, blight, pathogens, golf/turf
Methyl salicylate	-	119-36-8	62828Z	Liniment, food, beverage, UV-absorbing lotion
Metolachlor	-	51218-45-2	82612Z	H (GUP), indicator of agricultural drainage
N,N-Diethyl-*meta*-toluamide (DEET)	-	134-62-3	61947Z	I, urban uses, mosquito repellent
Naphthalene	-	91-20-3	34696Y	Fumigant, moth repellent, major component (about 10 percent) of gasoline
Nonylphenol, diethoxy (total)	K	26027-38-3	61703Z	Nonionic detergent metabolite
Nonylphenol, monoethoxy (total)	K	104-35-8	61704A	Nonionic detergent metabolite
Octylphenol, diethoxy	K	26636-32-8	61705Z	Nonionic detergent metabolite
Octylphenol, monoethoxy	K	26636-32-8	61706Z	Nonionic detergent metabolite
p-Cresol	-	106-44-5	77146Z	Wood preservative
Pentachlorophenol	S	87-86-5	39032Z	H, F, wood preservative, termite control
Phenanthrene	-	85-01-8	34416Z	Manufacture of explosives, component of tar, diesel fuel, or crude oil; CP
Phenol	-	108-95-2	34694Z	Disinfectant, manufacture of several products, leachate
Prometon	-	1610-18-0	39056Z	H (noncrop only), applied antecedent to blacktop surfacing
Pyrene	-	129-00-0	34469Z	Component of coal tar and asphalt (only traces in gasoline or diesel fuel); CP
Tetrachloroethylene	-	127-18-4	34475Y	Solvent, degreaser, veterinary anthelmintic
Tribromomethane (bromoform)	-	75-25-2	32104Y	WW ozonation byproduct, military/explosives
Tris(2-butoxyethyl) phosphate	-	78-51-3	62830Z	FR
Tris(2-chloroethyl) phosphate	S	115-96-8	62831Z	Plasticizer, FR
Tris(dichloroisopropyl) phosphate	S	13674-87-8	61707Z	FR
Tributyl phosphate	-	126-73-8	62832Z	Antifoaming agent, FR
Triclosan	S	3380-34-5	61708Z	Disinfectant, antimicrobial (concern for acquired microbial resistance)
Triethyl citrate	-	77-93-0	62833Z	Cosmetics, pharmaceuticals
Triphenyl phosphate	-	115-86-6	62834Z	Plasticizer, resin, wax, finish, roofing paper, FR

[1] Colburn and others (2000).

[2] CAS Registry Number® is a registered trademark of the American Chemical Society. CAS recommends the verification of the CAS Registry Numbers through CAS Client Services (*http://www.cas.org*).

[3] Parameter codes corresponding to sample constituent variables are linked to compound analytical results stored in the USGS National Water Information System database.

[4] ChemFinder Webserver (2006); National Toxicology Program (2006); National Institute of Standards and Technology (2006); HealthCentral.com (2006); Extension TOXicology NETwork (2006).

The study found that generally constituent concentrations were lower in dry weather stream samples compared to wet weather samples. The report noted constituents related to upstream sources were specific conductance, nitrite plus nitrate, nitrite, hardness, calcium, magnesium, chloride, arsenic, barium, selenium, uranium, and atrazine. Constituents derived more from CSOs than from SWOs or upstream sources were chemical oxygen demand, biochemical oxygen demand, total suspended solids, ammonia, total nitrogen, orthophosphate, total phosphorus, copper, lead, mercury, silver, and others. Results indicate that upstream sources, CSOs, and SWOs each contribute to concentrations of most of the constituents within the Omaha area. The report also describes the recovery time for stream sites that can be further used to distinguish between stormwater and baseflow for a stream.

The USGS study also evaluated for E. coli in the watershed. The study found that 99 percent of E. coli samples were above the NDEQ criterion for the Papillion Creek Watershed sites, and 76 percent of E. coli samples were above the NDEQ criterion for the Missouri River near Omaha.

3.3.2 “Assessing the Value of the Papillion Creek Watershed, 2003” by HDR

This study was established for the Papillion Creek Watershed Partnership (HDR 2003a) to provide an inventory of existing pertinent watershed information, such as policies, ordinances, GIS mapping water quality data, hydrologic/hydraulic, streamflow data, precipitation data, etc. The study also was established to provide a master database for tracking proposed BMP projects and relationally tying such activities to water quality related information, including interfacing to existing GIS mapping. Other objectives where to: update hydrologic/hydraulic modeling and provide new water quality modeling, provide assistance for public and stakeholder education/engagement in the planning process, provide regulatory assistance for the USEPA NPDES Phase II stormwater Program, provide funding research/procurement assistance, and to develop a preliminary watershed management plan.

The study found that imperviousness is projected to increase from 13.8 percent in 2002 to 25.1 percent in 2040. The increase in imperviousness will lead to decreased infiltration and increased runoff which will result in higher streamflows for the watershed. The increased streamflows will correlate with higher water surface elevations which could result in more flooding during larger storms.

Fecal coliform loading curves developed for stream segments indicated loading differences between stream reaches in the watershed. Pollution sources were identified from statistical correlations of fecal coliform dependencies on flow, precipitation, and turbidity. Fecal coliform bacterial levels were found to be highly dependent on surface runoff events and sediment transport mechanisms. Fecal coliform levels were well above NDEQ’s surface water quality standards. Fecal coliform levels during runoff events were typically three to four orders of magnitude above the NDEQ criteria. The report found that urbanized metropolitan area contributes another order of magnitude above non-urban contributions of bacteria levels during medium flow conditions. Short travel times do not allow fecal coliform decay to keep pace with progressively additive bacterial loadings.

Existing reservoirs reduce fecal coliform levels. Regulatory compliance for fecal coliform levels will be difficult.

3.3.3 "Papillion Creek Watershed Management Plan, 2009" by HDR

The report is the second phase of the study of the Papillion Creek Watershed by HDR (HDR 2009). The report was generated to fulfill requirements of the stormwater permits of the PCWP partnership members. The report is a Watershed Management Plan to address strategies for structural and non-structural Best Management Practices (BMPs) in the watershed.

The objectives of the second phase included: establishing water quality improvements that should be implemented in the watershed; discussing the benefits and disadvantages of water quality improvements that consist of Low Impact Development (LID) throughout the watershed and establishment of water quality basins; evaluating where to establish peak flow reduction improvements for the 100 year storm protection in the watershed; and defining how flow reduction should consist of maximum Low Impact Development in Washington County, regional detention basins in Douglas and Sarpy counties, and watershed management plan flexibility. Finally, the report established a plan to implement these objectives.

Five different scenarios were examined for the peak flow reduction including: existing (2004), full build-out with no stormwater controls, full build-out with max LID only, full build-out with regional retention only, and combination of LID and regional detention. Full build-out was designated for the year 2040 for the watershed.

This study found that Water Quality Low Impact Development is an effective strategy to mitigate additional pollutant loadings from future development in the watershed. Overall pollutant loadings become greater downstream because existing developments have no source controls. The study found that BMPs will not be enough to reduce bacterial loadings during large storm events because the current BMPs are only designed for small storms. Even with Water Quality Low Impact Development, E. coli criteria will not be consistently met except under very low or baseflow conditions in future scenarios. Although not currently regulated, total suspended solids, nitrogen, and phosphorus reductions should be considered in the BMP designs. Although some water quality standards will not be met, the addition of Water Quality Low Impact Development is desirable for the protection of downstream waterbodies to the extent practicable.

3.4 Background of Stream Sampling

3.4.1 Sampling Approach

In water quality sampling there are generally two different sampling approaches that can be used. These approaches include project specific and holistic representative sampling (Burton and Pitt 2002). Project specific sampling usually exists on a small scale and focuses on one specific water quality project. Specific sampling usually is used to determine the effectiveness of a specific water quality measure. Examples of this type of sampling include examining Best Management Practices (BMPs), construction sites, and water quantity control measures (Burton and Pitt 2002). This type of sampling limits the numbers of variables examined, which allows the results to relate specifically back to the project sampled. Holistic representative sampling encompasses a large area to examine the impact of many different projects that exist in the watershed selected (Burton and Pitt 2002). The design of holistic sampling is to look at how a waterbody is functioning with many different sources and contributions. Examples of holistic sampling include land use water quality sampling and basin sampling. The holistic approach provides information about how water quality is affected by the contributions of many sources in the watershed. This sampling is normally referred to as watershed or basin monitoring (Burton and Pitt 2002).

3.4.2 Sampling Schemes

Different types of sampling schemes exist for water quality sampling, these include: simple random sampling, stratified random sampling, multistage sampling, cluster sampling, and systematic sampling (Burton and Pitt 2002). The simple random sampling technique entails sampling randomly from the complete population of conditions. The scheme involves sampling where effects are expected to be shown, but the whole population is not sampled. The stratified random sampling technique entails sampling at random from several population groups that are assumed to be internally more homogeneous than the population as a whole. The scheme focuses results on the subgroups of a total population that is thought to have more significance to the project. The multistage sampling technique entails collecting samples in the field to be brought to the laboratory for subsequent splitting for several different analyses. The cluster sampling technique entails sampling that is targeted towards a specific cluster of a population. The scheme is dedicated to looking at the results of only a select subgroup of a total population. The systematic sampling technique entails collecting samples as evenly spaced intervals for an extended period of time (Burton and Pitt 2002). These frequencies can be described in different terms when samples are being conducted in flowing waterbodies.

The sampling schemes for flowing waterbodies can be described as Time-series, Time of Travel, and Hydrographic (HDR 2003b). Time-series sampling is a form of systematic sampling which consists of sampling water quality at a location at preset time intervals. An example of this type of sampling, is sampling that is conducted once a week at a uniform time regardless of hydrologic parameters. Time-series sampling allows for trend analysis of the results.

Time of travel sampling is a form of cluster sampling which consists of sampling water quality with respect to travel time for the stream. This essentially means that the same water is sampled multiple times as it flows past different locations within the watershed. Time of Travel allows for source contribution analysis of the results by studying the differences in the water quality as the water passes through different parts of the watershed.

Hydrographic sampling is a form of stratified random sampling which consists of sampling water quality with respect to time of travel but at multiple times throughout a hydrograph of a storm. This type of sampling frequency is an extension of Time of Travel, but the samples are conducted at multiple times. Hydrographic sampling allows for a runoff analysis to be completed for the water. Results will be able to be examined to determine if differences exist between the rise, peak, and recession parts of the hydrograph to determine how the concentrations of pollutants change with respect to each part of the hydrograph.

3.4.3 Sampling Methods

Sampling methods for a project are dependent upon the objectives. For either project specific or holistic sampling, water samples can either be collected with automatic sampling equipment, manual grab sampling, or a combination of the two. Advantages to automatic sampling include: consistent samples, minimal labor requirement for sampling, and reduced hazards for sampling personnel. Disadvantages to automatic sampling include: considerable maintenance of equipment, inflexibility, and vandalism. Advantages to manual sampling include low capital cost, ability to compensate for various situations, in-field reconnaissance, and flexibility of sampling plan. Disadvantages of manual sampling include probability of increased variability, inconsistency in collection, and high cost of labor (Burton and Pitt 2002). Because of these reasons sampling methods are based upon project-specific objectives and constraints. Often projects use a combination of automatic and manual sampling techniques.

The USGS study of the Papillion Creek used a combination of automatic and manual sampling. Automatic sampling was used to provide a continuous view of selected water quality parameters of the stream. The USGS installed flow meters and multi-parameter probes that measured parameter values every fifteen minutes. Manual sampling was also used at determined intervals. Manual sampling was conducted to collect grab water samples for other parameters. These grab samples are considered discrete samples because they represent the water quality at one specific place and time.

Discrete and continuous monitoring of a waterbody presents two very different views. Discrete monitoring provides a view of the water quality only at specific times. Because of this, different waterbody scenarios can often be missed by sampling, and expert judgment must be used to determine when the proper time to sample is. Continuous monitoring provides a much broader view that captures different waterbody scenarios that can happen. Continuous monitoring, however, is limited by the technology that exists today. Currently continuous monitoring can only be achieved for the parameters: depth, dissolved oxygen, turbidity, chlorophyll, cyanobacteria, temperature, pH, specific conductance, ammonia, and nitrate (Eureka Environmental 2011). Due to the limitations of discrete and continuous monitoring, sampling project designs are tailored to present the best results of waterbody sampling to meet the objectives of the project.

Stream samples for a well-mixed (laterally and vertically) waterbody can be collected at a single spot at the centroid-of-flow (USGS 2010c). This method of collecting stream samples is one of the most used. For most streams the centroid of flow is located at one third depth at the thalweg of the stream (Gupta 2008). However, this location can vary dependent upon the cross section profile of the stream.

3.5 Stormwater Pollutants and Their Impacts

Stormwater pollution can have various effects on a waterbody. These effects can include habitat destruction, hazards to aquatic organisms, and hazards to non-aquatic organisms that use the waterbody. Impacts from stormwater pollution often cause waterbodies to become impaired for their beneficial uses. Sources of these pollutants can include: agriculture, silviculture, resource extraction, hydro-modification, urban areas, land disposal, and contaminated sediments. Contribution from these sources is based on a site specific basis (Burton and Pitt 2002).

Traditional pollution monitoring has been accomplished by evaluating a suite of traditional water quality parameters. These parameters and their associated effects are discussed in the subsequent sections.

3.5.1 Chemical, Physical, and Sediment Indicators

Chemical indicators include biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, pH, specific conductivity, temperature, total solids, total dissolved solids, total suspended solids, and turbidity.

Biochemical oxygen demand (BOD) measures the rate of oxygen uptake by bacteria and other microorganisms in stabilizing decomposable organic matter in a sample of water stored at 20°C in the dark (Weiner and Matthews 2003). The BOD test is often used to estimate the impacts of discharges of effluents to a waterbody that contain large amounts of biodegradable organics. Excessive amounts of BOD can decrease the concentration of dissolved oxygen in a waterbody which will adversely affect aquatic organisms in that waterbody.

Chemical oxygen demand (COD) indirectly measures the amount of all oxidizable compounds in a water sample (Weiner and Matthews 2003). A COD test measures the amount of all oxidizable compounds, whereas a BOD test only measures biologically active organic matter.

Dissolved Oxygen (DO) measures the amount of oxygen dissolved in a waterbody. Oxygen is fundamental to aquatic life. Without free dissolved oxygen, waterbodies become uninhabitable to aerobic organisms, which include fish and most invertebrates (Weiner and Matthews 2003).

The water quality parameter pH is a measure of the hydrogen ion concentration of a solution expressed as the negative base-10 logarithm, which is a measure of acidity. The parameter pH is an important measurement in water quality because aquatic organisms are sensitive to pH changes. Few aquatic organisms can tolerate pH levels less than four or greater than ten (Weiner and Matthews 2003).

Specific conductivity (SC) is the ability of water to conduct an electric current and is a function of the amount of dissolved ions in the water. Typically groundwater entering a stream has a higher SC than precipitation sources (Jason, et al. 2009). This is because groundwater has percolated through soils rich in minerals.

Water temperature (WT) is an important parameter in freshwater ecosystems because it affects: the solubility of dissolved constituents such as dissolved oxygen and SC and it affects the chemical rates of reactions and biological activity (Jason, et al. 2009).

Total solids (TS) measures the material left in a container after the water is removed by evaporation, usually at 103°C to 105°C (Weiner and Matthews 2003). Total solids can be separated into total suspended solids and total dissolved solids.

Total dissolved solids (TDS) measures the salt and other dissolved chemicals that remain after the water is evaporated from a filtered water sample. TDS measurement is used in fresh water to understand the salt content of a solution. High salt concentrations can threaten the natural population of plants and animals in a body of water if these concentrations reach a certain level (Davis and Masten 2004).

Total suspended solids (TSS) measures the material filtered out of a water sample. TSS is a measure of the organic and inorganic particles that are carried by a waterbody. A high level of TSS can result in the water sample being very cloudy. This can be from a high amount of organic and inorganic particles entering the stream from natural processes, soil erosion, industrial wastewater, and other processes. A natural level of TSS is required for most streams to maintain a food source for the ecosystem of a waterbody. However, high amounts of TSS can make it difficult for fish to find prey and at high levels suspended sediment can even cause direct physical harm (USEPA 1999b).

Turbidity (Turb) is a measure of the clarity of water sample that is affected by suspended matter such as sediment, particulate-organic matter, plankton, and other microscopic organisms (Jason et al. 2009). Specifically turbidity is a measure of the optical properties of a water sample that cause light to scatter. In most water samples turbidity has been shown to have a strong correlation to TSS. Therefore, excessive levels of turbidity generally have similar effects on a waterbody as TSS.

3.5.2 Nutrient Indicators

Nutrient indicators include total nitrogen, organic nitrogen, ammonia, Kjeldahl nitrogen, nitrate plus nitrite, nitrite, organic phosphorus, phosphates, dissolved phosphorus, and total phosphorus.

Nitrogen is one of the essential building blocks for biological growth, but excessive levels of nitrogen can lead to the negative effect of eutrophication. Nitrogen occurs in five major forms in aquatic environments: organic nitrogen, ammonia, nitrite, nitrate, and dissolved nitrogen gas (Weiner and Matthews 2003). The typical decomposition of nitrogen compounds in surface water proceeds from organic nitrogen to ammonia to nitrite to nitrate. Organic nitrogen represents the nitrogen fraction of tissue such as blood. Organic nitrogen is broken down in the environment to ammonia.

Total ammonia (NH_3) is a measure of one of the intermediate compounds formed during biological metabolism. This compound is considered an indicator of recent pollution especially from sources carrying sewage or runoff from livestock facilities (Weiner and Matthews 2003). Aerobic decomposition of organic nitrogen and ammonia produces nitrite (NO_2) and nitrate (NO_3).

Total Kjeldahl nitrogen (TKN) is a measure of ammonia and organic nitrogen. Because organic nitrogen and ammonia are broken down into nitrite and nitrate through the natural process of aerobic decomposition, TKN is used as a measure of a recent pollution or source to a waterbody.

Nitrate plus nitrite (NO_2+NO_3) is a measure of nitrogen in its decomposed or oxidized state that exists in a water sample. Total nitrogen of a water sample is calculated by the addition of total Kjeldahl nitrogen and nitrate plus nitrite.

Phosphorus is one of the essential building blocks for biological growth, but excessive levels of phosphorus can lead to the negative effect of eutrophication. Organic phosphorus represents the phosphorus in tissue such as blood; organic phosphorus typically breaks down to phosphates in surface waterbodies. Organic phosphorus is generally in the particulate form while orthophosphate is generally dissolved.

Dissolved phosphorus (DP) is a measure of phosphorus that passes through a filter membrane. DP is the measure of phosphorus that is dissolved into the water column (Weiner and Matthews 2003).

Total phosphorus (TP) is a measure of all the forms of phosphorus that exist in the water column.

3.5.3 Pathogen Indicators

Monitoring of pathogens in water is currently achieved by the use of indicator organisms. Although these indicator organisms are not directly harmful to humans, they indicate the possible presence of pathogens. Pathogens that exist in water that pose a direct threat to humans include bacteria, protozoans, and viruses (Weiner and Matthews 2003). Two indicator organisms that are commonly used in water quality monitoring include fecal coliforms and Escherichia coli. Coliform bacteria are nonspore forming, rod-shaped bacteria capable of fermenting lactose within 48 hours at 35°C.

Fecal coliforms (FC) are a subset of total coliform bacteria, but they are more fecal-specific in origin (USEPA 2011a). Unfortunately, coliform species exist that are not fecal in origin but are still detected in the FC analysis by standard detection methods. The USEPA began recommending the use of E. coli instead of fecal coliforms for an indicator organism because E. coli are a subset of fecal coliforms that contain only coliform species that are fecal in origin.

Escherichia coli (E. coli) are a specific species of fecal coliform bacteria that are from humans and other warm-blooded animals (USEPA 2011a). Fecal coliforms and E. coli concentrations can be quantified by using the IDEXX Colilert test method. This test method utilizes a counting colony method to detect the presence of the indicator organisms in a water sample. The presence of coliforms in a water sample does not prove that there are pathogenic organisms, but indicates that such organisms might be present (Weiner and Matthews 2003).

Unfortunately, recent studies have demonstrated the survival of coliform species in waterbodies. This means that these species may not indicate recent pollution. Studies have also shown that the presence of animal coliforms contribute to the amount of detectable indicator organisms in a water sample. This means that these tests cannot discern between human and animal sources of pollution. This indicates the need for a new pathogenic indicator to be developed.

3.6 Pollution Control Strategies

Point source pollution control is currently addressed with the National Pollutant Discharge Elimination System (NPDES) permit program. In most cases this program is administered by authorized states. In Nebraska the NDEQ administers the NPDES program. This program requires a permit for every discharge of pollutants from a point source to waters of the United States. This permit gives the permittee the right to discharge specified pollutants from specified outfalls. This permit usually sets numerical limitations on the authorized discharges and imposes other conditions on the permittiee (Sullivan 2009). Municipal separate storm sewers (MS4s) are assigned NPDES permits.

Nonpoint source pollution control is currently addressed with the use of best management practices (BMPs). The National Menu of BMPs include: public education, public involvement, illicit discharge detection and elimination, construction, post-construction, and pollution prevention/good housekeeping. Public education for nonpoint source pollution control includes: developing municipal outreach programs, promoting the stormwater message, stormwater outreach materials, education for homeowners, and education for businesses. Public involvement includes: Adopt-A-Stream program, storm drain marking, volunteer monitoring cleanup, soliciting public opinion, etc. Illicit discharge detection and elimination control includes: an Illicit Discharge Detection and Elimination Program development, monitoring and controlling illegal dumping, preventing septic system failures, establishing public reporting pathways, etc. Construction control includes: municipal program oversight, construction site planning and management, structural erosion control measures (silt fences, runoff basins, land cover applications, and etc.), structural runoff control measures, etc. Post-construction control includes: municipal program oversight, structural runoff control measures (green roofs, Low Impact Development, infiltration basins, filtration basins, etc.), retention/detention basins, etc (USEPA 2008b).

3.7 Pollutant Loading and Impact Analysis

A pollutant load is the mass or weight of a pollutant which passes a cross-section of a waterbody in a specific time. Many different approaches exist to calculate loads from observed concentrations and flow data. The methods include: direct numeric integration, averaging approaches, flow internal technique, and regression approaches (Richards 1998). Numeric integration is only satisfactory when the sampling frequency is high, usually 100 samples or more per year. This method calculates the loading based on the summation of the multiplicative result of concentration, flow, and the time interval. Averaging approaches are procedures where an average concentration for some period of time is multiplied by the average flow. The flow interval technique is a procedure where several intervals of average fluxes are calculated and summed to determine the load for a specified period of time. The regression approach procedure develops a relationship between concentration and flow based on the samples taken. Then the relationship is used to calculate a representative concentration for days not sampled. The approach allows for the calculation of the load when no concentrations are collected based on flow data. Then the annual load is calculated from the observed and regressed loading values.

Chapter 4. Methods

4.1 Sampling Objectives

The Papillion Creek sampling was completed by using the holistic approach to sampling. The holistic approach allowed the watershed to be sampled at different points to understand the water quality throughout the basin. The sampling objectives were as follows according to the "City of Omaha Sampling and Analysis Plan for the Papillion Creek Watershed" (City of Omaha 2005):

- Determine if water quality conditions meet applicable state water quality standards,
- Identify pollutants and their potential sources that are affecting water quality,
- Estimate the current watershed loadings for the identified pollutants,
- Collect the information needed to identify potential BMPs that could be implemented to improve surface water quality, and
- Establish a baseline by which to evaluate the effectiveness of future BMPs.

4.2 Stream Sampling

4.2.1 Site Selection Plan

Site selection for the sampling plan was completed by the City of Omaha. The City wanted a sampling plan that would include both rural and urban areas. Four sites were chosen and labeled sites B, D, F, and S. Site B is located on the Big Papillion Creek at 168th Street and Highway 36. Site D is located on the Papillion Creek at Capehart Road and Highway 75. Site F is located on the Little Papillion Creek at 64th and L Street. Site

S is located on the Big Papillion Creek at 76th and L Street. Figure 4-1 shows the sampling locations relative to the City of Omaha.

Site B is located at the approximate upstream limit of urban development on the Big Papillion Creek. This site is representative of rural land use north of the city. This location represents the incoming water quality of the Big Papillion Creek to the City of Omaha. Site B represents the upper part of the Big Papillion Creek watershed. The upper part of the Big Papillion Creek watershed has a land use that is characterized by 5.4 percent of urban development, 12.3 percent rural open land, and 82.3 percent rural cultivated crops.

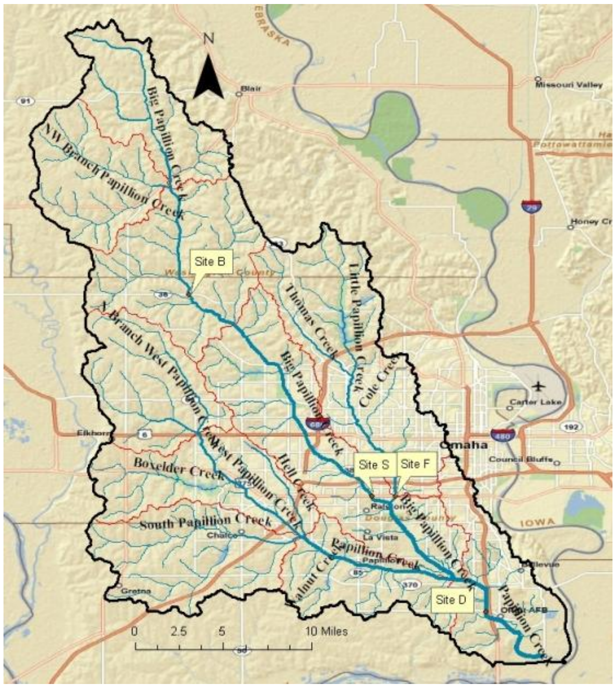

Figure 4-1 Sampling Locations in the Papillion Creek Watershed

Site S is located on the Big Papillion Creek just before the confluence of the Big Papillion Creek and the Little Papillion Creek. This site is designed to evaluate how the water quality has been affected with the addition of urban sources to the Big Papillion Creek downstream of site B. The difference in water quality between sites S and B will be assumed the contribution of urban sources to the water quality of the stream. Site S represents the entire Big Papillion Creek watershed. The Big Papillion Creek watershed has a land use that is characterized by 25.4 percent of urban development, 12.5 percent rural open land, and 62.2 percent rural cultivated crops.

Site F is located on the Little Papillion Creek just before the confluence of the Big Papillion Creek and the Little Papillion Creek. This site is designed to evaluate the water quality of a stream affected by combined sewer overflows (CSOs). The Little Papillion Creek watershed has a land use that is characterized by 54.9 percent of urban development, 18.4 percent rural open land, and 26.7 percent rural cultivated crops.

Site D is located on the Papillion Creek 5.3 miles before the confluence of the Papillion Creek and the Missouri River. This site is representative of the water quality of the stream just before it leaves the basin. This location is designed to evaluate the water quality of all of the watershed source contributions. The Papillion Creek watershed has a land use that is characterized by 43.7 percent of urban development, 12.8 percent rural open land, and 43.5 percent rural cultivated crops.

4.2.2 Sampling Team Establishment and Training

The University of Nebraska was responsible for sampling for this project. A team of four students and one faculty member was assembled. Two employees from the City of Omaha Environmental Control Division were also able to help if needed. The sampling team was trained during two different sessions by the City of Omaha staff. Training included proper sample handling techniques, probe operation, site location, lab analysis, and safety. On a given sampling day, only two people were needed. One person would enter the stream to collect the samples, and the other person would operate the sample probe and stand by for safety on the bank. The two-person sampling team would also handle the multi-parameter probe calibration, completing the chain of custody documents, and completing the field documentation.

4.2.3 Sampling Scheme and Frequency

For the Papillion Creek Project, Time-series sampling was chosen. Sampling was scheduled to be performed weekly during the recreational season (May 1st – September 30th) and monthly during the non-recreational season. Due to conflicts of schedules weekly sampling was only completed from May 1st through the third week in August. This was determined by the City of Omaha to be an adequate sampling plan for the recreational season. The objective for the sampling was to establish an annual pollutant load that exists in the Papillion creek which discharges to the Missouri River. For this objective the Time-series sampling approach was chosen to obtain random samples in regards to streamflow conditions. By sampling at a specific time in the week, streamflow was not a dependent factor. However the time of day was kept constant to limit diurnal biases in the results. Some water quality parameters such as dissolved oxygen exhibit a diel cycle. By keeping the time of sampling constant, the effect of the diurnal variability of these water quality parameters will be minimized.

Figure 4-2 Sampling Personnel Fitted with Appropriate Sampling and Safety Gear

4.2.4 Sampling Protocol

Grab and multi probe samples were collected at the centroid of the streamflow, approximately one third depth of the stream, by wading, lowering a fillable pitcher from a bridge, or using an extension pole from the bank. This was in accordance with the City of Omaha guidelines (City of Omaha 2005). During baseflow sampling, collectors were able to wade into the stream to take the sample. When high water conditions precluded collecting a midstream sample, the sample was collected from a point as near to the thalweg as safely possible. High water grab samples were collected by using a pitcher attached by a rope lowered from the bridge above the sample site location. High water multi-parameter probe samples were collected by extending the probe an arm's reach from the sampling personnel that waded as far as safely possible into the stream. This sample was collected as close to the thalweg as safely possible. During extremely high water samples an extension pole was used for the multi-parameter probe to sample the thalweg of the stream from the bank. Bacteria samples were taken directly from the stream in either baseflow or stormflow sampling. Bacteria samples collected during baseflow conditions were achieved by wading to the thalweg. Bacteria samples collected during high water stormflow conditions were achieved by using a fishing pole attachment to extend the reach of the sampler.

Sampling personnel wore appropriate sampling and safety gear to enter the streams to take a sample. This gear included a personal flotation device, rope harness with safety tether attached, hip waders, and arm length gloves. Figure 4-2 shows one of the sampling personnel outfitted with the appropriate sampling gear collecting a grab sample.

In-field documentation was recorded on the field data and chain of custody sheets. This documentation included stream parameters of flow conditions, odor, color, visible pollution, etc. Sampling tags were attached to the bottles for identification by lab analysts. The sample bottles were immediately stored and were transported on ice in coolers to the different labs. The bottles were transported with respect to their holding times. The shortest holding time was for E. coli samples. This holding time was only six hours. This holding time was not violated for any of the samples collected during 2010 and 2011. Sodium thiosulfate was used as a preservative in the E. coli sample bottles. All other samples did not contain any other preservatives. Table 4-1 and Table 4-2 display the abbreviations, units, collection methods, collection containers, labs, holding times, analyzing methods, and detection limits for the water quality parameters sampled. Appendix A contains a copy of the sampling procedure, calibration procedures, example tags, example checklist, example field data sheets, and example chain of custody forms used for the Papillion Creek Monitoring Program.

Table 4-1 Collection Methods and Containers of Water Quality Parameters Sampled

Water Quality Parameter	Water Quality Parameter	Units	Collection Method	Collection Container
Ammonia	NH_3	(mg/L as N)	Grab	Plastic 1 L
Biochemical Oxygen Demand	BOD	(mg/L)	Grab	Plastic 1 L
Dissolved Phosphorus	DP	(mg/L)	Grab	Plastic 1 L
Dissolved Oxygen	DO	(mg/L)	MP	NA
Escherichia Coli	E. coli	(cfu/100mL)	Grab	Plastic 100 mL
Fecal Coliforms	FC	(cfu/100mL)	Grab	Plastic 100 mL
Nitrite	NO_2	(mg/L as N)	Grab	Plastic 1 L
Nitrite + Nitrate	NO_2+NO_3	(mg/L as N)	Grab	Plastic 1 L
pH (field)	pH		MP	NA
pH (lab)	pH		Grab	Plastic 1 L
Specific Conductance	SpCond	(µS/cm)	MP	NA
Total Dissolved Solids	TDS	(mg/L)	Grab	Plastic 1 L
Temperature	WT	(°C)	MP	NA
Total Kjeldahl Nitrogen	TKN	(mg/L as N)	Grab	Plastic 1 L
Total Phosphorus	TP	(mg/L)	Grab	Plastic 1 L
Total Solids	TS	(mg/L)	Grab	Plastic 1 L
Total Suspended Solids	TSS	(mg/L)	Grab	Plastic 1 L
Turbidity	Turb	(NTU)	MP	NA

Grab-Grab sample
MP-Multi-parameter probe
NA-Not applicable

Table 4-2 Analyzing Lab, Holding Time, Method, and Detection Limit of Water Quality Parameters Sampled

Water Quality Parameter	Lab	Holding Time	Analyzing Method	Lower Detection Limit
NH_3	MRTP	28 days	Standard Methods 4500-NH_3 D	1 mg/L
BOD	MRTP	2 days	Standard Methods 5210 B	2 mg/L
DP	MWL	28 days	Standard Methods 4500 P F	0.05 mg/L
DO	FM	NA		
E. coli	ST	6 hours	Colilert®	
FC	ST	6 hours	Colilert®	
NO_2	MWL	28 days	Standard Methods 4500-NO_2^- B	0.02 mg/L
NO_2+NO_3	MWL	28 days	USEPA 353.2	0.2 mg/L
pH	FM	NA		
pH	MRTP	NA	Standard Methods 4500-H^+ B	
SpCond	FM	NA		
TDS	MRTP	7 days	By arithmetic difference	1 mg/L
WT	FM	NA		
TKN	MWL	28 days	USEPA 351.3	0.5 mg/L
TP	MWL	28 days	Standard Methods 4500 P F	0.05 mg/L
TS	MRTP	7 days	Standard Methods 2540 B	1 mg/L
TSS	MRTP	7 days	Standard Methods 2540 D	1 mg/L
Turb	FM	NA		

MRTP-Missouri River Treatment Plant Lab
MWL-Midwest Laboratories
FM-Field measurement
ST-Sampling team
NA-Not applicable

4.2.5 Grab Sampling Methods

Several water quality parameters were sampled by grab and probe sampling techniques. Grab samples were used to collect samples for: ammonia as nitrogen, biochemical oxygen demand, dissolved phosphorus, Escherichia coli, fecal coliforms, total Kjeldahl nitrogen, nitrate plus nitrite, nitrite, total dissolved solids, total phosphorus, total solids, and total suspended solids. Grab samples entail collecting a specified volume of water in a bottle to be used in lab analysis later. For this project, five grab samples were collected at each site. Samples were collected at the thalweg of the cross section of the stream. The thalweg is the deepest part of the cross section of a stream, which usually results in the centroid of the flow. Samples were taken at approximately one third of the depth of the stream from the surface. Sample jars were filled by placing the bottle opening away from the direction of flow in the stream. Tags were added to samples and then the samples were placed on ice in appropriate coolers for transport. One duplicate set of samples was collected for one of the four sites each week for quality control/quality assurance procedures. The duplicate site for the set of samples varied each week and was chosen by discretion of the sampling team. The duplicate site was rotated randomly between the four sites. The duplicate site was recorded on the appropriate data sheets, but the location and time was not indicated on the tags. Therefore the respective labs did not know which site the duplicate was representing to ensure an unbiased result of quality assurance.

4.2.6 Bacteria Sampling Method

Bacteria samples were collected for analysis by the IDEXX Laboratories Colilert test method (IDEXX 2011) for fecal coliforms and E coli. 100 milliliter pre-sterilized bottles with sodium thiosulfate were used to collect the sample directly from the stream. Care was taken to not allow the preservative in the bottles to be flushed out of the bottle. Samples were then tagged and transported on ice back to the lab to be analyzed.

4.2.7 Multi Probe Sampling Methods

Field measurements taken by the multi-parameter probe include: pH, dissolved oxygen, temperature, turbidity, and specific conductivity. Multi probe sampling entailed collecting samples in-situ. These probes collect parameter data as the water passes by the sensors when the probe is placed in the stream. A Eureka Manta2 probe attached to an Amphibian display was used for this project (Eureka Environmental 2011). Probe sensors were calibrated according to the manufacturer’s guidance each day before taking samples to ensure quality assurance/quality control procedures. Samples taken using the probe were taken at or as near to the thalweg of the stream as safely possible. Four samples were taken at one third depth of the stream, and four samples were taken just above the of the stream bed. Sampling data were later extracted from the Amphibian software. These data were also hand recorded on field sheets to provide a copy of the results.

4.3 Water Quality Parameters

Water quality samples collected were analyzed for chemical, physical, sediment, nutrient, and pathogen indicators. These indicators were analyzed for every sampling event unless prevented by an equipment malfunction. Chemical, physical, and sediment indicators include biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, pH, specific conductivity, temperature, total solids total, dissolved solids, and total suspended solids, and turbidity. Nutrient indicators included total nitrogen, total ammonia as nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite, nitrite, dissolved phosphorus, and total phosphorus. Pathogen indicators included Escherichia coli and fecal coliforms.

4.4 Lab Analysis

Three different labs were used for analysis for this study. Midwest laboratories (Midwest Laboratories 2011) and the Missouri River Treatment Plant Lab analyzed most of the samples for this project. The sampling team analyzed the bacteria samples. Samples were distributed to the labs according to their respective holding times. After the analyses were completed sample data were emailed back to the appropriate individuals involved in the project. In 2010, 21 sampling events were completed. Table 4-2 displays the analyzing method for each parameter used by the respective lab.

4.5 Data Analysis Methods

4.5.1 Reporting Limits

Bacteria analysis used the IDEXX Colilert detection method to report the number of fecal coliforms and Escherichia coliforms. Three samples were used for each site. This included a non-diluted 100 mL sample of water with a maximum reporting limit of 2,419.6 cfu/100 mL, a diluted sample containing 10 mL of sample water and 90 mL of deionized water with a maximum reporting limit of 24,196 cfu/100 mL, and a diluted sample containing 1mL of sample water and 99 mL of deionized water with a maximum reporting limit of 241,960 cfu/100 mL. To report the values, the methodology was as follows. If the non-diluted sample contained a value of coliforms less than the maximum reporting limit the non-diluted value was used. However, if the non-diluted coliform value was greater than the reporting limit, the diluted value of coliforms was reported.

4.5.2 Methods for Gathering Streamflow Data

Streamflow data were gathered from the United States Geological Survey (USGS), United States Army Corps of Engineers (USACE), and City of Omaha. Data collected included: water depth, velocity, and flow. The USGS currently operates three gages within the watershed which include: the Big Papillion Creek at Fort Street (station number 06610732), the Little Papillion Creek near Irvington (station number 06610750), and the Papillion Creek at Fort Crook (station number 06610795). The USGS flow gages collect stage information through the use of bubble-gage sensor connected to an electronic recording device (Gupta 2008). The USACE also shares the operating responsibility of the Fort Crook gage. The City of Omaha also installed flow meters at four locations within the watershed which include: the Big Papillion Creek at 168th Street and Highway 36, the Big Papillion Creek at 76th and L Street, the Little Papillion Creek 64th and L Street, and the Papillion Creek at Capehart Road and highway 75. The City of Omaha used ISCO flow meters to collect data. These flow meters use pressure transducers connected to an electronic recording device (Gupta 2008).

The USGS and City of Omaha measurements were collected and reported at fifteen minutes intervals, while the USACE measurements were collected every 15 minutes but reported as an hourly average value. This data were used to calculate loadings for the Papillion Creek Watershed. Streamflow data were used to calculate a total flow volume per year for each sampling site.

At site F (Little Papillion Creek at 64th and L Street) streamflow data were determined by Teledyne ISCO meters (Teledyne 2010) installed and maintained by the City of Omaha. These flows were examined and corrected as needed for ice effects on the sensor. Site F contained the most complete record of flow data from the ISCO flow meters. The Flowlink software (Teledyne 2010) determined total flow values. This flow was used in the calculation of the annual loadings. The 15-minute flow values were used in the calculation of the instantaneous mass loadings.

At site D (Papillion Creek at Highway 75 and Capehart Road) flows were obtained from the USGS/USACE Fort Crook gage. In early 2010 ISCO meters were installed at this site, but stormflows continued to wash out in-stream sensors. For financial reasons the ISCO meters were removed, and it was decided to use the USACE flow data. These values were provisional and had to be adjusted for backwater effects of the Missouri River during flood flows. Backwater flows were subtracted from the original flow value to obtain the corrected flow. Backwater flows were calculated by examining the discharge data for the gage. Backwater flows were calculated by the difference between the flow value reported and the expected baseflow of the stream. Then the backwater flows were subtracted from the reported flow values. These corrected flow values were then used in the calculation for the instantaneous mass loadings. The calculated total flow values were used in the calculation of the annual loadings.

At site B (Big Papillion Creek at Highway 36 and 168th Street) and site S (Big Papillion Creek at 76th and L Street), streamflows were obtained from an extrapolation of flow values from the USGS gaging station on the Big Papillion Creek at Fort Street. In early 2010 ISCO meters were installed at these sites, but stormflows caused problems at both sites. Causes of poor data from the ISCO samplers include: frequent sediment covering the sensors, frequent dislodging of sensors from supports, and channel cave-in. For these reasons it was decided to use the data from the Fort Street USGS gaging station. The obtained USGS discharges received approval from January 1, 2010 to October 10, 2010. The rest of the discharge values are provisional. USGS gaging data are considered provisional (subject to adjustment by the USGS) until the data are approved. Approval for the discharge data usually happens after the gage has been inspected and adjusted to match in-stream conditions. Discharge values at the sampling sites were obtained by an extrapolation method using watershed area and coefficients of runoff for the respective gages. These extrapolated flow values were used to calculate a total flow, instantaneous loading, and annual loading for the two stream sites.

The discharge extrapolation equation is:

$$Qy = (Qx * Ay * Cy)/(Ax * Cx)$$

Qy represents the discharge at site Y. Qx represents the discharge at site X. Ay represents the drainage area for site Y. Ax represents the drainage area for site X. Cx represents the coefficient of land use for site X. Cy represents the coefficient of land use for site Y (Gupta 2008).

4.5.3 Methods for Calculating Instantaneous Mass Loadings

Instantaneous mass loadings were calculated for ammonia, biochemical oxygen demand, dissolved phosphorus, Escherichia coli, fecal coliforms, nitrite, nitrite plus nitrate, total nitrogen, total dissolved solids, total Kjeldahl nitrogen, total phosphorus, total solids, and total suspended solids. Mass loading values report the mass of the substance that passes a point of interest over a given time. These values were reported as grams per second (g/s) or colony forming units per second (cfu/s) for the respective parameter. Mass loadings are equal to the concentration of the parameter multiplied by the flow rate. The flow values were reported in cubic feet per second. The concentration values were reported in milligrams per liter (mg/L) or colony forming unit per 100 milliliters (cfu/100 mL). For concentrations below the detection limit, a value of half of the detection limit value was substituted. Therefore the mass loading equations are as follows:

For discharge in cfs and concentrations in mg/L, mass loading is:

$$\mathrm{ML\ (g/s) = Q\ (ft^3/s) * C\ (mg/L) * 0.028317\ (L{*}g/ft^3{*}mg)}$$

For discharge in cfs and concentrations in cfu/100 mL, mass loading is:

$$\mathrm{ML\ (cfu/s) = Q\ (ft^3/s) * C\ (cfu/mL) * 283.168(mL/ft^3)}$$

4.5.4 Methods for Calculating Annual Average Concentrations

Average annual stream concentrations were calculated for selected sampling sites to aid in the calculation of mass loadings. In addition these averages can be useful in showing differences in water quality between different stream segments. The averages presented in this report are only presented as a calculated average based on the limited sampling data gathered. These averages may or may not represent the true average concentrations of the stream. This is because water quality parameters can show great variations depending on when the samples are taken. Therefore, the following results should be used with caution.

Average annual concentrations were calculated for each of the four sampling sites by analyzing the data collected for each site separately. First a distribution was determined for the data from each site by the individual parameters. Data distributions were determined by using the Shapiro-Wilk test (Helsel and Hirsch 2002). Distributions were either determined to be normal, lognormal, gamma, or none of the above. Some water quality parameters experienced the same data distribution at each site, while other parameters experienced different distributions between the different sites. An overall distribution was chosen for each specific parameter by determining which distribution held for the majority of the sites. Either the arithmetic mean or geometric mean was chosen to represent the average. The arithmetic mean was chosen to represent the average at sites that experienced a normal distribution. The arithmetic mean is calculated as follows:

$$x = \sum_{i=1}^{n} Xi/n$$

Where x is the arithmetic mean, n is the total number of samples, Xi is the ith sample value, and i is the current sample (Helsel and Hirsch 2002). The geometric mean was chosen to represent the average at sites that experienced a lognormal distribution (Helsel and Hirsch 2002). The geometric mean is calculated as follows:

$$\mathrm{x} = \ antilog\ (\frac{1}{n}\sum_{i=1}^{n} \log Xi)$$

For data that did not follow a normal, lognormal, or gamma distribution, the average was represented by the arithmetic mean.

4.5.5 Methods for Calculating Annual Mass Loadings

Annual mass loadings were calculated for ammonia, biochemical oxygen demand, dissolved phosphorus, Escherichia coli, fecal coliforms, nitrite, nitrite plus nitrate, total nitrogen, total dissolved solids, total Kjeldahl nitrogen, total phosphorus, total solids, and total suspended solids. Mass loading values report the mass of the substance that passes a point of interest over a given time. These values were reported as kilograms per year (kg/yr) or kilocolony forming units per year (kcfu/yr) for the respective parameter. Mass loadings are equal to the annual average concentration of the parameter multiplied by the total annual flow rate. The flow values were reported in cubic feet per year. The concentration values were reported in milligrams per liter (mg/L) or colony forming units per 100 milliliters (cfu/100 mL). For concentrations below the reporting limit, half of the report limit value was used in the calculations (Helsel and Hirsch 2002). Therefore the annual mass loading equations are as follows:

For discharge (ft^3/yr) and concentration (mg/L)

$$\text{AL (kg/yr)} = \text{Q } (\text{ft}^3\text{/yr}) * \text{C (mg/L)} * 0.000028317 \ (\text{L*kg/ft}^3\text{*mg})$$

For discharge (ft^3/yr) and concentration (cfu/100 mL)

$$\text{AL (kcfu/yr)} = \text{Q } (\text{ft}^3\text{/yr}) * \text{C (cfu/mL)} * 0.283168(\text{kcfu*mL/ft}^3\text{*cfu})$$

Chapter 5. Results

5.1 2010 Sampling Results

5.1.1 Sampling Collection and Sampling Issues

Twenty one sampling events were conducted from March 10, 2010 to December 17, 2010. A total of 1,380 samples were collected and analyzed for a suite of water quality parameters. Samples were analyzed for ammonia (NH_3), biochemical oxygen demand (BOD), dissolved phosphorus (DP), Escherichia coli (E. coli), fecal coliforms (FC), nitrite (NO_2), nitrite plus nitrate (NO_2 + NO_3), pH, specific conductance (SpCond), temperature (WT), total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), total nitrogen (TN), total phosphorus (TP), total solids (TS), total suspended solids (TSS), and turbidity (Turb).

Dissolved oxygen, pH, Specific conductance, temperature, and turbidity were analyzed using a multi-parameter probe (Manta2) from Eureka Environmental Engineering. The sampling team experienced problems with this probe during May because of flaws in the calibration system of the multi-parameter probe before samples were gathered. Because of these flaws in calibration water quality parameter values were misrepresented for dissolved oxygen. Water quality values that were misrepresented were discarded for the parameters that were affected. The multi-parameter probe could not be used to collect data at site D on June 2, 2010 because of a lack of safe entry point to the stream because of high flows. However, grab samples were collected from the bridge that day.

For the samples collected from May 26, 2010 through July 28, 2010 a different multi-parameter probe (Manta1) was used to collect data. The change in probes was due to the failure of the dissolved oxygen and turbidity sensors of the original probe. The Manta2 probe was sent back to the manufacture for repairs. The Manta2 probe was received back from the manufacture in late July and was used to collect data from August 4, 2010 to December 17, 2010. During this time the probe worked correctly and only a few isolated problems were experienced for the rest of the sample attempts.

The multi-parameter probe could not be used when the air temperature was below freezing. Therefore stream data could not be collected for dissolved oxygen, pH, specific conductance, temperature, and turbidity during some of the winter sampling events.

5.1.2 Summary Results of 2010 Samples

Table 5-1 shows the summary results from the samples collected during 2010. Figure 5-1 through Figure 5-5 displays the graphical representation of 2010 sampling results for selected water quality parameters. Data for individual samples taken in 2010 can be found in Appendix C.

Table 5-1 Selected Statistics of 2010 Water Quality Data

Ammonia (mg/L as N)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	20	19	19	19
Minimum	0.50[a]	0.50[a]	0.50[a]	0.50[a]
Maximum	1.40	2.90	1.40	1.20
Arithmetic Mean	0.54	0.70	0.57	0.56
Median	0.50	0.50	0.50	0.50
Standard Deviation	0.196	0.652	0.220	0.196

Biochemical Oxygen Demand (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	13	9	6	8
Minimum	1.0[a]	1.0[a]	1.0[a]	1.0[a]
Maximum	8.0	14.0	18.0	18.0
Arithmetic Mean	2.3	3.3	4.0	3.8
Median	1.0	2.0	3.0	2.0
Standard Deviation	2.22	3.35	4.12	4.01

Dissolved Phosphorus (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	3	1
Minimum	0.07	0.07	0.05[a]	0.05[a]
Maximum	0.26	0.21	0.19	0.20
Arithmetic Mean	0.17	0.15	0.08	0.13
Median	0.18	0.16	0.08	0.14
Standard Deviation	0.040	0.033	0.032	0.038

Dissolved Oxygen (mg/L)				
	Site B	Site S	Site F	Site D
Count	6	6	6	7
ND Count	0	0	0	0
Minimum	8.6	8.1	7.0	5.9
Maximum	12.6	12.8	12.6	12.8
Arithmetic Mean	9.9	9.6	8.9	8.6
Median	9.5	9.0	8.3	7.9
Standard Deviation	1.60	1.85	2.03	2.40

Escherichia Coli (cfu/100 mL)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	1	1
Minimum	122	133	201	104
Maximum	2909	15531	24196[b]	24196[b]
Arithmetic Mean	1551	2645	3310	3541
Median	1553	1553	1414	1553
Geometric Mean	1214	1412	1322	1379
Standard Deviation	844	3952	5798	6908

Fecal Coliforms (cfu/100 mL)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	12	18	12	14
Minimum	1300	2035	2420	1553
Maximum	24196[b]	24196[b]	24196[b]	24196[b]
Arithmetic Mean	17341	22814	20717	19565
Median	24196	24196	24196	24196
Geometric Mean	12601	21166	18481	15705
Standard Deviation	9453	4991	6550	8222

Nitrite (mg/L as N)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	2[a]
Minimum	0.02	0.02	0.02	0.02
Maximum	0.14	0.12	0.11	0.10
Arithmetic Mean	0.07	0.06	0.04	0.04
Median	0.06	0.06	0.04	0.04
Geometric Mean	0.06	0.05	0.04	0.04
Standard Deviation	0.03	0.03	0.02	0.02

Nitrite Plus Nitrate (mg/L as N)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	0
Minimum	5.2	1.5	0.5	0.7
Maximum	11.8	10.0	6.2	9.3
Arithmetic Mean	8.6	6.2	1.8	4.0
Median	8.8	6.6	1.6	3.7
Geometric Mean	8.5	5.7	1.6	3.5
Standard Deviation	1.6	2.2	1.1	2.1

pH (Field)				
	Site B	Site S	Site F	Site D
Count	16	16	16	16
ND Count	0	0	0	0
Minimum	7.9	7.4	7.4	7.2
Maximum	8.5	8.2	8.1	8.4
Arithmetic Mean	8.1	7.9	7.8	7.8
Median	8.0	7.9	7.8	7.8
Standard Deviation	0.195	0.268	0.227	0.298

pH (Lab)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	0
Minimum	7.5	7.3	7.4	7.2
Maximum	8.0	8.0	7.9	8.0
Arithmetic Mean	7.8	7.8	7.7	7.7
Median	7.8	7.9	7.7	7.8
Standard Deviation	0.130	0.185	0.139	0.184

Specific Conductance (µS/cm)				
	Site B	Site S	Site F	Site D
Count	17	17	17	17
ND Count	0	0	0	0
Minimum	545	317	238	202
Maximum	711	754	832	757
Arithmetic Mean	656	590	596	577
Median	678	634	648	629
Standard Deviation	55.6	147.7	173.9	159.5

Temperature (°C)				
	Site B	Site S	Site F	Site D
Count	17	17	17	16
ND Count	0	0	0	0
Minimum	3.1	2.7	4.5	3.6
Maximum	26.4	26.4	26.4	26.4
Arithmetic Mean	15.2	16.4	18.0	18.1
Median	15.4	17.2	17.9	19.5
Standard Deviation	5.7	6.5	6.8	7.0

Total Dissolved Solids (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	0
Minimum	346	222	185	50
Maximum	587	705	1719	1091
Arithmetic Mean	487	461	466	459
Median	481	468	420	423
Standard Deviation	57	114	307	224

Total Kjeldahl Nitrogen (mg/L as N)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	6	4	3	3
Minimum	0.3[a]	0.3[a]	0.3[a]	0.3[a]
Maximum	6.0	9.5	9.7	19.5
Arithmetic Mean	1.2	1.7	1.4	2.1
Median	0.7	0.8	0.9	1.0
Standard Deviation	1.5	2.1	2.0	4.1

Total Nitrogen (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	6	4	3	3
Minimum	5.81	3.46	1.80	2.91
Maximum	16.33	19.48	15.92	28.80
Arithmetic Mean	9.85	7.90	3.21	6.11
Median	9.81	7.74	2.63	4.55
Standard Deviation	2.06	3.21	2.96	5.41

Total Phosphorus (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	1	0
Minimum	0.16	0.12	0.05[a]	0.12
Maximum	1.90	2.53	2.39	5.05
Arithmetic Mean	0.66	0.71	0.35	0.85
Median	0.42	0.43	0.20	0.39
Geometric Mean	0.52	0.53	0.22	0.49
Standard Deviation	0.50	0.60	0.50	1.21

Total Solids (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	0
Minimum	493	507	303	424
Maximum	1852	2646	2171	3573
Arithmetic Mean	868	915	636	960
Median	715	692	499	587
Standard Deviation	371	559	451	812

Total Suspended Solids (mg/L)				
	Site B	Site S	Site F	Site D
Count	21	21	21	21
ND Count	0	0	0	0
Minimum	38	20	2	30
Maximum	1265	2000	1600	2830
Arithmetic Mean	381	454	170	502
Median	241	224	36	140
Geometric Mean	250	234	42	196
Standard Deviation	356	546	351	743

Turbidity (NTU)				
	Site B	Site S	Site F	Site D
Count	16	16	16	16
ND Count	0	0	0	0
Minimum	41	18	5	20
Maximum	1033	2529	2384	2180
Arithmetic Mean	289	545	368	328
Median	171	202	74	93
Geometric Mean	193	230	70	127
Standard Deviation	308	805	788	552

[a] Value is one-half of detection limit.
[b] Value is upper detection limit.
One half of the detection limit was substituted for samples reported as non-detect.
Arithmetic mean was used for data determined to be normally distributed.
Geometric mean was used for data determined to be lognormally distributed.
ND Count is the number of samples with concentrations below the detection limit.

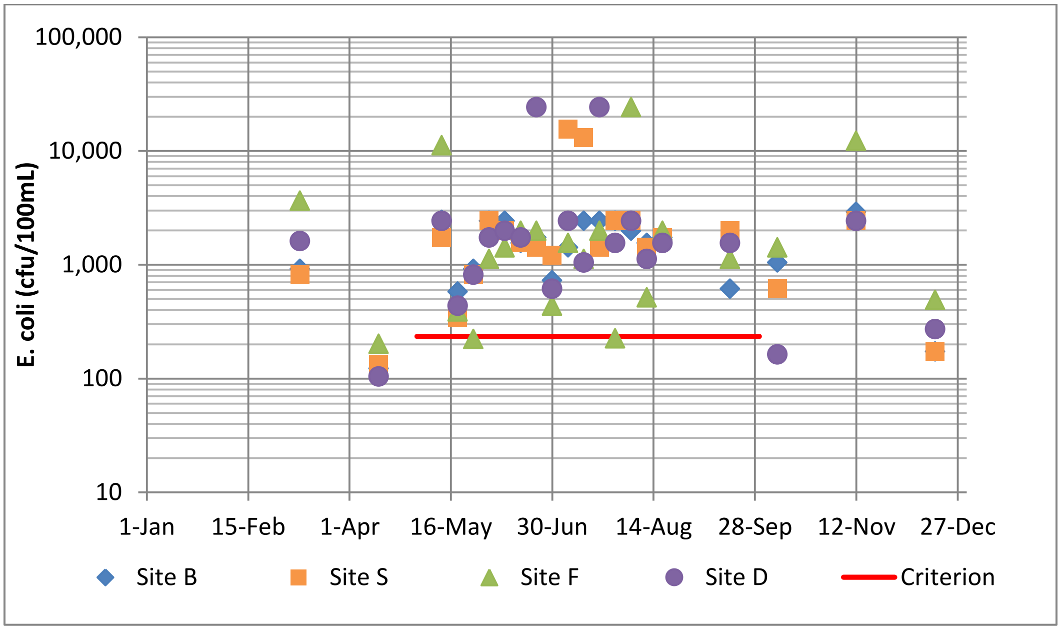

Figure 5-1 2010 Sampling Results for Escherichia coli (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

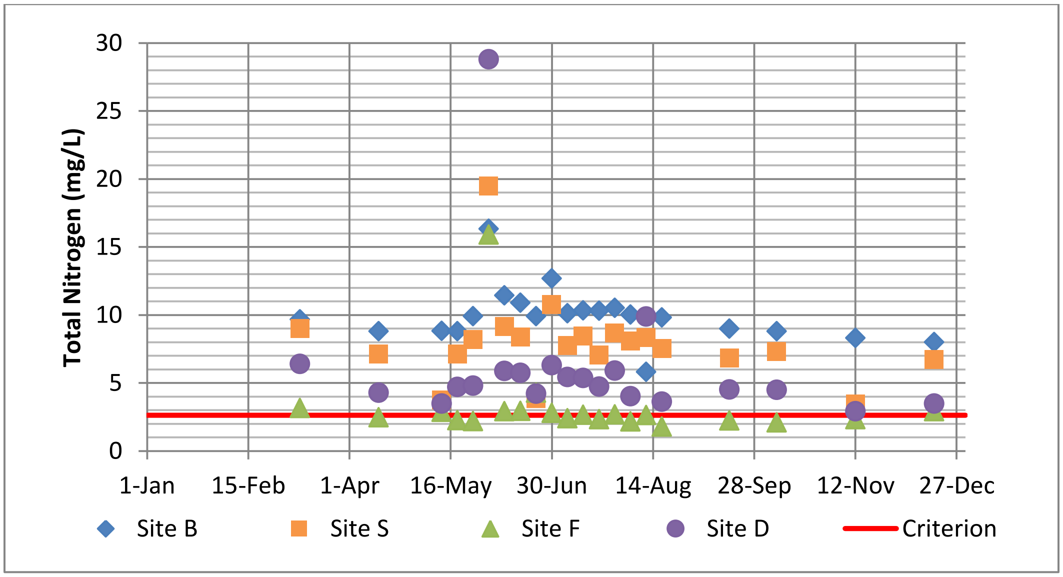

Figure 5-2Sampling Results for Total Nitrogen (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

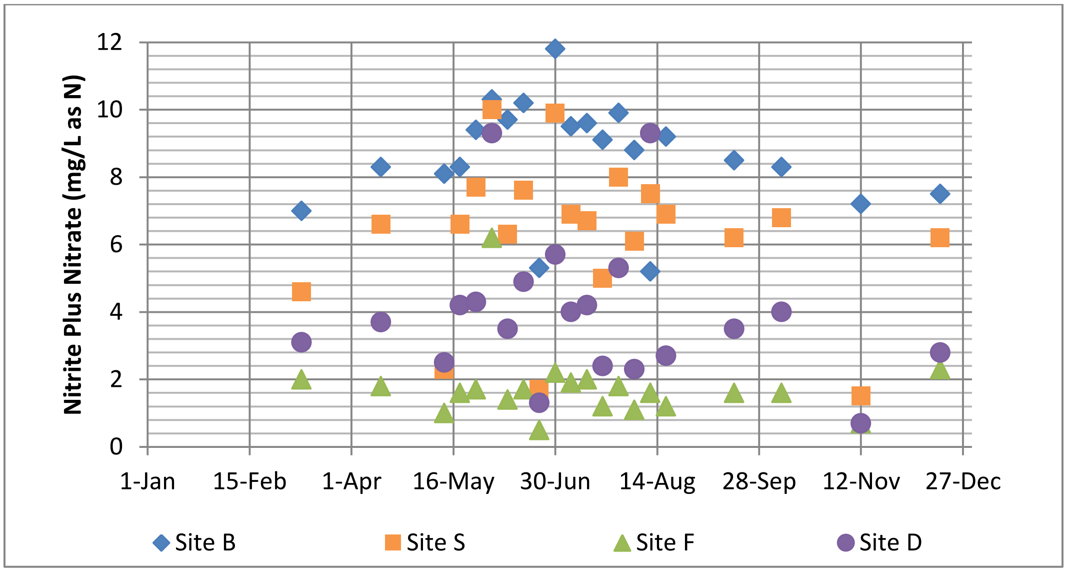

Figure 5-3 Sampling Results for Nitrite Plus Nitrate

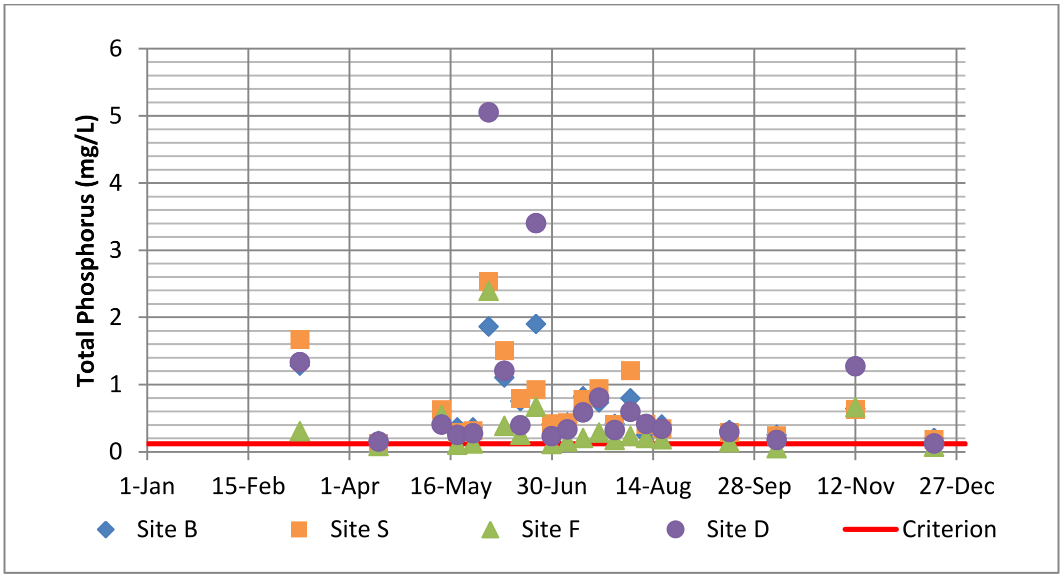

Figure 5-4 Sampling Results for Total Phosphorus (Criterion: sample concentrations are not to exceed 0.12 mg/L)

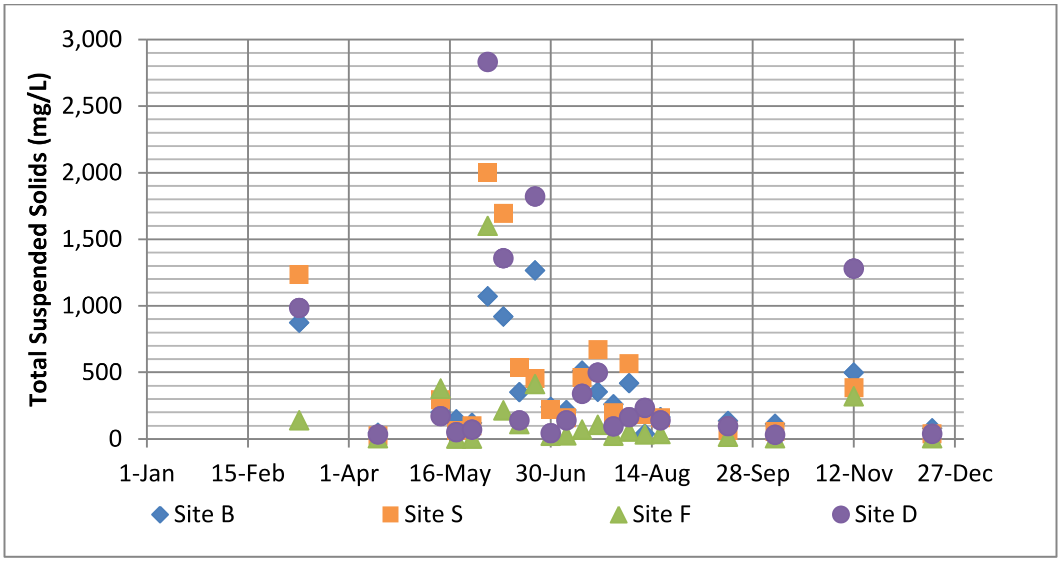

Figure 5-5 Sampling Results for Total Suspended Solids

5.1.2.1 Chemical, Physical, and Sediment Indicators

Biochemical oxygen demand (BOD) samples were measured by laboratory methods 84 times in 2010. Thirty-six of the samples were reported as non-detects by the laboratory methods at a detection limit of 2.0 mg/L. The maximum BOD measurement was 18.0 mg/L at sites F and D. Based on the Shapiro-Wilk test the data could not be confirmed to follow a normal, lognormal, or gamma distribution for the different sampling sites. Average BOD concentrations were represented by the arithmetic mean.

Dissolved oxygen (DO) samples were measured in the field 25 times in 2010. The minimum DO measurement was 5.86 mg/L at site D. The maximum measurement was 12.82 mg/L at site S. Not enough observations were collected in 2010 to complete a data distribution analysis. Average DO concentrations were represented by the arithmetic mean.

The pH concentrations were measured in the field and by laboratory methods. Field pH measurements were conducted 64 times during 2010. Laboratory pH measurements were conducted 84 times during 2010. The minimum pH field measurement was 7.23 at site D. The minimum pH lab measurement was 7.24 at site D. The maximum pH field measurement was 8.52 at site B. The maximum pH lab measurement was 8.01 at site S. Based on the Shapiro-Wilk test the pH data were confirmed to follow a normal distribution. Average pH concentrations were represented by the arithmetic mean.

Specific conductance was measured in the field 68 times in 2010. The minimum specific conductance measurement was 202.1 µS/cm at site D. The maximum measured specific conductance measurement was 832.5 µS/cm at site F. Based on the Shapiro-Wilk test the specific conductance data were confirmed to follow a normal distribution. Average specific conductance concentrations were represented by the mean.

Total dissolved solids (TDS) were measured by laboratory methods 84 times in 2010. The minimum TDS measurement was 50 mg/L at site D. The maximum TDS measurement was 1,719 mg/L at site F. Based on the Shapiro-Wilk test the TDS data were confirmed to follow a normal distribution. Average TDS concentrations were represented by the arithmetic mean.

Water temperature (WT) was measured in the field 67 times in 2010. The minimum WT measurement was 2.74°C at site S. However, this does not represent the minimum water temperature of the stream because the multi-parameter probe could not be used when the air temperature was below freezing. The maximum WT measurement was 26.43°C at sites B, F, and D. Based on the Shapiro-Wilk test the WT data were confirmed to follow a normal distribution. Average WT measurements were represented by the mean.

Total solids (TS) were measured by laboratory methods 84 times in 2010. The minimum TS measurement was 303 mg/L at site F. The maximum TS measurement was 3,573 mg/L at site D. Based on the Shapiro-Wilk test the TS data were not confirmed to follow a normal, lognormal, or gamma distribution. Average total solids concentrations were represented by the arithmetic mean.

Total suspended solids (TSS) were measured by laboratory methods 84 times in 2010. The minimum TSS measurement was 2 mg/L at site F. The maximum TSS measurement was 2,830 mg/L at site D. Based on the Shapiro-Wilk test the TSS data were confirmed to follow a lognormal distribution. Average total suspended solids concentrations were represented by the geometric mean.

Turbidity (Turb) was measured in the field 64 times in 2010. The minimum turbidity measurement was 5.2 NTUs at site F. The maximum turbidity measurement was 2,529 NTUs at site S. Based on the Shapiro-Wilk test the turbidity data were confirmed to follow a lognormal distribution. Average turbidity concentrations were represented by the geometric mean.

5.1.2.2 Nutrient indicators

Total nitrogen (TN) was not measured by laboratory methods. This parameter was calculated from the summation of total Kjeldahl nitrogen, nitrite, and nitrate. TN was calculated 84 times for 2010. The minimum calculated TN value was 1.80 mg/L at site F.

The maximum calculated TN value was 28.80 mg/L at site D. Based on the Shapiro-Wilk test the TN data were not confirmed to follow a normal, lognormal, or gamma distribution. Average total nitrogen concentrations were represented by the arithmetic mean.

Total ammonia (NH_3) as nitrogen was measured 84 times by laboratory methods in 2010. Seventy-seven of the samples were reported as non-detects by the laboratory methods at a detection limit of 1.0 mg/L. The maximum NH_3 measurement was 2.9 mg/L at site S. There were not enough NH_3 detectable measurements to test the distribution of the data. Average NH_3 concentrations were represented by the arithmetic mean.

Total Kjeldahl nitrogen (TKN) was measured 84 times by laboratory methods in 2010. Sixteen of the samples were reported as non-detects by the laboratory methods at a detection limit of 0.5 mg/L. The maximum TKN was 19.5 mg/L at site D. Based on the Shapiro-Wilk test the TKN data were not confirmed to follow a normal, lognormal, or gamma distribution. Average TKN concentrations were represented by the arithmetic mean.

Nitrite (NO_2) as nitrogen was measured 84 times by laboratory methods in 2010. Two of the samples were reported as non-detects by the laboratory methods at a detection limit of 0.02 mg/L. The maximum NO_2 measurement was 0.14 mg/L at site B. Based on the Shapiro-Wilk test the NO_2 data were confirmed to follow a lognormal distribution. Average nitrite concentrations were represented by the geometric mean.

Nitrite plus Nitrate ($NO_2 + NO_3$) as nitrogen was measured 84 times by laboratory methods in 2010. The minimum $NO_2 + NO_3$ measurement was 0.5 mg/L as site F. The maximum $NO_2 + NO_3$ measurement was 11.8 mg/L at site B. Based on the Shapiro-Wilk test the $NO_2 + NO_3$ data were confirmed to follow a lognormal distribution. Average $NO_2 + NO_3$ concentrations were represented by the geometric mean.

Total phosphorus (TP) was measured 84 times by laboratory methods in 2010. One of the samples were reported as non-detects by the laboratory methods at a detection limit of 0.5 mg/L. The maximum TP measurement was 5.05 mg/L at site D. Based on the Shapiro-Wilk test the TP data were confirmed to follow a lognormal distribution. Average TP concentrations were represented by the geometric mean.

Dissolved phosphorus (DP) was measured 84 times by laboratory methods in 2010. Four of the samples were reported as non-detects by the laboratory methods at a detection limit of 0.05 mg/L. The maximum DP measurement was 0.26 mg/L at site B. Based on the Shapiro-Wilk test the DP data were confirmed to follow a normal distribution. Average DP concentrations were represented by the arithmetic mean.

5.1.2.3 Pathogenic Indicators

Escherichia coli (E. coli) were measured 84 times by laboratory methods in 2010. The minimum E. coli measurement was 104.3 cfu/100 mL at site D. Two of the samples were reported as non-detects by the laboratory methods because the samples contained concentrations above the detection limit of 24,196 cfu/100 mL. Because there are two samples that were above the detection limit, the statistics will likely be underestimated. . Based on the Shapiro-Wilk test the E. coli data were confirmed to follow a lognormal distribution. Average Escherichia coli concentrations were represented by the geometric mean.

Fecal coliforms (FC) were measured 84 times by laboratory methods in 2010. The minimum FC measurement was 1,299.7 cfu/100 mL at site B. Fifty-six of the samples were reported as non-detects by the laboratory methods because the samples contained concentrations above the detection limit of 24,196 cfu/100 mL. Because there are 56 samples that were above the detection limit, the statistics will likely be underestimated. There were too many values above the detection limit to test for data distribution. Average fecal coliform concentrations were represented by the geometric mean.

5.2 Comparison of Average Annual Stream Concentrations by Sampling Site

5.2.1 Description of Average Annual Stream Concentrations and Watershed Land Use for Sampling Site Subbasins

Average annual stream concentrations were calculated for selected streams to aid in the calculation of mass loadings. In addition these averages can be useful in showing differences in water quality between different stream segments. The averages presented in this report are only presented as a calculated average based on the limited sampling data gathered. These averages may or may not represent the true average concentrations of the stream. This is because water quality parameters can show great variations depending on when the samples are taken. Therefore, the following results should be used with caution. The following tables display the concentrations according to the sample sites B, S, F, and D.

Sample site B is located on the Big Papillion Creek at 168th Street and Highway 36 in Bennington, NE. Site B represents the upper part of the Big Papillion Creek Watershed. The upper part of the Big Papillion Creek Watershed has a land use that is characterized by 5.4 percent urban development, 12.3 percent rural open land, and 82.3 percent rural cultivated crops.

Sample site S is located on the Big Papillion Creek at 76th and L Street in Omaha, NE. Site S represents the entire Big Papillion Creek Watershed (including site B). The Big Papillion Creek Watershed has a land use that is characterized by 25.4 percent urban development, 12.5 percent rural open land, and 62.2 percent rural cultivated crops.

Sample site F is located on the Little Papillion Creek at 64th and L Street in Omaha, NE. Site F represents the entire Little Papillion Creek Watershed. The Little Papillion Creek Watershed has a land use that is characterized by 54.9 percent urban development, 18.4 percent rural open land, and 26.7percent rural cultivated crops.

Sample site D is located on the Papillion Creek at Capehart Road and Highway 75 in Bellevue, NE. Site D represents the entire Papillion Creek Watershed. The Papillion Creek Watershed has a land use that is characterized by 43.7 percent urban development, 12.8 percent rural open land, and 43.5 percent rural cultivated crops.

5.2.2 2010 Average Stream Concentrations

Table 5-2 lists the average annual concentrations for each sampling site. These averages were calculated from data collected by the University of Nebraska Lincoln for the City of Omaha during 2010. The data collected for each of the four sampling sites was analyzed separately. First a distribution was determined for the data from each site by individual parameters. Some water quality parameters experienced the same data distribution at each site, while other parameters experienced different distributions between the different sites. Then an overall distribution was chosen for each specific parameter by determining which distribution held for the majority of the sites. Either the arithmetic mean or geometric mean was chosen to represent the average. The arithmetic mean was chosen to represent the average at sites that experienced a normal distribution. The geometric mean was chosen to represent the average at sites that were not determined to be normally distributed and were then considered to have a lognormal distribution (Helsel and Hirsch 2002).

Table 5-2 2010 Comparison of Average Concentrations by Sampling Site

Site Name	Ammonia (mg/L as N)	Biochemical Oxygen Demand (mg/L)	Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)
Site B (Big Papillion Creek)	0.54	2.3	0.17	9.9
Site S (Big Papillion Creek)	0.70	3.3	0.15	9.6
Site F (Little Papillion Creek)	0.57	4.0	0.08	8.9
Site D (Papillion Creek)	0.56	3.8	0.13	8.6

Site Name	Escherichia Coli (cfu/100 mL)	Fecal Coliforms (cfu/100 mL)	Nitrite (mg/L as N)	Nitrite + Nitrate (mg/L as N)
Site B (Big Papillion Creek)	1,214	12601	0.06	8.5
Site S (Big Papillion Creek)	1,412	21166	0.05	5.7
Site F (Little Papillion Creek)	1,322	18481	0.04	1.6
Site D (Papillion Creek)	1,379	15705	0.04	3.5

Site Name	pH (field)	pH (lab)	Specific Conductance (µS/cm)	Temperature (°C)
Site B (Big Papillion Creek)	8.1	7.8	656	15.2
Site S (Big Papillion Creek)	7.9	7.8	590	16.4
Site F (Little Papillion Creek)	7.8	7.7	596	18.0
Site D (Papillion Creek)	7.8	7.7	577	18.1

Site Name	Total Dissolved Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Site B (Big Papillion Creek)	487	1.2	9.7	0.52
Site S (Big Papillion Creek)	461	1.7	7.4	0.53
Site F (Little Papillion Creek)	466	1.4	2.7	0.22
Site D (Papillion Creek)	459	2.1	5.2	0.49

Site Name	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
Site B (Big Papillion Creek)	868	250	193
Site S (Big Papillion Creek)	915	234	230
Site F (Little Papillion Creek)	636	42	70
Site D (Papillion Creek)	960	196	127

See Table 5-1 for standard deviation of each parameter for according to each sampling site

5.3 Instantaneous Pollutant Loadings

Instantaneous mass loadings were calculated for the 2010 sampling data. This data can be found in Appendix D. Instantaneous pollutant loadings were not used in the comparison of sampling sites because differences in concentrations were overshadowed by differences in discharge values.

5.4 Annual Pollutant Loadings

5.4.1 2010 Mass Loadings

Table 5-3 displays the 2010 mass loadings for the four sampling sites. These loadings were calculated from the 2010 average concentrations and total flow values. A detailed explanation of the calculation process can be found in section 4.5.5.

Table 5-3 2010 Pollutant Loads for the Four Sampling Sites

Site Name	Ammonia (kg/yr as N)	Biochemical Oxygen Demand (kg/yr)	Dissolved Phosphorus (kg/yr)
Site B (Big Papillion Creek)	3.82E+04	1.64E+05	1.22E+04
Site S (Big Papillion Creek)	1.01E+05	4.78E+05	2.14E+04
Site F (Little Papillion Creek)	1.90E+04	1.35E+05	2.82E+03
Site D (Papillion Creek)	1.84E+05	1.23E+06	4.34E+04

Site Name	Escherichia Coli (kcfu/yr)[b]	Fecal Coliforms (kcfu/yr)[b]	Nitrite (kg/yr as N)
Site B (Big Papillion Creek)	8.54E+11	8.86E+12	4.36E+03
Site S (Big Papillion Creek)	2.02E+12	3.03E+13	7.70E+03
Site F (Little Papillion Creek)	4.42E+11	6.18E+12	1.32E+03
Site D (Papillion Creek)	4.52E+12	5.14E+13	1.33E+04

Site Name	Nitrite + Nitrate (kg/yr as N)	Total Dissolved Solids (kg/yr)	Total Kjeldahl Nitrogen (kg/yr as N)
Site B (Big Papillion Creek)	5.96E+05	3.42E+07	8.58E+04
Site S (Big Papillion Creek)	8.12E+05	6.61E+07	2.38E+05
Site F (Little Papillion Creek)	5.22E+04	1.56E+07	4.82E+04
Site D (Papillion Creek)	1.13E+06	1.50E+08	6.96E+05

Site Name	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	Total Solids (kg/yr)
Site B (Big Papillion Creek)	6.79E+05	3.66E+04	6.10E+07
Site S (Big Papillion Creek)	1.06E+06	7.64E+04	1.31E+08
Site F (Little Papillion Creek)	9.19E+04	7.20E+03	2.13E+07
Site D (Papillion Creek)	1.71E+06	1.60E+05	3.15E+08

Site Name	Total Suspended Solids (kg/yr)
Site B (Big Papillion Creek)	1.76E+07
Site S (Big Papillion Creek)	3.35E+07
Site F (Little Papillion Creek)	1.39E+06
Site D (Papillion Creek)	6.41E+07

[a] Loadings = Total Flow per year multiplied by average concentration multiplied by a correction factor

[b] Kcfu/100mL represents 1000 colony forming units per 100 milileters

Chapter 6. Data Analysis and Discussion of Results

6.1 Water Quality, Aquatic Health, and Ecological Standards and Criteria

Water quality, aquatic health, and ecological standards and criteria for a waterbody are established by designating its uses and setting criteria to protect those uses to the waters from pollutant levels that exceed the criteria (Jason et al. 2009). Sampling results collected during 2010 and 2011 were compared to standards and criteria from the Nebraska Department of Environmental Quality (NDEQ) and the United States Environmental Protection Agency (USEPA). Criteria obtained from the NDEQ included the Nebraska Title 117 Surface Water Quality Standards (NDEQ 2009b). Criteria obtained from the USEPA included the National Recommended Water Quality Criteria (USEPA 2011c). Standards obtained from the USEPA included the Ambient Water Quality Criteria Recommendations (USEPA 2000). Associated sampling results were compared to the criteria and standards above to evaluate the condition of the Papillion Creek stream segments sampled. Most comparisons of study results with standards and criteria consisted of direct comparison of the measured concentrations to the standards and criteria. However, some criteria required the calculations of seasonal values or adjustments of the criteria themselves for comparison. It is important to remember that the samples taken represent only a specific concentration for that point in time. The stream may or may not experience concentrations that violate established criteria for various stream conditions that were not sampled due to restrictions of this study.

The four stream sampling sites used during 2010 represented the conditions of different stream segments within the Papillion Creek Watershed. Sites B and S represent segment MT1-10120 the Big Papillion Creek from the confluence with Butter Flat Creek to the confluence with the Little Papillion Creek. Site F represents segment MT1-10111 the Little Papillion Creek from the confluence with Thomas Creek to the confluence with the Big Papillion Creek. Site D represents segment MT1-10100 the Papillion Creek from the confluence with the Big Papillion Creek to the confluence with the Missouri River. Section 2.3 lists the designated uses of the Papillion Creek stream segments.

Figure 2-5 displays the stream segments by reference of their segment number in the watershed. The criteria discussed directly relate back to the stream segment's designated uses. Appendix B contains a table of the Nebraska water quality criteria applicable to the sample parameters collected in this study.

6.1.1 Comparison of General Chemical, Physical, and Sediment Indicators to Water Quality Criteria

Dissolved oxygen (DO) is used as an indicator of conditions to support aquatic life in a stream. DO criteria are set to maintain key species on a year-round basis. This criterion also protects other warmwater fish, associated vertebrate and invertebrate organisms, and plants. Nebraska streams classified as Class A or B Warmwater must maintain dissolved oxygen levels of one day minimum not less than 5.0 mg/L for early life stages, April 1st through September 30th; and one day minimum not less than 3.0 mg/L for non-early life stages, October 1st through March 31st (NDEQ 2009b). All of the DO sample concentrations taken during 2010 for the four different sites met the DO criteria.

The pH parameter is used as an indicator to support aquatic life conditions of a stream. The pH criteria are used to maintain key species on a year-round basis. These criteria protect warmwater fish, vertebrate organisms, invertebrate organisms, and plants. Nebraska streams classified as Class A or B Warmwater must maintain a pH level not less than 6.5 and not greater than 9.0 (NDEQ 2009b). All of the pH samples taken during 2010 for the four different sites met the criteria

Specific conductance is used as an indicator to support agricultural use of a stream. Specific conductance criteria maintain the stream segments as a source of water for general agricultural purposes, irrigation, and livestock watering without treatment. This criterion has been set to ensure that the water withdrawn from the stream will not produce undesirable physiological effects in crops or livestock. Nebraska streams classified to support agriculture supply must maintain a specific conductance less than 2,000 µS/cm (NDEQ 2009b). Table 2-2 shows which stream segments in the Papillion Creek Watershed are to support use of the water for agriculture supply. Each of the four sampling sites (sites B, S, F, and D) were located in stream segments that were listed to support the use of the water for agricultural supply. All of the specific conductance samples taken during 2010 for the four different sites met the criteria.

Sediment is a vital natural component of waterbodies and the uses they support. However excessive amounts of sediment can impair designated uses of waterbodies. Aquatic life can be affected when excess sediment chokes spawning gravel beds, impairs food sources, fills in rearing pools, and reduces habitat complexity in stream channels. Excessive suspended sediment can make it difficult for fish to find prey, and at high levels suspended sediment can even cause direct physical harm. High levels of sediment can alter channel form and adversely affect aesthetics, which impairs waterbodies designated for recreational uses (USEPA 1999b). Currently there are no developed criteria or recommendations for sediment. This includes the water quality parameters of total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), and turbidity (Turb).

6.1.2 Comparison of General Nutrient Indicators to Water Quality Criteria

Excess nutrients can have detrimental effects on waterbodies designated for water supply, recreation, aquatic life, and aesthetics. Excess nutrients can lead to eutrophication of a waterbody. In an eutrophic system the waterbody contains an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and macrophytes. When these plants decay, the result can be oxygen depletion in the waterbody. This breakdown of dead organic matter can also produce un-ionized ammonia. At certain ammonia levels fish may suffer a reduction in hatching success, reductions in growth rate and morphological development, and injury to gill tissue, liver and kidneys (USEPA 1999a).

Currently there are no enforceable criteria for total nitrogen and total phosphorus concentrations in Nebraska streams. There are, however, recommendations for in-stream total nitrogen and total phosphorus concentrations. Nebraska streams, which are in Ecoregion VI, are recommended to maintain total nitrogen concentrations less than 2.615 mg/L (USEPA 2000). Total nitrogen concentrations were not measured directly; they were calculated from the summation of total Kjeldahl nitrogen, nitrite, and nitrate concentrations. The calculated total nitrogen concentrations from samples collected during 2010 violated the recommended concentrations.

Table 6-1 displays the total number of samples exceeding and the percent of samples exceeding the total nitrogen recommendations during 2010. Site F, the Little Papillion Creek, was the only stream segment that did not violate the recommendation for every sample.

Table 6-1 Summary of 2010 Total Nitrogen Calculations with USEPA Ambient Water Quality Recommendations

Site	Parameter	Samples Exceeding the Criterion	Percent of Samples Exceeding the Criterion (%)
B (Big Papillion Creek)	Total Nitrogen	21	100
S (Big Papillion Creek)	Total Nitrogen	21	100
F (Little Papillion Creek)	Total Nitrogen	11	52
D (Papillion Creek)	Total Nitrogen	21	100

Nebraska streams, which are in Ecoregion VI, are recommended to maintain total phosphorus concentrations less than 0.118 mg/L (USEPA 2000). Total phosphorus concentrations were directly measured from samples collected during 2010. Table 6-2 displays the total number of samples exceeding and the percent of samples exceeding the total phosphorus recommendations during 2010. Site F, the Little Papillion Creek, was the only stream segment that did not exceed the recommendation for sample.

Table 6-2 Summary of 2010 Total Phosphorus Concentrations with USEPA Ambient Water Quality Recommendations

Site	Parameter	Samples Exceeding the Criterion	Percent of Samples Exceeding the Criterion (%)
B (Big Papillion Creek)	Total Phosphorus	21	100
S (Big Papillion Creek)	Total Phosphorus	21	100
F (Little Papillion Creek)	Total Phosphorus	16	76
D (Papillion Creek)	Total Phosphorus	21	100

Total nitrogen and total phosphorus recommended concentrations developed for Ecoregion VI by USEPA are based on the 25th percentiles of nutrient data sampled for various streams. This includes a comparison of reference conditions for the aggregate ecoregion versus the subecoregions (USEPA 2000). Therefore these recommendations are designed to improve stream water quality to pristine conditions. Currently these concentration limits are only recommendations by the USEPA, they are not established criteria, and are therefore not legally binding requirements.

Ammonia is used as an indicator to support aquatic life in a stream. Ammonia criteria are set to maintain key species on a year-round basis. This criterion also protects other warmwater fish, vertebrate organisms, invertebrate organisms, and plants. Nebraska streams classified as Class A or B Warmwater must have one-hour average ammonia concentrations that do not to exceed criteria set by an equation dependent upon pH (NDEQ 2009b). Table 2-2 shows which stream segments in the Papillion Creek Watershed are to support use of the water for agriculture supply. Ammonia criteria are also based on 30-day sample averages dependent upon pH and temperature. Non-detect values were substituted with values that were half of the detection limit. No ammonia sample concentrations taken during 2010 for the four different sites exceeded the criteria.

Neither nitrate nor nitrite currently has any recommended criteria or standards for lotic waterbodies to protect aquatic life. This is because concentrations of nitrate and nitrite that would exhibit toxic effects on warm or cold water fish could rarely occur in nature. Therefore restrictive criteria were not recommended by the USEPA (USEPA 1976).

Nitrite plus nitrate is used as an indicator for agricultural use of a stream. The nitrite plus nitrate criterion maintains the stream segments as a source of water for general agricultural purposes, irrigation, and livestock watering without treatment. This criterion has been set to ensure that the water withdrawn from the stream will not produce undesirable physiological effects in crops or livestock. Nebraska streams classified for Agriculture supply must maintain a nitrite plus nitrate concentration less than 100 mg/L as N (NDEQ 2009b). Table 2-2 shows which stream segments in the Papillion Creek Watershed are to support use of the water for agriculture supply. None of the nitrite plus nitrate samples taken during 2010 for the four different sites exceeded the criterion.

6.1.3 Comparison of Pathogen Indicators with Water Quality Criteria

Escherichia coli (E. coli) concentrations are used as an indicator for primary contact recreation of a waterbody. These criteria have been set to allow the waterbody to be used for recreational activities where the body may come into prolonged or intimate contact with the water, such that water may be accidentally ingested, and sensitive body organs may be exposed. These criteria are only applicable during the recreational period, May 1st through September 30th, in Nebraska. The criterion states that the E. coli concentration in streams that support primary contact recreation shall not exceed a geometric mean concentration of 126 cfu/100mL. Single-sample maximum E. coli concentrations can also be used for issuing periodic public advisories. The single-sample maximum criterion is a concentration that does not exceed 235 cfu/100mL (NDEQ 2009b). Table 6-3 displays the total number of samples exceeding and the percent of samples exceeding the E. coli single sample maximum and geometric mean criteria for the samples collected during 2010. Site F, the Little Papillion Creek, was the only segment that did not exceed the single-sample maximum for every sample. All of the sample sites exceeded the seasonal geometric mean.

Table 6-3 Summary of 2010 E. coli Concentrations with Nebraska Surface Water Quality Standards

Criteria Only Applicable During Recreational Season (May 1-Sept 30)		Single Sample Maximum		Season Geometric Mean	
Site	Parameter	Samples Exceeding the Criterion	Percent of Samples Exceeding the Criterion (%)	Samples Exceeding the Criterion [a]	Percent of Samples Exceeding the Criterion (%)
B (Big Papillion Creek)	E. coli	16	100	1	100
S (Big Papillion Creek)	E. coli	16	100	1	100
F (Little Papillion Creek)	E. coli	14	87.5	1	100
D (Papillion Creek)	E. coli	16	100	1	100

[a] One sample represents the seasonal mean for 2010.

Fecal coliform concentrations are no longer used as an indicator for primary contact recreation. Therefore comparisons of fecal coliform concentrations are not shown.

6.1.4 Toxic Chemical Indicators

Toxic substances were not sampled or evaluated for this study. However a study completed by the United States Geological Survey (Jason et al. 2009) did evaluate toxic substances. The Nebraska Department of Environmental Quality (NDEQ) has developed numerical criteria of selected toxic substances for the protection of aquatic life including toxicity to aquatic organisms and significant bioaccumulation or biomagnification that would result in these organisms being unsuitable or unsafe for consumption (NDEQ 2009b).

The USGS study of the Papillion Creek Watershed focused on the eastern and southeastern part of the watershed. The USGS study sampled for total concentrations. The criteria developed by the NDEQ, however, are for dissolved concentrations except for selenium and mercury. Therefore the total concentrations were converted to dissolved concentrations. The USGS report stated that this comparison will most likely result in the overestimation of the number and frequency of samples having concentrations that exceed the criteria (Jason et al. 2009).

Zinc concentrations above the chronic toxicity criterion were found in the samples from the Little Papillion and Big Papillion Creeks. Selenium concentrations that were above the 4-day average chronic toxicity were found in samples from the Big Papillion Creek. Total arsenic and phenanthrene concentrations above the chronic toxicity criteria were found in samples from the Big Papillion Creek. Because of the sampling methods of the USGS study, the report stated that the toxic substances of zinc, selenium, phenanthrene, and arsenic should be further monitored (Jason et al. 2009).

6.1.5 Comparison of Results with Nebraska Department of Environmental Quality Reports

As discussed earlier the Nebraska Department of Environmental Quality (NDEQ) has the authority to sample and analyze the Papillion Creek Watershed. The 2010 integrated report listed six stream segments as impaired by high E. coli concentrations, one segment by low dissolved oxygen concentrations, and one segment by high selenium concentrations.

Table 2-3 displays the impaired waterbodies for the watershed according to their impairments, parameters of concern, and comments/action that were taken. The NDEQ did not evaluate the stream segments for total nitrogen or total phosphorus concentrations. This is because there are currently not any enforceable criteria regulations for total nitrogen or total phosphorus in the state of Nebraska. The comparison of sampling data to established criteria and standards results presented from this study validate the NDEQ results.

6.2 Water Quality Parameter Correlations with Discharge

Correlations were examined between water quality parameters and discharge. These correlations were prepared to determine if there was a difference in concentrations at different flows in the streams. These correlations could be used to determine if a pollutant is derived more from point (baseflow) or nonpoint (stormflow) sources.

Table 6-4 Correlation Coefficients for Comparison of Water Quality Parameters to Discharge

Parameter	Site B	Site S	Site F	Site D
Ammonia	[a]	[a]	[a]	[a]
Biochemical Oxygen Demand	0.42	0.14	0.48	0.87
Dissolved Phosphorus	0.35	0.03	0.41	0.39
Dissolved Oxygen	-0.57	-0.66	0.80	0.60
Escherichia Coli	0.25	0.03	0.19	0.26
Fecal Coliforms	0.16	0.19	0.27	0.34
Nitrite	0.07	-0.03	-0.31	0.06
Nitrite + Nitrate	-0.19	-0.30	-0.38	-0.13
pH (field)	-0.63	-0.67	-0.36	-0.31
pH (lab)	-0.78	-0.51	-0.16	-0.53
Specific Conductance	-0.67	-0.42	-0.56	-0.78
Temperature	-0.11	0.00	-0.15	-0.19
Total Dissolved Solids	0.23	-0.24	-0.32	-0.33
Total Kjeldahl Nitrogen	0.65	0.36	0.27	0.34
Total Nitrogen	0.32	0.02	0.04	0.21
Total Phosphorus	0.82	0.51	0.21	0.46
Total Solids	0.83	0.41	-0.05	0.42
Total Suspended Solids	0.83	0.47	0.21	0.55
Turbidity	0.71	0.75	0.62	0.42

[a] Large percentage of non-detect samples prohibited correlation test.

Table 6-4 displays the correlation coefficient for comparison of water quality parameters to discharge for the 2010 sampling data. Correlation coefficients have a range of -1 to +1. A correlation coefficient of -1 implies that the parameter is perfectly negatively correlated with discharge. A correlation coefficient of 0 indicates that there is no correlation between the water quality parameter and discharge. A correlation coefficient of +1 implies that the parameter is perfectly positively correlated with discharge. The ammonia to discharge correlation coefficient could not be calculated because of the large percentage of non-detect samples.

Water quality parameters that were positively correlated to discharge are: biochemical oxygen demand (site D), total Kjeldahl nitrogen (site B), total phosphorus (sites B and S), total solids (site B), total suspended solids (site B and D), and turbidity (sites B, S, F, and D). A positive correlation indicates that as discharge increases, the parameter also increases in concentration or vice versa.

Water quality parameters that were negatively correlated to discharge are: dissolved oxygen (sites B, S, F, and D), pH (sites B and S), and specific conductance (sites B, F, and D). A negative correlation indicates that as discharge increases, the parameter decreases in concentration or vice versa.

Site B was the only site that showed consistent correlations between water quality constituents and discharge. At site B, the correlation coefficients for TKN, TP, TS, TSS, and turbidity were all at or above 0.65. This indicates that constituents commonly associated with agricultural runoff (e.g., sediment and nutrients) are present at higher concentrations in the Big Papillion Creek at site B during runoff events (i.e., high flow periods).

The NDEQ has currently developed TMDLs for E. coli in six stream segments of the Papillion Creek Watershed. E. coli showed neither a positive nor negative correlation with discharge in this study's sampling results. This is result of the large amount of variability associated with E. coli in waterbodies.

6.3 Comparison of Sampling Concentrations between Sites

Comparison of data between the four sampling sites is displayed by graphical representation in the form of boxplots and travel scatterplots. A boxplot representation displays the following characteristics of data: center of data, variation of spread, skewness, and presence or absence of unusual values (outliers). Boxplots of similar sizes of top and bottom halves and whiskers show symmetry between the data sets displayed. Boxplots that have taller box halves and whiskers show that the data demonstrates a right-skewed distribution (Helsel and Hirsch 2002). The outliers of the boxplots were calculated by the ProUCL software. Boxplots are displayed for the parameters of: Escherichia coli, nitrite plus nitrate, total nitrogen, total phosphorus, and total suspended solids. These parameters (except for nitrite plus nitrate) were shown to be above the criteria and recommendations for Nebraska streams. Nitrite plus nitrate was also displayed because of its decreasing trend through the watershed. Total suspended solids were also displayed to represent sediment concentrations in the stream. The Total suspended solids parameter does not have any established recommended criteria at this time

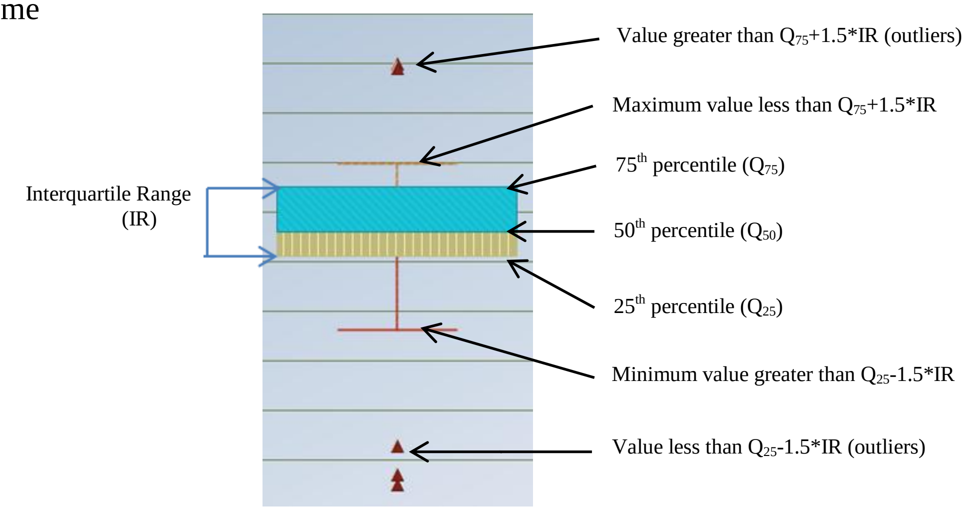

Figure 6-1 Explanation of Boxplot

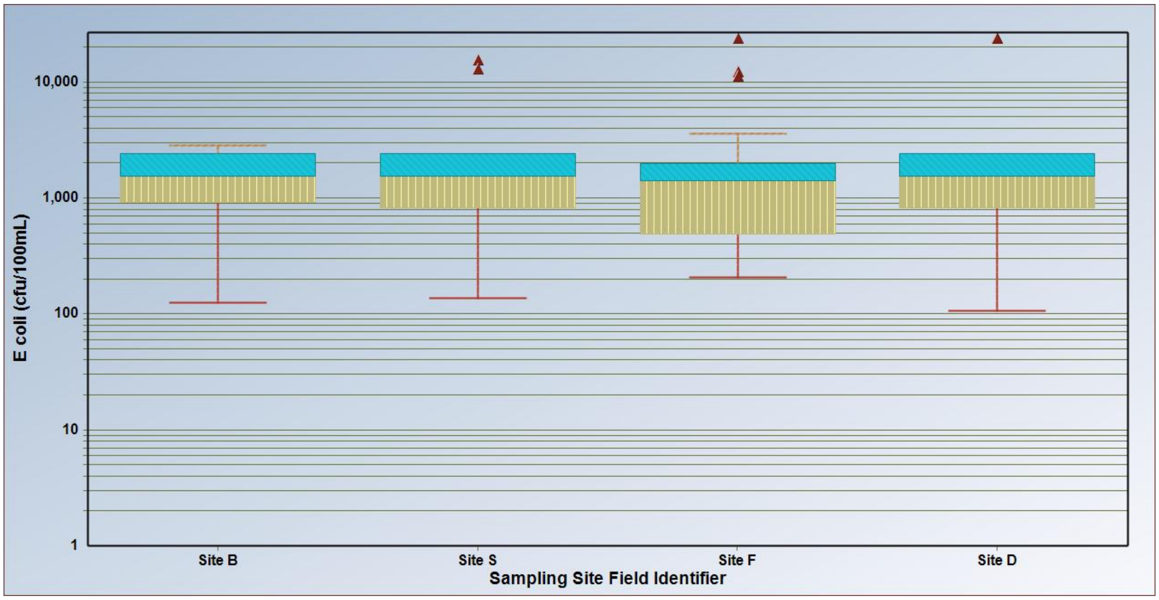

Figure 6-2 Boxplot of 2010 Escherichia coli Sampling Results (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

Figure 6-2 shows that most of the sampling results between the four sites were relatively similar for 2010. It can be seen that the median E. coli concentrations sampled for each of the four sites are similar. The greatest difference that can be seen is the maximum concentrations. The maximum sampled concentration at site B was less than site S. Sites F and D both had maximum concentrations that were above the detection limit of 24,196 cfu/100 mL.

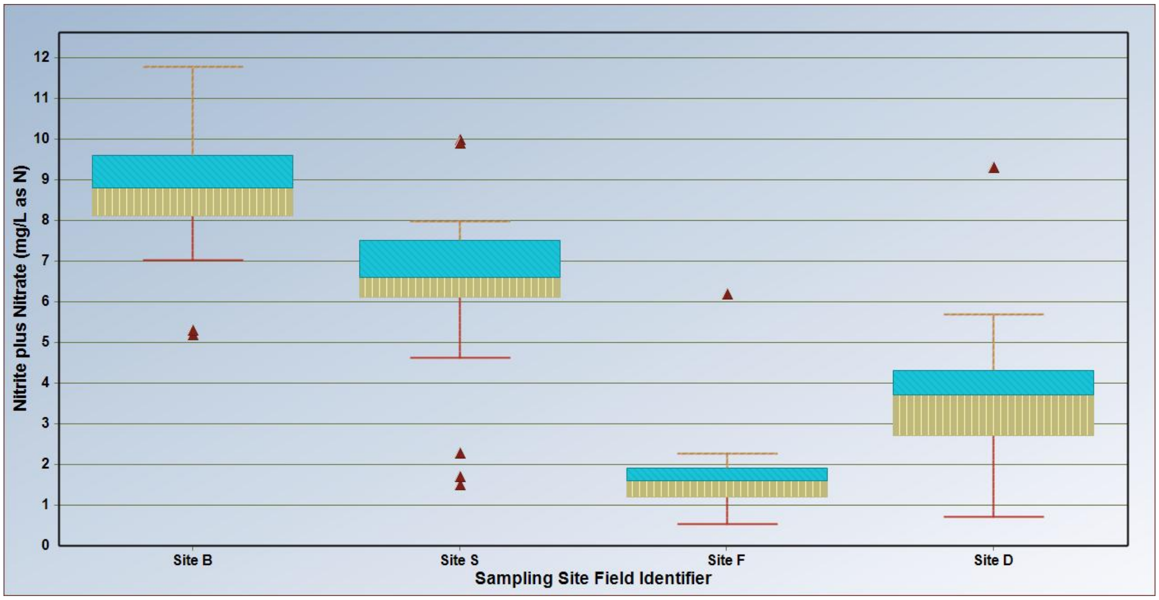

Figure 6-3 Boxplot of 2010 Nitrite plus Nitrate Sampling Results (Criterion: sample concentrations are not to exceed 100 mg/L)

Figure 6-3 shows higher concentrations of nitrite plus nitrate at the upstream agricultural site (site B) then the urban sites. Site B showed the highest median and overall range of concentrations. Site F shows the least amount of variability and smallest concentrations for nitrite plus nitrate. This is because site F has the smallest watershed (60 square miles) and smallest percent of agriculture land use (26.7 percent).

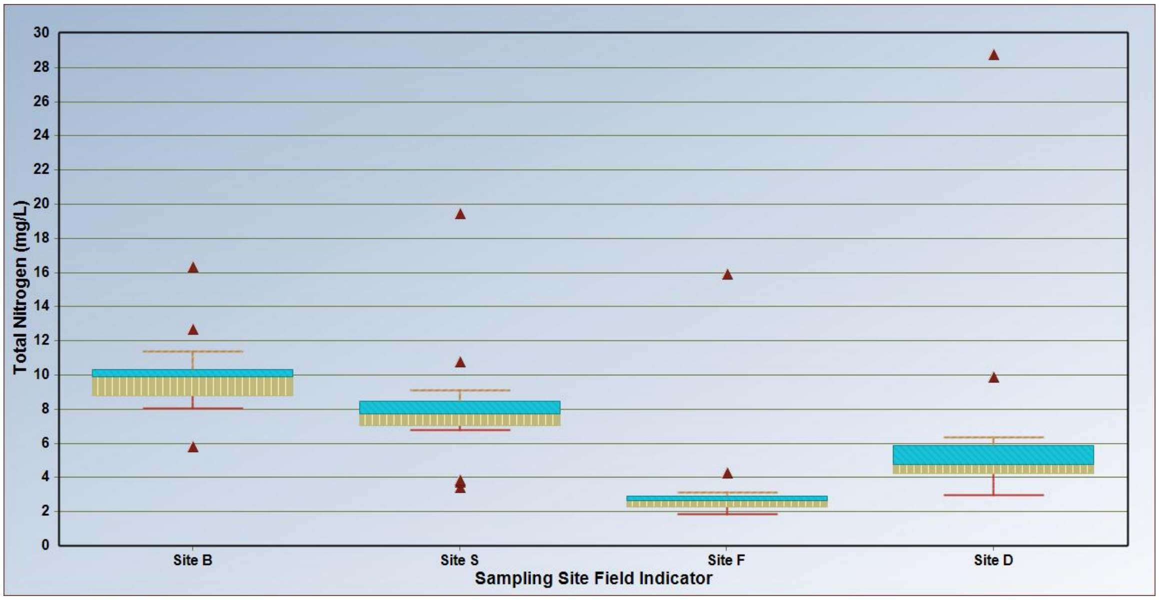

Figure 6-4 Boxplot of 2010 Total Nitrogen Sampling Results (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

Figure 6-4 shows higher calculated total nitrogen concentrations for most samples at the agricultural site (site B) then the urban sites. However, sites S and D both contained one sample that had a maximum concentration that was higher than site B. Site F shows the least amount of variability and smallest concentrations for calculated total nitrogen concentrations. This is because site F has the smallest watershed (60 square miles) and smallest percent of agriculture land use (26.7 percent).

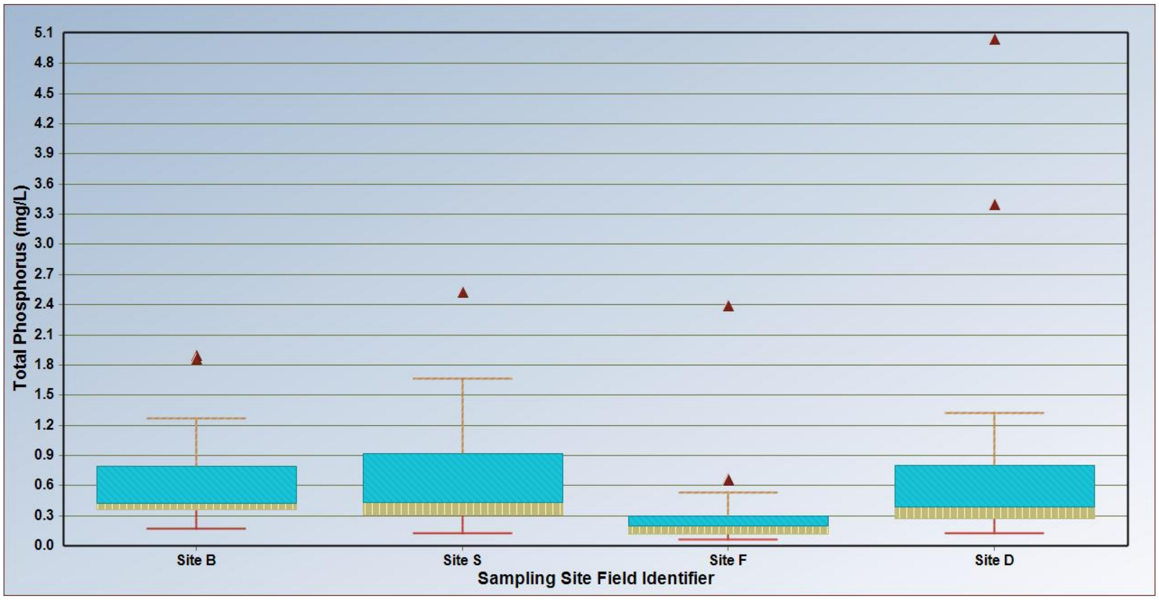

Figure 6-5 Boxplot of 2010 Total Phosphorus Sampling Results (Criterion: sample concentrations are not to exceed 0.12 mg/L)

Figure 6-5 shows similar median concentrations between sample sites B, S, and D for total phosphorus. Site D had a maximum concentration that was twice as high as the other sites. It can be seen that site F had the smallest median concentration and the least spread. This is because site F has the smallest watershed (60 square miles) and smallest percent of agriculture land use (26.7 percent).

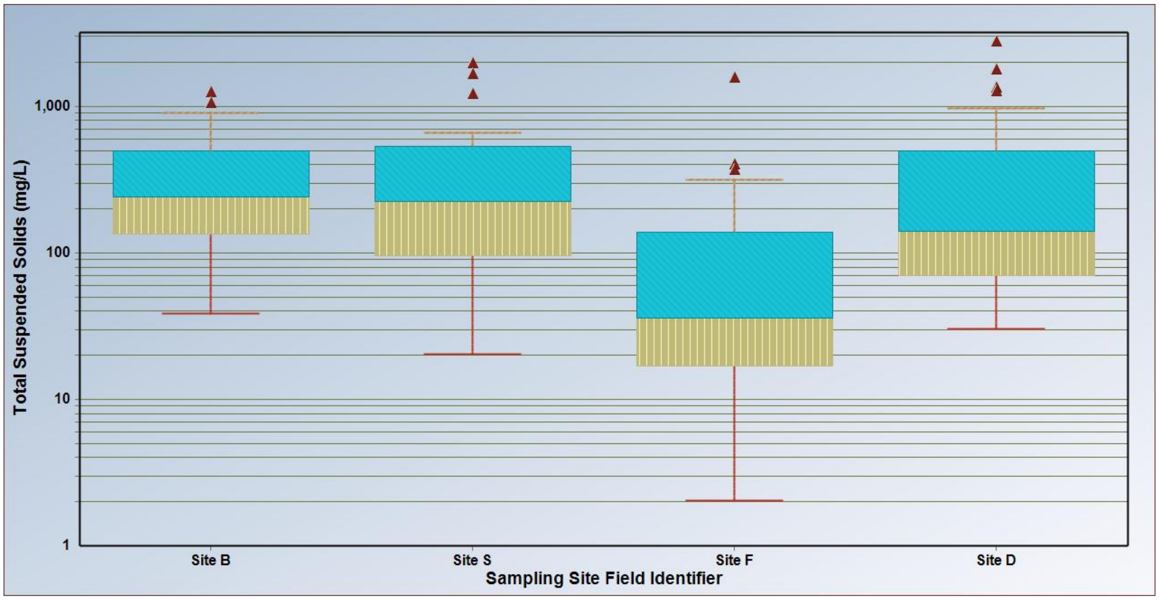

Figure 6-6 Boxplot of 2010 Total Suspended Solids Sampling Results

Figure 6-6 shows that sites B and S had similar median concentrations of total suspended solids. The median concentrations for site B and S were both above the median concentrations of sites F and D. Site F contained the largest spread, however overall the concentration statistics were lower for this site than the other sites.

A travel scatterplot represents the following results from the sampling data: minimum, maximum, and mean concentrations. These statistics are shown from an upstream to downstream perspective of the Big Papillion to Papillion Creek. It is important to illustrate that the lines on the scatterplot between the sampling sites do not actually represent the water quality concentrations in the stream. These lines only serve to help illustrate the differences between the statistics for each sampling site. Site F was not represented on the following plots because site F is located on a tributary of the Papillion Creek. Travel scatterplots are displayed for the parameters of: Escherichia coli, nitrite plus nitrate, total nitrogen, total phosphorus, and total suspended solids. These parameters (except for nitrite plus nitrate) were shown to be above the criteria and recommendations for Nebraska streams. Nitrite plus nitrate was also displayed because of its decreasing trend through the watershed. Total suspended solids were also displayed to represent sediment concentrations in the stream. The Total suspended solids parameter does not have any established recommended criteria at this time.

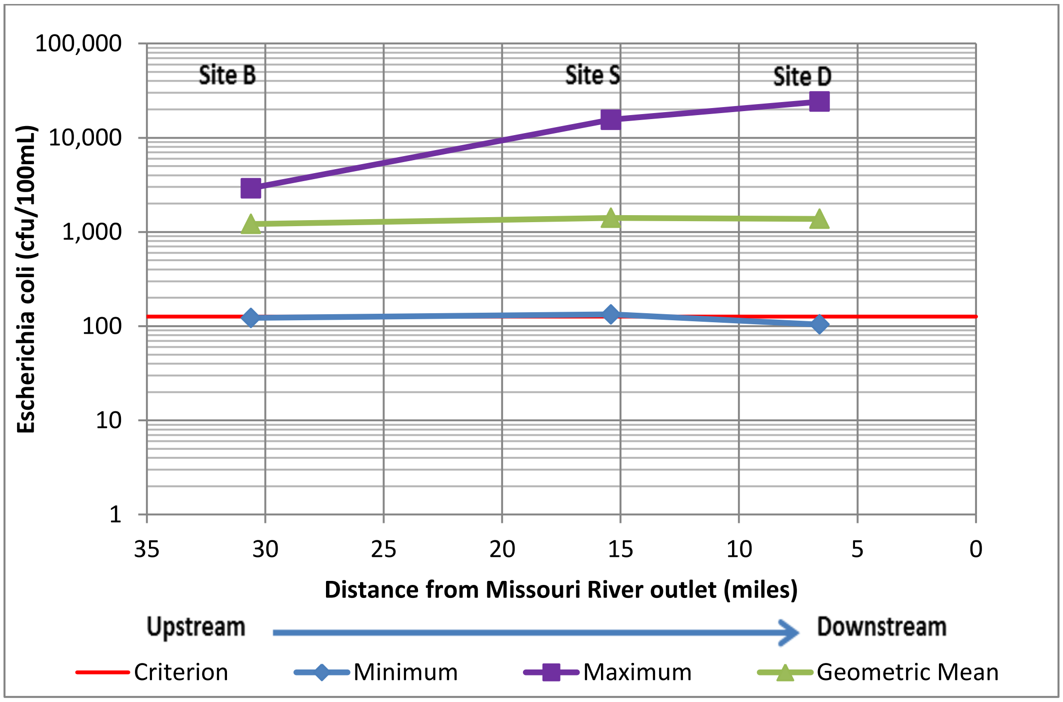

Figure 6-7 Travel Scatterplot of 2010 Escherichia coli Concentration Statistics (Criterion: geometric mean not to exceed 126 cfu/100 mL)

Figure 6-7 shows the variability of E. coli concentrations increase as the water moves through the watershed. The increase in maximum concentrations could be the result of the addition of the urban pollution sources, the addition of combine sewer overflows, or the result of when the samples were collected with respect to the time of precipitation. The decrease in minimum concentrations could be the result of dilution of the E. coli concentrations as the water moves downstream. It can be seen from the graph that only the minimum concentrations were close to the water quality criteria for E. coli.

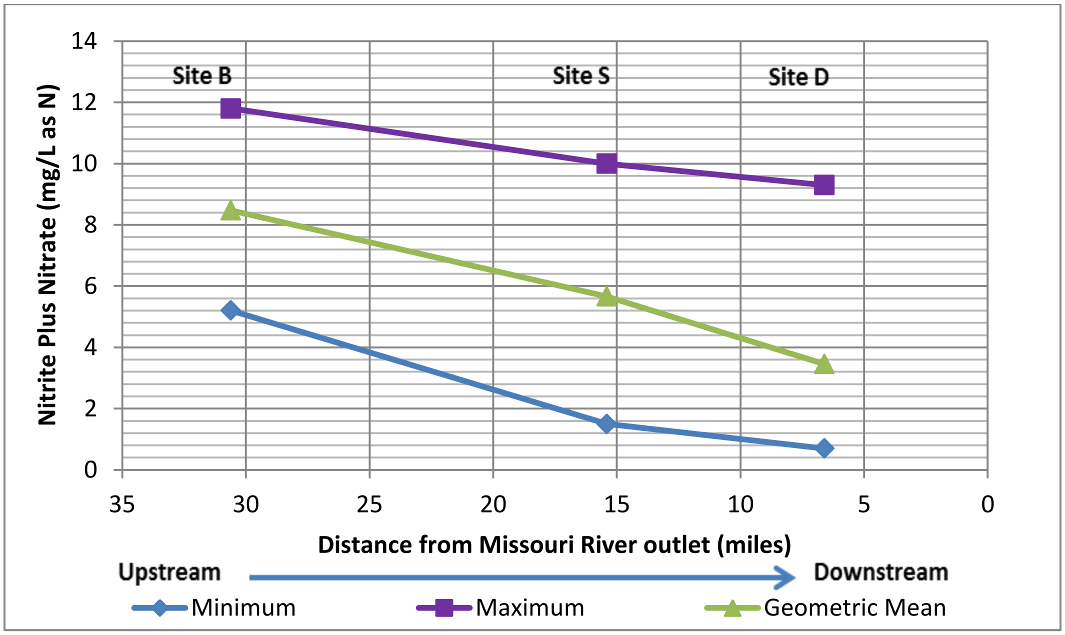

Figure 6-8 Travel Scatterplot of 2010 Nitrite Plus Nitrate Concentration Statistics

Figure 6-8 show the decreasing trend of nitrite plus nitrate concentrations as the water moves through the watershed. The decrease in maximum, geometric mean, and minimum concentrations could be the result of dilution of the nitrite plus nitrate concentrations as the water moves downstream. These decreases indicate that upstream sources are the major contributor of the pollution to the Papillion Creek.

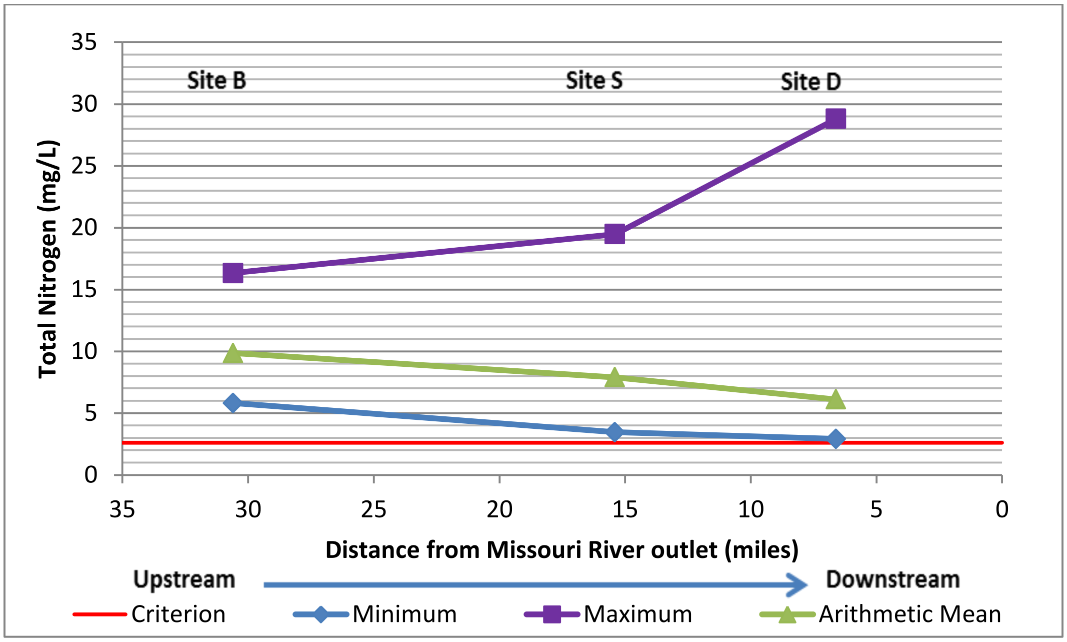

Figure 6-9 Travel Scatterplot of 2010 Total Nitrogen Concentration Statistics (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

Figure 6-9 show the decreasing trend of calculated total nitrogen mean and minimum concentrations as the water moves through the watershed. The decrease in mean and minimum concentrations could be the result of dilution of the total nitrogen concentrations as the water moves downstream. The increase that is shown in the maximum concentrations for total nitrogen that was not seen in the nitrite plus nitrate concentrations is due to the effects of total Kjeldahl nitrogen. This is because total nitrogen concentrations were calculated from the summation of total Kjeldahl nitrogen and nitrite plus nitrate concentrations. The increase in maximum concentrations could be the result of the addition of the urban pollution sources, the addition of combine sewer overflows, or the result of when the samples were collected with respect to the time of precipitation.

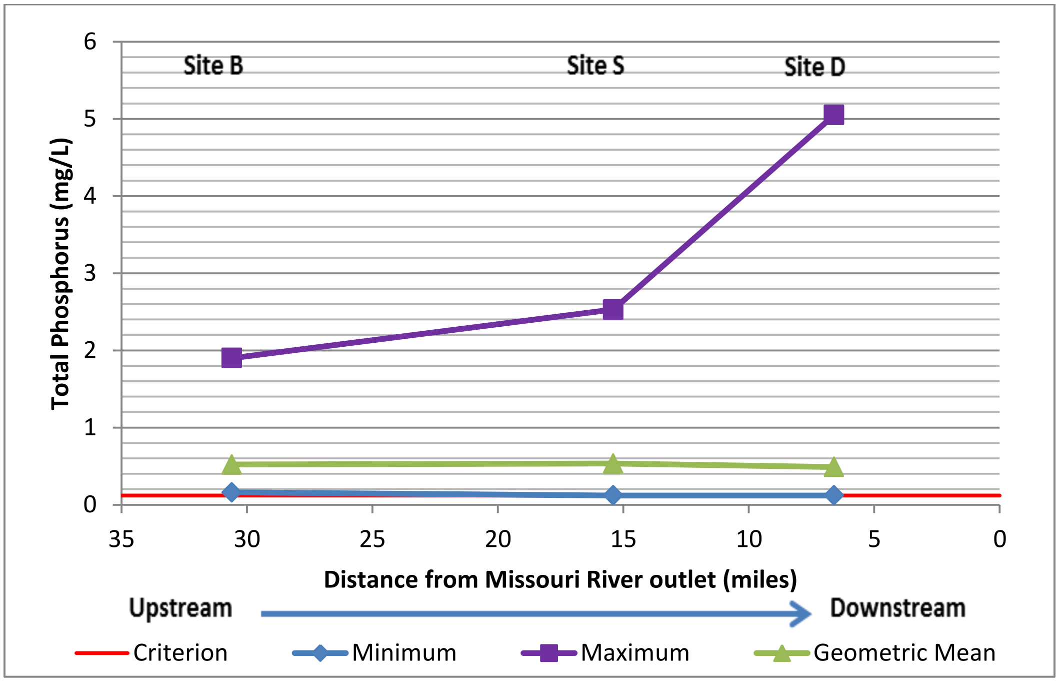

Figure 6-10 Travel Scatterplot of 2010 Total Phosphorus Concentration Statistics (Criterion: sample concentrations are not to exceed 0.12 mg/L)

Figure 6-10 show the slight decreasing trend of total phosphorus mean and minimum concentrations as the water moves through the watershed. The decrease in mean and minimum concentrations could be the result of dilution of the total phosphorus concentrations as the water moves downstream. The increase that is shown in the maximum concentrations for total phosphorus could be the result of the addition of the urban pollution sources, the addition of combine sewer overflows, or the result of when the samples were collected with respect to the time of precipitation.

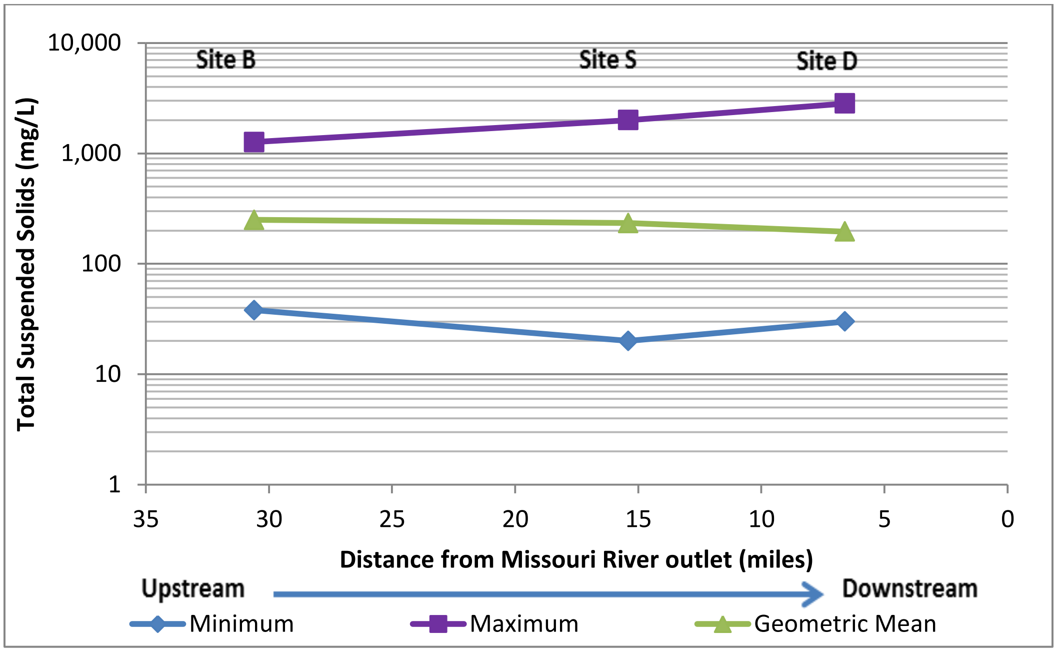

Figure 6-11 Travel Scatterplot of 2010 Total Suspended Solids Concentration Statistics

Figure 6-11 show the slight decreasing trend of total phosphorus mean concentrations as the water moves through the watershed. The decrease in mean and minimum concentrations could be the result of dilution of the total phosphorus concentrations as the water moves downstream. The increase that is shown in the maximum concentrations for total phosphorus could be the result of the addition of the urban pollution sources, the addition of combine sewer overflows, or the result of when the samples were collected with respect to the time of precipitation.

6.4 Long Term Trends of Selected Water Quality Parameters

Long term trends of the Papillion Creek Watershed are displayed by graphical representation using scatterplots. These scatterplots show concentrations for the water quality parameters of Escherichia coli (E. coli), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). These parameters were shown to be above the criteria and recommendations for Nebraska streams. Total suspended solids were also displayed to represent sediment concentrations in the stream. The total suspended solids parameter does not have any established recommended criteria at this time. Concentrations were used to display historical trends because flow data were not available to calculate annual loadings for past samples. The sample concentrations displayed were obtained from data provided by the City of Omaha (Kee 2011b), the United States Geological Survey (USGS) (Jason et al. 2009), and the United States Environmental Protection Agency (USEPA) (USEPA 2011d). Monitoring data gathered from each organization adhered to that organization's quality control/quality assurance plan. As a result, the E. coli parameter had various upper detection limits. This obscures the graphical representation because samples with concentrations higher than the upper detection limit where assigned the detection limit value. This underestimates the concentrations for E. coli. The detection limit problem was isolated to only E. coli. The parameters of TN, TP, and TSS did not have upper detection limits that interfered with reported concentrations.

The historical trends displayed in this section are for the four sampling sites used in this study (sites B, S, F, and D). The red lines on the graphs represent either regulatory or recommended criteria for the parameter.

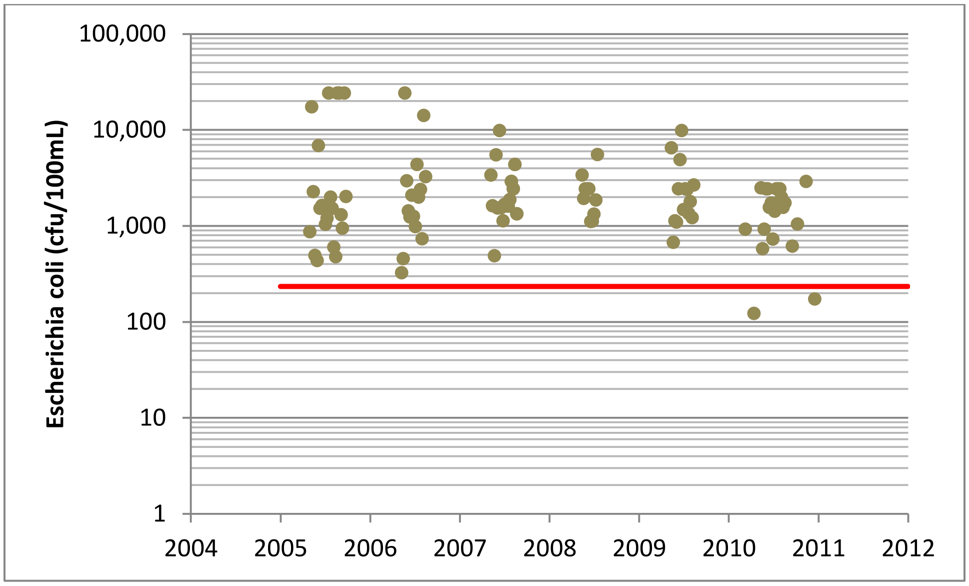

Figure 6-12 Historical Trends for Escherichia coli Concentrations at Site B (upper detection limit of 24,196 cfu/100 mL for all years) (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

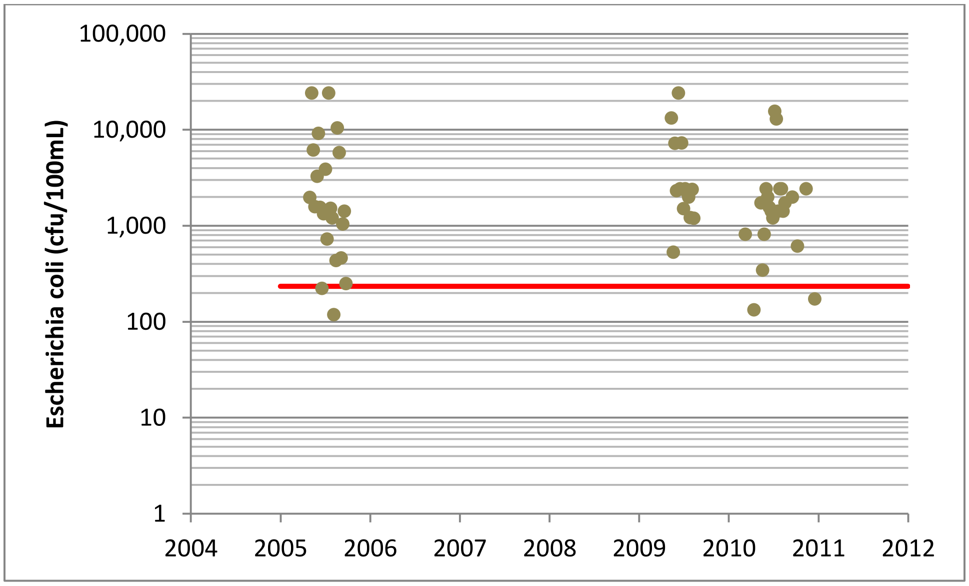

Figure 6-13 Historical Trends for Escherichia coli Concentrations at Site S (upper detection limit of 24,196 cfu/100mL for all years) (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

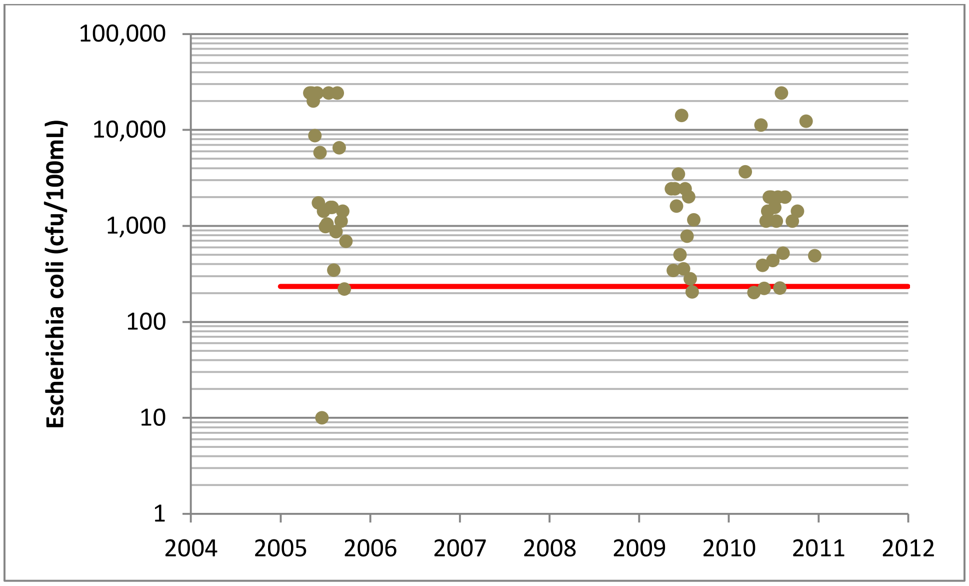

Figure 6-14 Historical Trends for Escherichia coli Concentrations at Site F (upper detection limit of 24,196 cfu/100mL for all years) (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

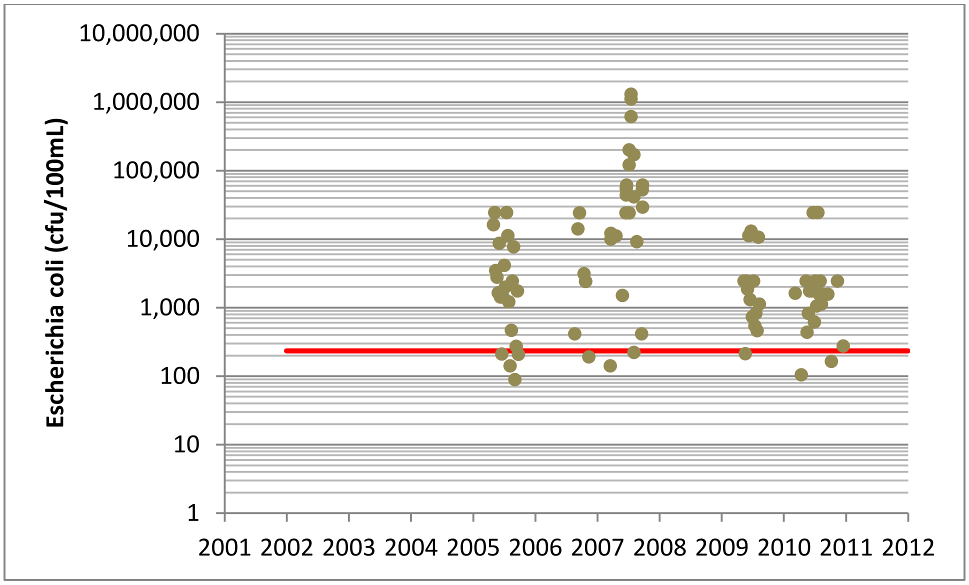

Figure 6-15 Historical Trends for Escherichia coli Concentrations at Site D (upper detection limit of 24,196 cfu/100mL for 2005, 2009, and 2010; upper detection limit of 241,196 cfu/100mL for 2006 and 2007) (Criterion: sample concentrations are not to exceed 235 cfu/100 mL)

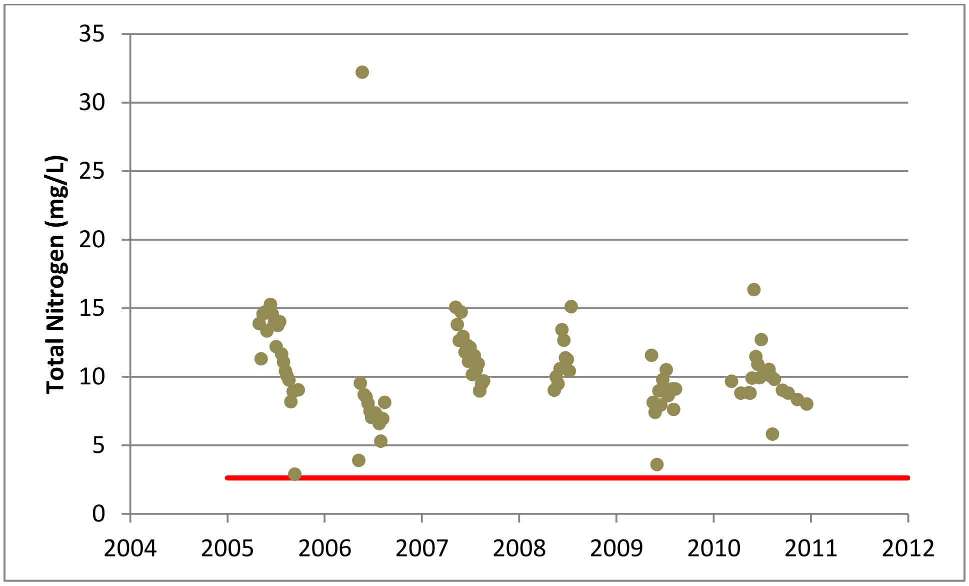

Figure 6-16 Historical Trends for Total Nitrogen Concentrations at Site B (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

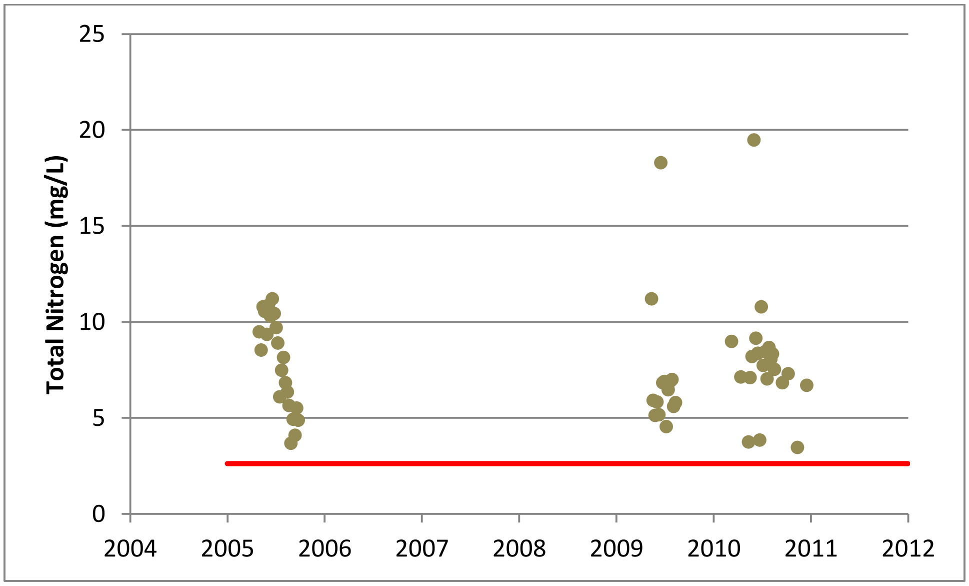

Figure 6-17 Historical Trends for Total Nitrogen Concentrations at Site S (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

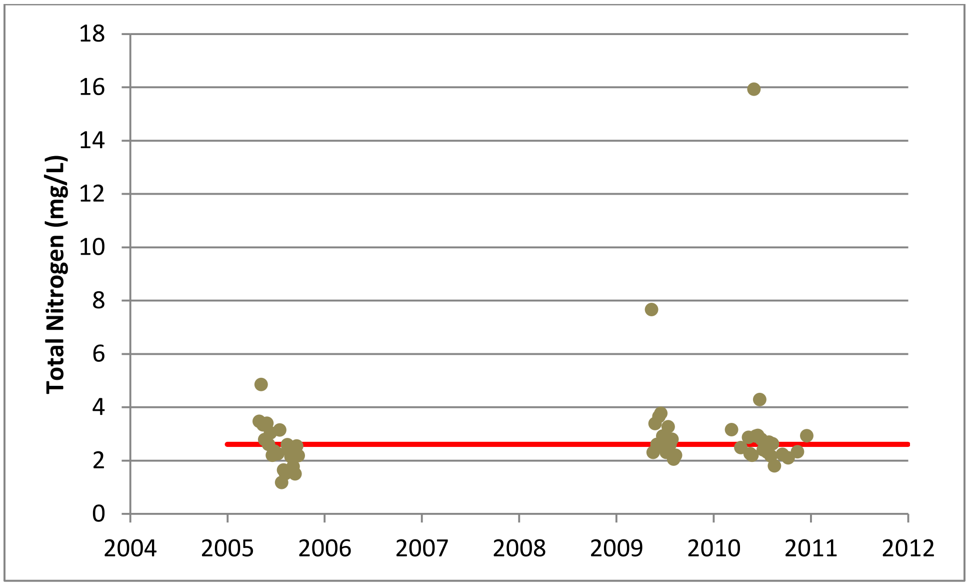

Figure 6-18 Historical Trends for Total Nitrogen Concentrations at Site F (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

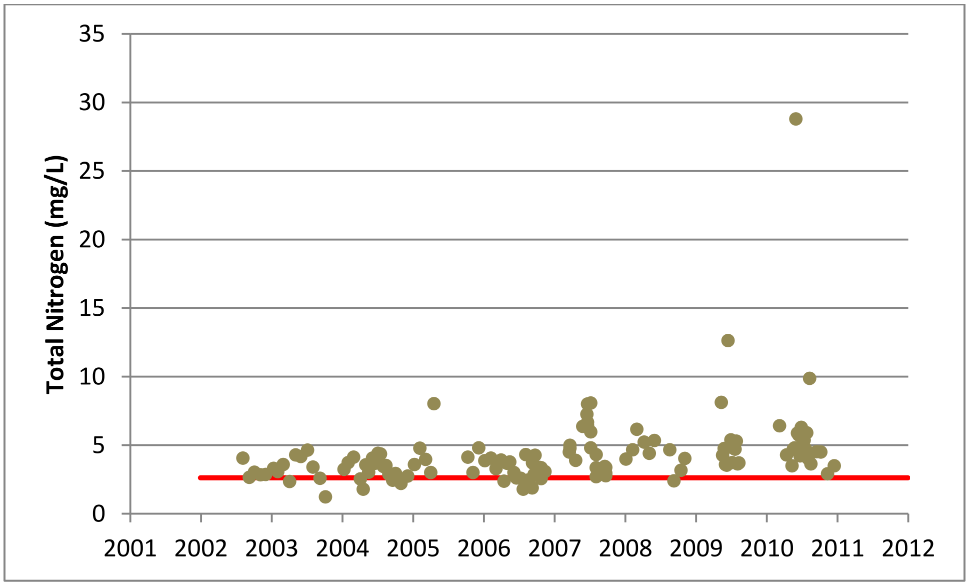

Figure 6-19 Historical Trends for Total Nitrogen Concentrations at Site D (Criterion: calculated concentrations are not to exceed 2.62 mg/L)

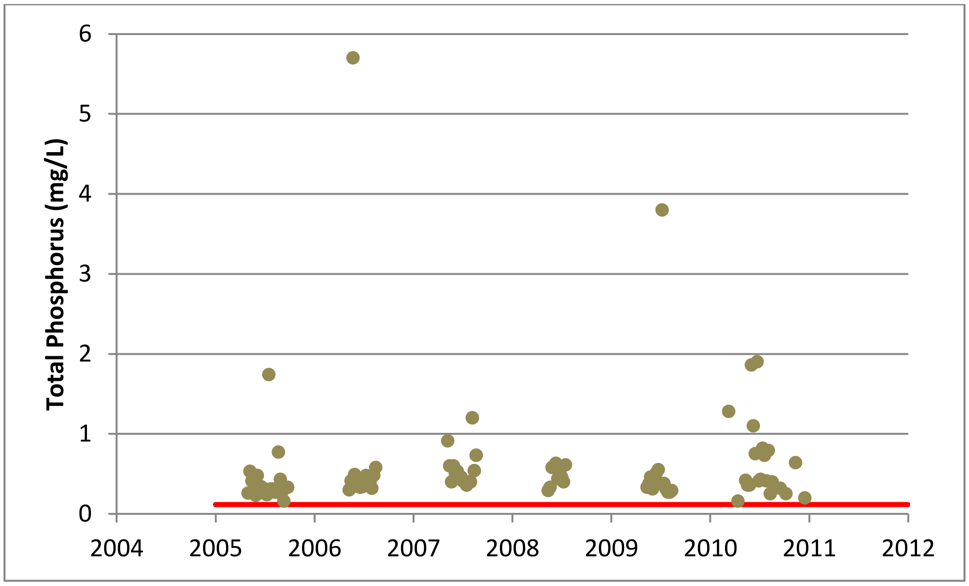

Figure 6-20 Historical Trends for Total Phosphorus Concentrations at Site B (Criterion: sample concentrations are not to exceed 0.12 mg/L)

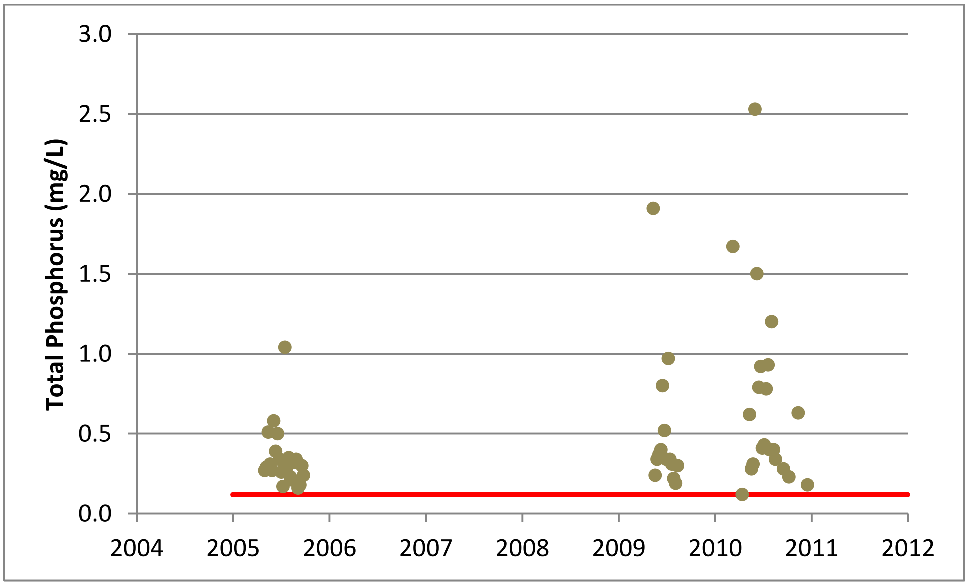

Figure 6-21 Historical Trends for Total Phosphorus Concentrations at Site S (Criterion: sample concentrations are not to exceed 0.12 mg/L)

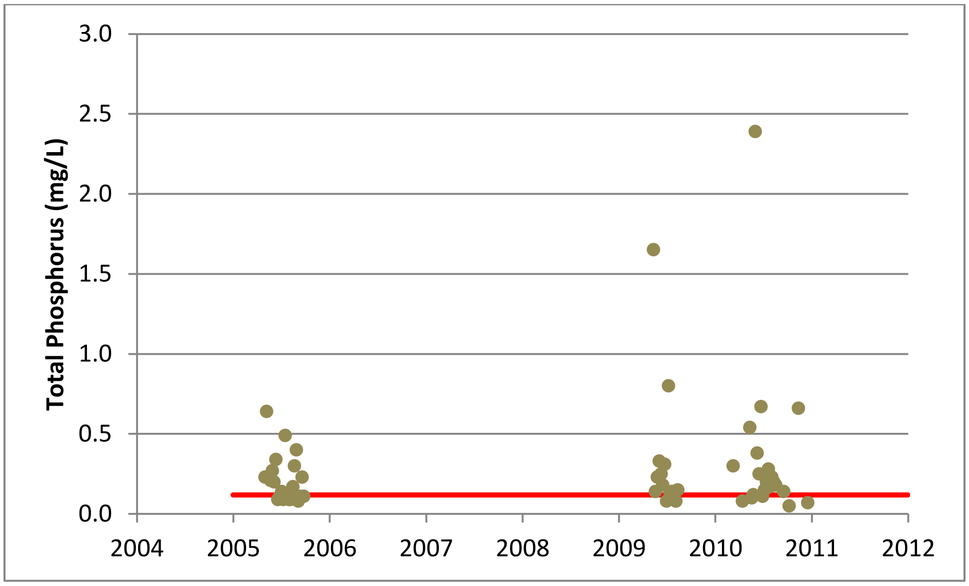

Figure 6-22 Historical Trends for Total Phosphorus Concentrations at Site F (Criterion: sample concentrations are not to exceed 0.12 mg/L)

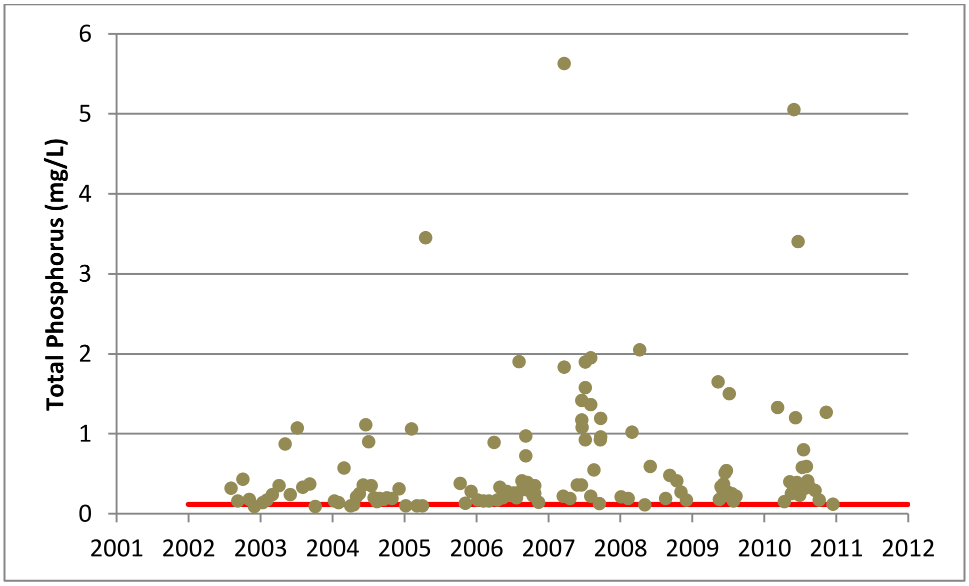

Figure 6-23 Historical Trends for Total Phosphorus Concentrations at Site D (Criterion: sample concentrations are not to exceed 0.12 mg/L)

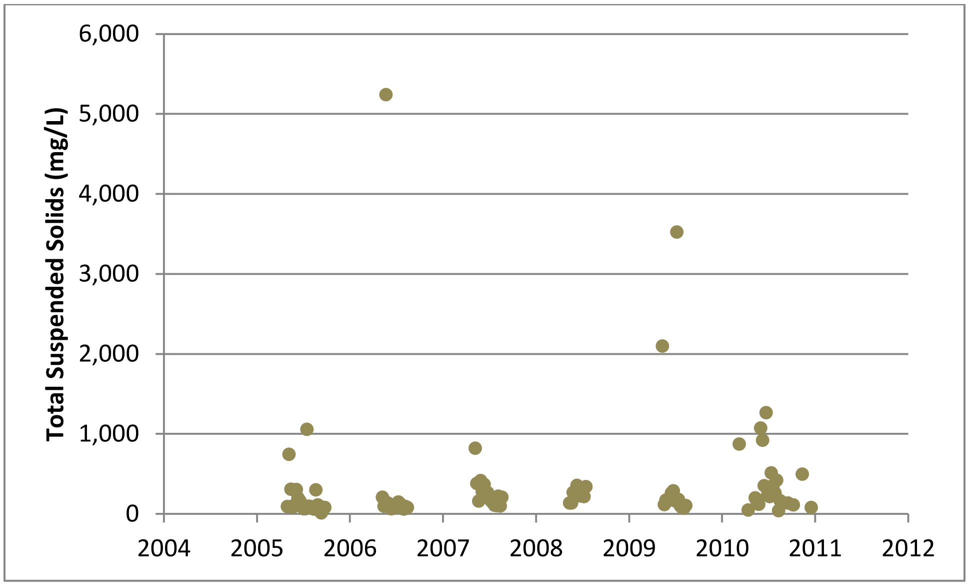

Figure 6-24 Historical Trends for Total Suspended Solids Concentrations at Site B

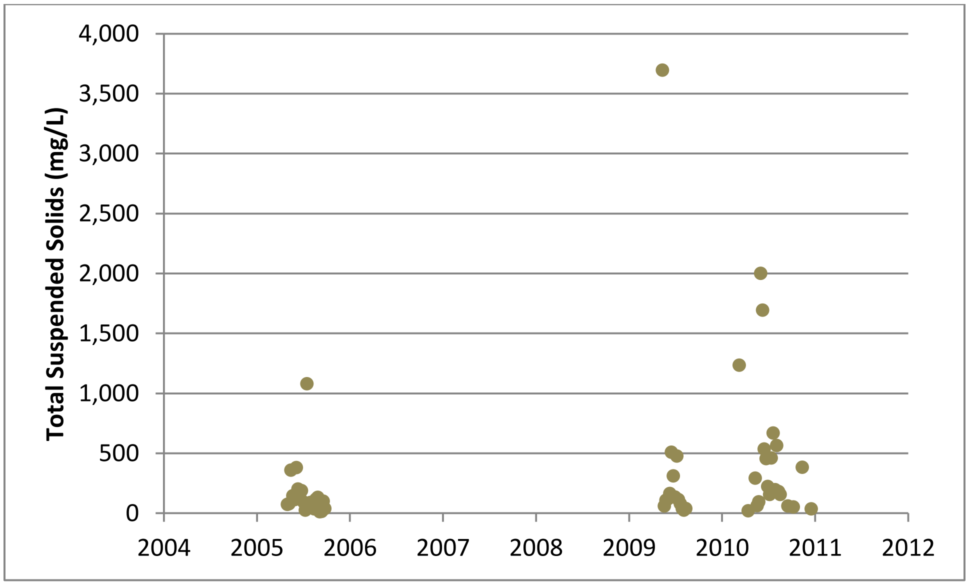

Figure 6-25 Historical Trends for Total Suspended Solids Concentrations at Site S

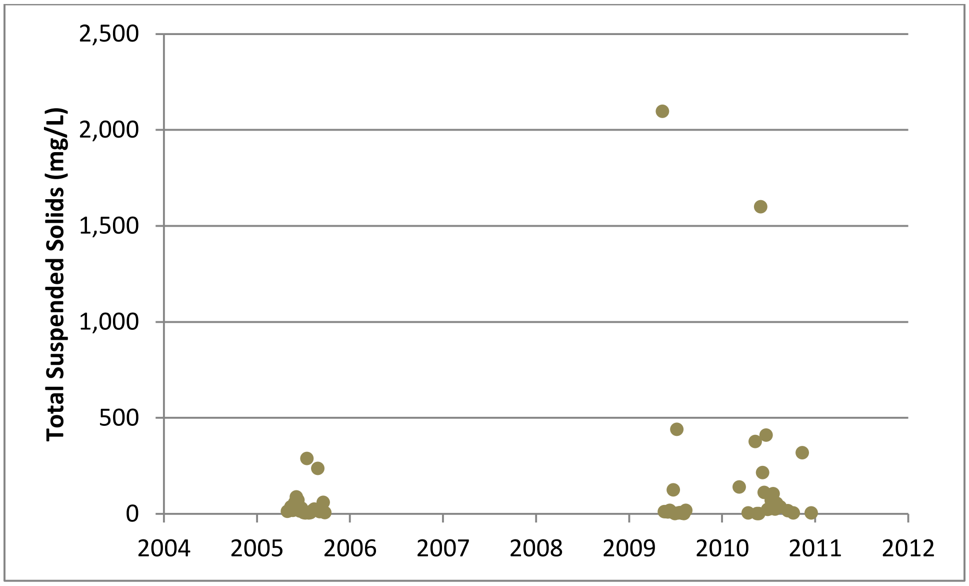

Figure 6-26 Historical Trends for Total Suspended Solids Concentrations at Site F

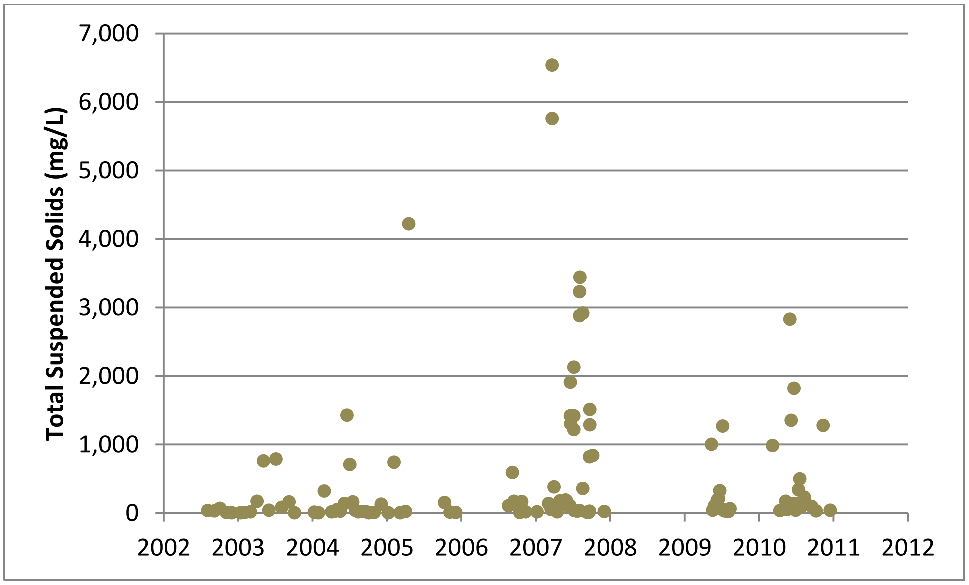

Figure 6-27 Historical Trends for Total Suspended Solids Concentrations at Site D

Figure 6-12 through Figure 6-27 show that there are no discernible trends for the selected parameters of the years shown. Statistical comparisons were not completed for these concentrations because these values are not loadings.

6.5 Comparison of Concentrations from Storm Sewers Outfalls, Combined Sewers Overflows, Raw Sewage, and In-Stream Samples

This study did not sample combined sewer overflows (CSOs) or storm sewers outfalls (SSOs). However, the City of Omaha did sample SSOs from 2004 to 2008 within the Papillion Creek Watershed. The United States Geological Survey (USGS) also sampled CSOs and SSOs from 2006 to 2007 within the Papillion Creek Watershed. The sampling data from the City of Omaha and the USGS can be used to provide reference concentrations for CSOs and SSOs. Table 6-5 displays the concentrations for selected pollutants from the USGS study data. The data is only used to provide a range of concentrations analyzed. The pollutant loads associated with these concentrations will vary depending on the amount of flow associated with the concentrations. Unfortunately, flow measurements were not collected with the sample concentrations.

Table 6-5 Comparison of Minimum and Maximum Concentrations from Municipal Separate Storm Sewers, Combined Sewer Overflows, Raw Sewage, and In-Stream Samples

	Total Suspended Solids		Total Nitrogen		Total Phosphorus		Escherichia coli	
	(mg/L)		(mg/L)		(mg/L)		(MPN/100 mL)	
	Min	Max	Min	Max	Min	Max	Min	Max
SSOs	25	802	1.0	13.5	0.1	1.4	1,000[a]	1,200,000
CSOs	55	7,260	0.6	55.5	0.4	16.5	9,700	24,000,000[b]
Raw Sewage	23	955	12.6	50.0	1.6	32.2	700,000	13,000,000
In-Stream	4	10,200	0.6	9.5	0.1	7.8	10	1,400,000

Data obtained from the USGS (Jason, et al. 2009).

[a] Actual concentration is less than the lower detection limit of 1000 MPN/100mL for E. coli samples.

[b] Actual concentration is greater than the upper detection limit of 24,000,000 MPN/100mL for E. coli samples.

[c] In-Stream concentrations were sampled in the urban parts of the watershed.

The USGS report analyzed water quality parameters to determine if the parameters where derived more from CSOs, SSOs, or upstream sources. The report noted that constituents related to upstream sources are specific conductance, nitrite plus nitrate, nitrite, hardness, calcium, magnesium, chloride, arsenic, barium, selenium, uranium, and atrazine. Constituents derived more from SSOs than CSOs are turbidity, antimony, cadmium, cobalt, zinc, and others. Constituents derived more from CSOs than from SSOs or upstream sources are chemical oxygen demand, biochemical oxygen demand, total suspended solids, ammonia, total nitrogen, orthophosphate, total phosphorus, copper, lead, mercury, silver, and others.

From Table 6-5 general sources of pollution can be seen. Total suspended solids appear to be resulting from other sources than CSOs and SSOs. Total nitrogen appears to be resulting more from CSOs and raw sewage. However, section 6.3 showed that total nitrogen could be resulting more from upstream sources as well. Total phosphorus appears to be resulting from raw sewage and other sources than SSOs. E. coli appears to be resulting from other sources than CSOs and SSOs, but slightly increased by these sources.

6.6 Comparison of Selected Water Quality Parameter Loadings to Previous Studies

Previous studies have been completed for the Papillion Creek Watershed that calculated pollutant loadings. These studies were completed by the University of Nebraska Lincoln (Alam 2006) and HDR (HDR 2009). The UNL study computed a total phosphorus (TP) mass loading for the Papillion Creek Watershed. This loading was estimated from the Event Mean Concentration for each land use type and from the land use areas using the USEPA Simple Method (Stormwater Center 2011). The estimated TP mass load for 2006 was 264,119 lbs/yr (119,804 kg/yr) (Alam 2006). The estimated TP mass load was calculated for the entire Papillion Creek Watershed. Therefore, site D should be compared to this estimation, because this Site D represents 95 percent of the watershed. The calculated TP mass load for 2010 at site D was 160,000 kg/yr. Thus the measured and predicted mass loads are in good agreement for the Papillion Creek Watershed.

The HDR study computed a mass loading for total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS), and Escherichia coli (E. coli). HDR calculated the mass loadings using the USEPA simplified method. Table 6-6 displays the comparison between the calculated pollutant loadings of this study and the results presented by HDR.

Table 6-6 Comparison of Calculated Mass Loadings with the HDR Study

	Total Nitrogen (kg/yr)		Total Phosphorus (kg/yr)		Total Suspended Solids (kg/yr)	
Location	HDR Study	Current Study	HDR Study	Current Study	HDR Study	Current Study
Site B	4.35E+04	6.79E+05	9.07E+03	3.66E+04	2.72E+07	1.76E+07
Site S	4.45E+04	1.06E+06	1.81E+04	7.64E+04	3.67E+07	3.35E+07
Site F	4.99E+04	9.19E+04	9.98E+03	7.20E+03	1.63E+07	1.39E+06
Site D	2.95E+05	1.71E+06	5.90E+04	1.60E+05	9.71E+07	6.41E+07

HDR data from (HDR 2009).

The table shows that calculated and predicted TSS loads were relatively close. However, the calculated and predicted TN and TP loads showed large differences. Site F did show closer values for calculated and predicted TN and TP loads compared to the other sites.

6.7 Best Management Practices Implementation

This study has shown the following pollutants to be of concern in the Papillion Creek Watershed: Escherichia coli, total nitrogen, total phosphorus, and total suspended solids. To reduce these pollutants to acceptable levels will require an integrated and comprehensive watershed plan targeting both the rural and urban runoff sources. The HDR report addressed the issue of implementing a watershed management plan that integrates water quality and peak flow reduction strategies (HDR 2009). The report should be consulted to view the Watershed Management Plan suggested. The report stated that localized source controls should be specifically engineered to capture the first 0.5 inches of net runoff of all storms and to provide “no net increase” in peak flows from a 2-year storm (HDR 2009).

For the Watershed Management Plan to be successful, focus must be shown for BMPs of each individual pollutant. Obviously, the best BMPs for E. coli are to minimize or eliminate human–source pollution. Human sources of bacterial contamination to the watershed derive from Combined Sewer Overflows (CSOs). The City of Omaha is currently addressing these sources of pollution in their Long Term Control Plan. The goal of this plan is to reduce the overflows from CSOs by October 2024 (Omaha CSO 2011). The generally accepted BMPs for non-point bacteria sources involve the effective control of water-borne solids. The control of water-borne solids can be accomplished through soil and granular bed filtering and/or surface water detention which promotes settling solids from the water column. Stream-side buffer strips can be effective in removing suspended particulates and associated bacteria in runoff. However, these dense, un-mowed vegetated strips adjacent to waterways can unintentionally become habitats for wildlife, and thus, sources of bacteria. Wet detention basins have been shown to be a more efficient removal mechanism for bacteria than dry detention basins because of buffering of incoming flow with respect to turbulence and re-suspension of previously deposited solids (HDR 2009). More information about specific BMPs and their performance can be found from the HDR report (HDR 2001) and the USEPA National Menu of Stormwater Best Management Practices (USEPA 2008a).

Nutrient control strategies are designed to address excessive levels of nitrogen and phosphorus in waterbodies. Soluble phosphorus and organic nitrogen pose the greatest threat to eutrophication in a waterbody. These soluble forms of pollution usually become bound to soil particles. Therefore the focus of nutrient control strategies has generally been focused at removing particulates from a waterbody (HDR 2009). This has included settling basins and buffer strips. More information about specific BMPs and their performance can be found from the HDR report (HDR 2001) and the USEPA National Menu of Stormwater Best Management Practices (USEPA 2008a).

These BMPs will help reduce the concentrations and loads of E. coli, TN, and TSS in the watershed. Unfortunately, compliance with established criteria and recommendations may be unrealistic for this watershed because of the geology and topography of the watershed. However, the overall goal is to provide a pathway for improvement that is practical for new development or significant redevelopment applications that will improve water quality in the watershed (HDR 2009).

6.8 Escherichia coli Analysis

In 2010 Nebraska Department of Environmental Quality (NDEQ) listed six stream segments as impaired by Escherichia coli (E. coli) in the Papillion Creek Watershed. Stream segments designated for recreation use must maintain a recreational season (May 1st-September 30th) geometric mean concentration of less than 126 cfu/100mL. Table 6-7 displays the calculated E. coli recreational season geometric means for selected stream segments of the Papillion Creek Watershed.

Table 6-7 Comparison of Escherichia coli Geometric Means for the Recreation Sesaon from NDEQ and City of Omaha

		Geometric Mean	
Stream Segment	Sample Site	NDEQ	City of Omaha
		(cfu/100 mL)	(cfu/100 mL)
MT1-10120	Site B	1,605	1,539
MT1-10120	Site S	1,605	1,967
MT1-10111	Site F	2,288	1,287
MT1-10100	Site D	1,708	1,960

[a] NDEQ data from samples taken in 2005 (NDEQ 2009c).
[b] City of Omaha data from samples taken in 2010 for the current study.

Table 6-7 displays the geometric mean for E. coli. It can be seen that the water flowing from the agricultural land (site B) is already impaired before it reaches the urban landscape. Unfortunately, it is not possible to discern specific sources within the watershed with the currently available bacterial data.

Another way to represent E. coli concentrations is to construct load duration curves. These curves were adopted by the NDEQ to distinguish between point and nonpoint sources of pollution for a flowing waterbody (NDEQ 2009a). These curves are based on the principal that if pollutant concentrations increase as flow increases, then the source of the pollutants is likely nonpoint source influenced. However, if high pollutant concentrations are associated with low flows (e.g., baseflow) then point sources are likely influencing the water quality. The curve methodology is used for streams where point sources have not been identified as the sole pollutant contributor (NDEQ 2009a). Points plotted above the red line indicate an exceedance of the water quality standard while points plotted on or below the red line indicate the water quality standard is being met and the beneficial use is being supported. Flows to the left of the vertical line are large flows (e.g., stormflows), and flows to the right of the vertical line are small flows (e.g., baseflows). For example, the 90 percent exceedance flow is exceeded 90 percent of the time. These vertical lines were determined by the calculating the baseflow of the stream for each site. Figure 6-28, Figure 6-29, Figure 6-30, and Figure 6-31 display the load duration curves developed for the Papillion Creek stream segments by NDEQ with the addition of the City of Omaha sampling data.

The plots show that the E. coli loading at sites B and S are almost entirely dominated by nonpoint (e.g., natural) sources. However, there appears to be a significant point source (possibly combined sewer overflows) of E. coli detected in the monitoring at site F. These sources may be the cause of the point source indication at site D (downstream of site F).

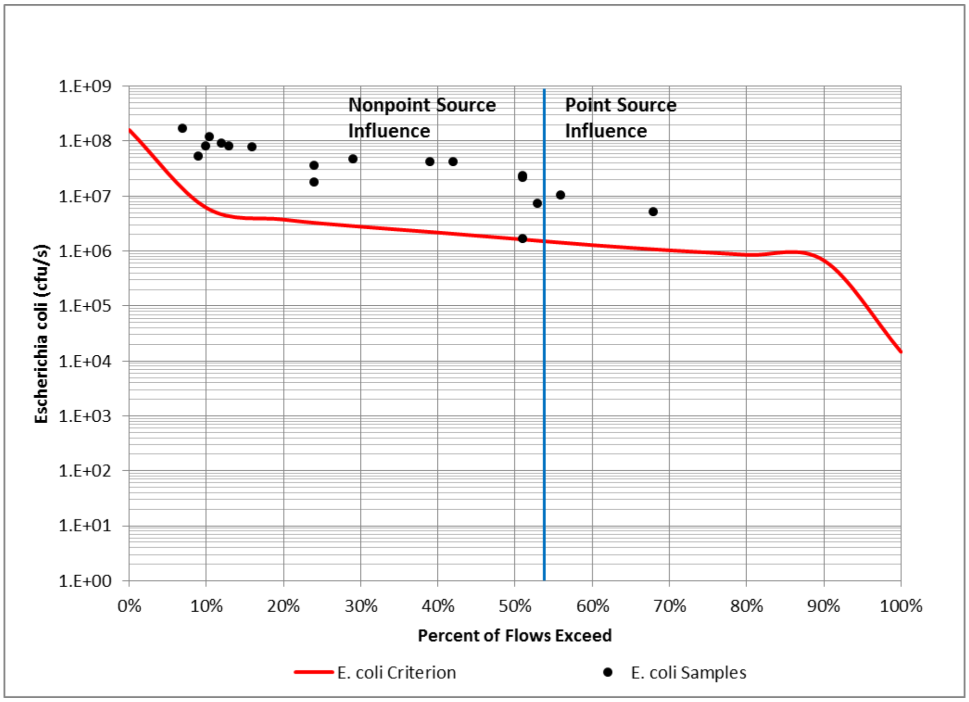

Figure 6-28 2010 Site B Escherichia Load Duration Curve

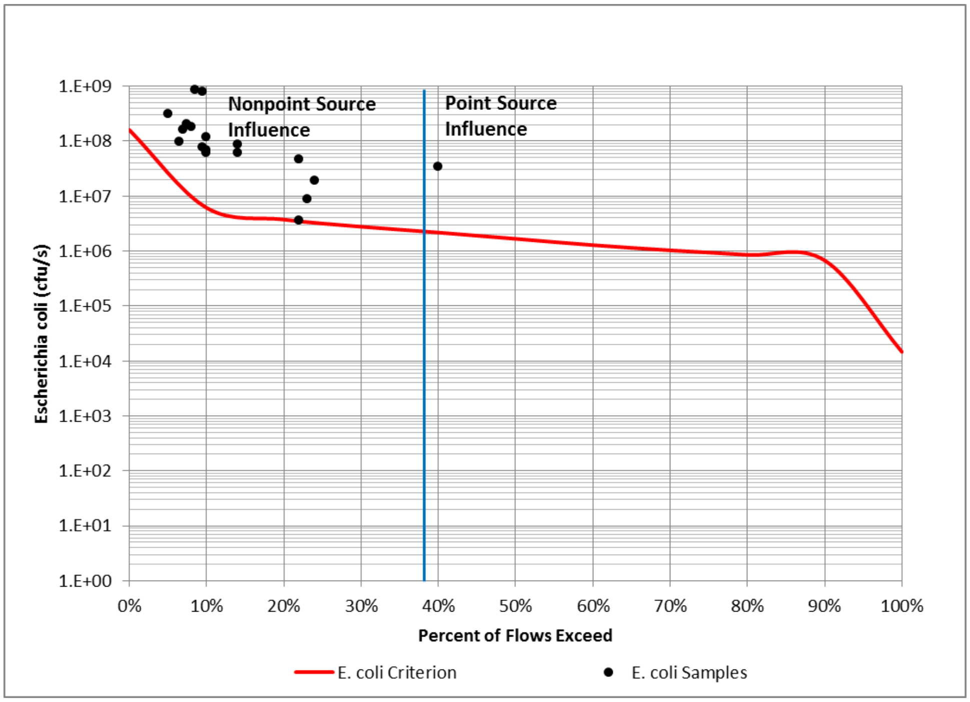

Figure 6-29 2010 Site S Escherichia Load Duration Curve

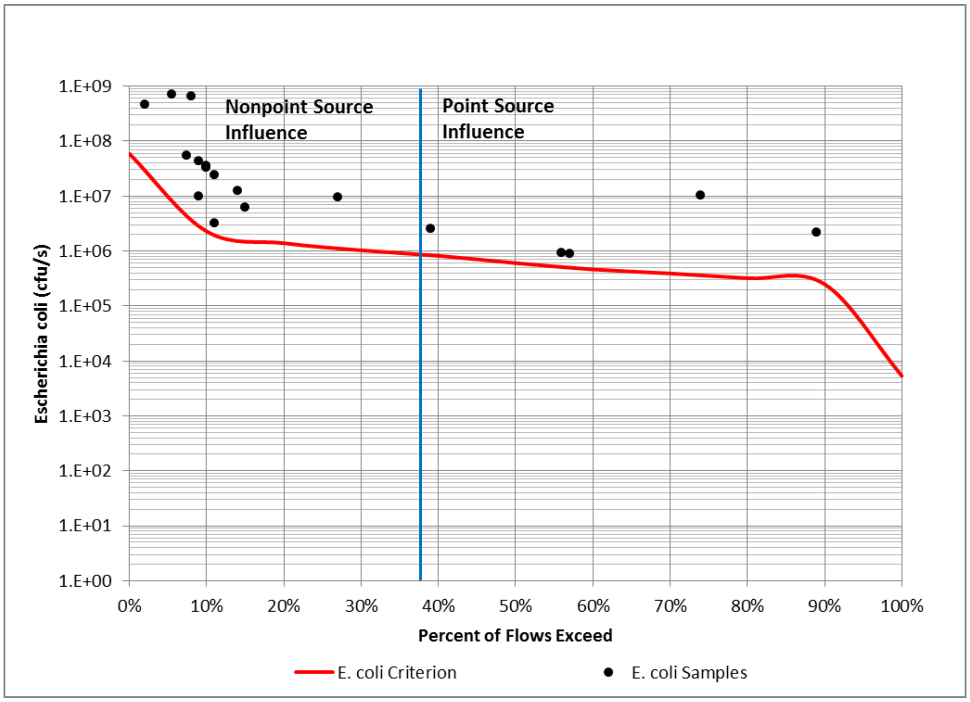

Figure 6-30 2010 Site F Escherichia Load Duration Curve

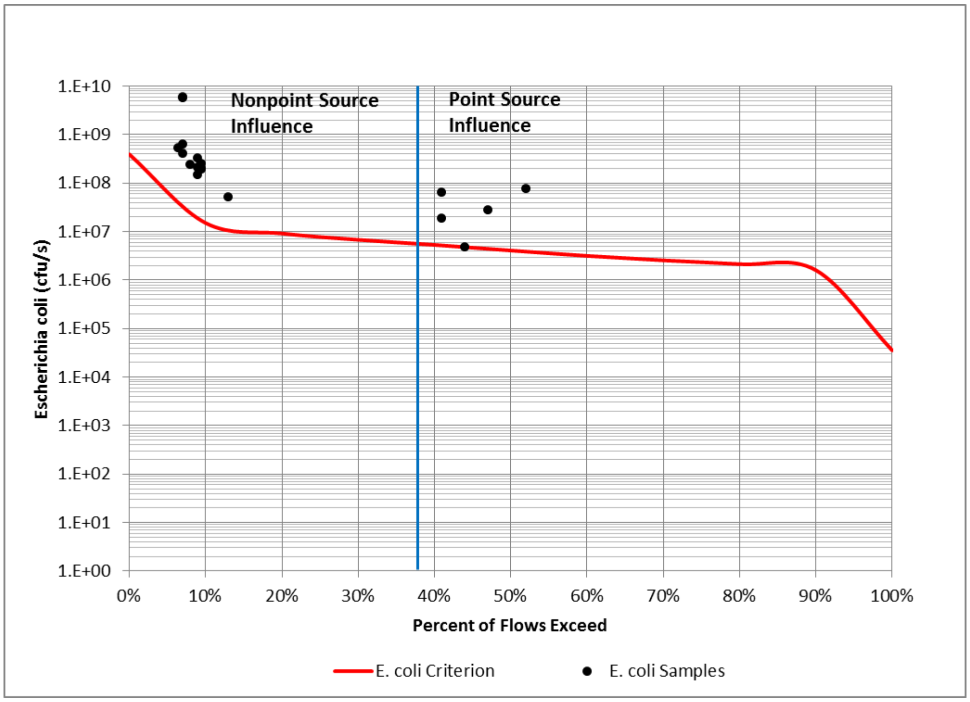

Figure 6-31 2010 Site D Escherichia Load Duration Curve

E. coli survival depends upon many different factors in a waterbody. These factors include but are not limited to: sedimentation, temperature, solar radiation, and predation (Bowie et al. 1985). E. coli survival is highly dependent on water temperature. Temperature has an inverse relationship with the survival of E. coli. Therefore, low temperatures allow for greater survival of E. coli (USEPA 2001). Water temperature also modifies other factors, including predation that affect the survival rate of E. coli (Bowie et al. 1985).

Sedimentation plays an important role in the overall removal of E. coli from the water column of a waterbody. A high rate of sedimentation usually correlates with low concentrations of E. coli (USEPA 2001). This is because E. coli organisms attach to sediment particles in a waterbody. As these sediment particles settle out of the water column, the E. coli concentrations decrease. In waterbodies the number of sediment particles tends to be higher after precipitation events because of nonpoint pollution. These particles then start to settle out of the water column after precipitation event.

Solar radiation has an inverse relationship with E. coli survival. Increased solar and ultraviolet radiation greatly decreases the survival rate of bacteria (USEPA 2001). Predation also has an inverse relationship with E. coli survival. Predation is increased at higher temperatures and decreased at lower temperatures of a waterbody (Bowie et al. 1985).

By examining these factors it can be seen that E. coli concentrations may only approach compliance levels during the recreational season when periods of baseflow conditions exist in the stream and after appropriate time has passed since the last precipitation event. This appropriate time varies for each stream segment. Benthic sediments will also need to not be disturbed for E. coli concentrations to be low.

Recently, studies have proven the survival of E. coli and fecal coliforms in benthic sediments (Garzio-Hadzick et al. 2010). Because E. coli can survive in benthic sediments, the theory that E. coli is an indicator of recent pollution is disproved. Survival times can be calculated as the amount of time to reduce a population by 50 percent. The survival time for a 50 percent reduction in a freshwater water column at 23°C is 1.4 days. The survival time for a 50 percent reduction in a freshwater column at 9°C is 2.0 days. The survival time for a 50 percent reduction in benthic sediments is 5.8 days. Other studies have also shown E. coli survival in sediment to be much larger than 5.8 days to reduce the population by 50 percent (Garzio-Hadzick, et al. 2010). These values were calculated by the first order decay model. K values were obtained from (Jamieson et al. 2005) and (Easton et al. 2005).

The average time between precipitation events was calculated to be 5.2 days for the Papillion Creek Watershed for the recreational season. This shows that E. coli populations are sustained between precipitation events in the benthic sediments. These sediments then act as a source of pollution and detection of E. coli that would be misrepresentative of health risk to enter the waterbody. The E. coli populations that reside in the sediments can be resuspended into the water column during the rising limb of a hydrograph or by disturbance, which would cause higher concentrations to be reported. These concentrations would serve as false positives.

E. coli concentrations are above compliance from the above city sources. Because E. coli from these sources survive and are transported within the sediment, the sediments cause the stream segments downstream to be out of compliance. Therefore, although the City of Omaha sources may contribute to E. coli concentrations in stream segments, the sources from upstream of the city are great enough to cause the segments to be out of compliance. Unfortunately, the data that is currently available cannot be used to discern specific sources for impairments of the stream segments.

Chapter 7. Conclusions

The results showed that concentrations of Escherichia coli (E. coli) are routinely above established criteria for the state of Nebraska. Concentrations of E. coli that exist in the Papillion Creek Watershed upstream of the City of Omaha have also been shown to be above established criteria. Therefore reduction of sources of E. coli within the city will not achieve compliance. Current data cannot discern specific sources of E. coli pollution in the Papillion Creek Watershed. Concentrations of total nitrogen and total phosphorus have been shown to be above recommended criteria for the Western Cornbelt Plains Ecoregion. Total nitrogen and nitrite plus nitrate were shown to be derived more from upstream sources above the City of Omaha.

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Appendix A. Papillion Creek Monitoring Procedures

A.1 Examples of In-Field Documentation

Table A-1 Example of Field Data Sheets

Field Data Sheet
City of Omaha BMP Assessment Monitoring
Papillion Creek Watershed In-Stream Sampling Program

Page 1 of 2

(to be completed in ink)

General

Station ID : **Site D** Location : Highway 75 and Capehart
Date : 5/1/2010 Start time : 8:30 End Time : 8:50
Sampling personnel : Joe Smith

Weather

Wind direction/speed : East 8 mph 75°F
Sky : Partly Sunny
Precipitation : none
Comments : none

In Situ Physical Examination of Stream Water

ISCO data downloaded? Y / N Notes: ISCO data not downloaded
Description of Flow : Medium
Color : clear green yellow [✓ brown] other :
Turbidity : clear [✓ semi-clear] turbid comments :
Odor : H_2S sewage petroleum [✓ none] other :
Petroleum hydrocarbons? no Floating solids? no
Sheens or films ? no Foam? no
Trash or debris? yes
Discharge from Storm Outfalls? no
Comments : none

							Comments
Water quality results :	battery:					volts	
	temperature :	22.1	22.1	22.1	22.1	C	
	DO%:	89.5	88	87.6	88.1		
	DO :	8.56	8.57	8.55	8.45	mg/L	
	conductivity:	713.6	712	711	714	uS/cm	
	pH :	8.23	8.23	8.23	8.23		
	turbidity :	125.3	126	125	126	NTUs	
	depth:	0.15	0.15	0.15	0.15	ft	

Measuring device used : Eureka Manta 2

****NOTE: USE "N/A" or a slash as appropriate -- NO BLANKS**

Field Data Sheet
City of Omaha BMP Assessment Monitoring
Papillion Creek Watershed In-Stream Sampling Program

Page 2 of 2

Station ID : **Site D**

Location : Highway 75 and Capehart

Date : 5/1/2010

Water Grab Sample Description

Sample depth : 1/3 of total stream depth

Description of location : center of channel

Sample access method : wading

Sampling device : direct fill bottles

Comments : none

Parameters :	E. coli (6-hour holding time)	time collected :	8:40	Laboratory :	QCD
	TKN/nitrate/total phosphorus		8:40		MWL
	Nitrite/dissolved phosphorus		8:40		MWL
	TDS/TSS/ammonia-nitrogen		8:40		QCD
	BOD		8:40		QCD

Duplicates/field blanks : no

In Situ Physical Examination of Sediment

Color : black [✓ brown] gray yellow mixed other :

Odor : H_2S sewage petroluem [✓ none] other :

Composition : [✓ silt/clay] sand cobble gravel boulder size riprap

Comments : no

Additional Observations

Photos/movies : no

Comments no

Table A-2 Example of the Midwest Labs Chain of Custody

Chain of Custody--City of Omaha

Independent Laboratory: Midwest Laboratories
Project Number / Identification: Papio Basin Stream Sampling
P.O. #: ______________________________

Quality Control Division
Attention: Don Thomsen
5600 South 10th Street
Omaha NE 68107-3501
(402) 444-3915 x233

BILL TO: Quality Control Division
Attention: Don Thomsen
5600 South 10th Street
Omaha NE 68107-3501
(402) 444-3915 x233

TIME AND DATE SAMPLED	Time and Date Sampled	CITY TAG #	SAMPLE MATRIX	ANALYSES REQUIRED	CONTAINER	FIELD PRESERVATION
050110 site D SWQ	5/1/10 8:40	50050	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 site D SWQ	5/2/10 8:40	50051	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none
050110 site F SWQ	5/3/10 9:07	50052	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 site F SWQ	5/4/10 9:07	50053	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none
050110 site S SWQ	5/5/10 9:35	50054	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 site S SWQ	5/6/10 9:35	50055	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none
050110 site B SWQ	5/7/10 10:15	50056	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 site B SWQ	5/8/10 10:15	50057	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none
050110 QC Dup	na	50058	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 QC Dup	na	50059	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none
050110 QC Blank	na	50060	WATER	Nitrate, Kjeldahl Nitrogen, Total Phosphorus	1 L Nalgene	none
050110 QC Blank	na	50061	WATER	Nitrite, Dissolved Phosphorus	1 L Nalgene	none

Relinquished by : ____________________________ Accepted by : ________________________________ Date : ____________ Time : ____________

Relinquished by : ____________________________ Accepted by : ________________________________ Date : ____________ Time : ____________

Relinquished by : ____________________________ Accepted by : ________________________________ Date : ____________ Time : ____________

Table A-3 Example of City of Omaha Missouri River Lab Chain of Custody

Chain of Custody--City of Omaha

Project Number / Identification: Papio Basin Stream Sampling

GRAB SAMPLE I.D.	TIME AND DATE SAMPLED	CITY TAG #	SAMPLE MATRIX	ANALYSES REQUIRED	CONTAINER	FIELD PRESERVATION
050110 site D SWQ	5/1/10 8:40	50025	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 site D SWQ	5/2/10 8:40	50026	WATER	TS, TSS	1L Nalgene	none
050110 site F SWQ	5/3/10 9:07	50027	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 site F SWQ	5/4/10 9:07	50028	WATER	TS, TSS	1L Nalgene	none
050110 site S SWQ	5/5/10 9:35	50029	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 site S SWQ	5/6/10 9:35	50030	WATER	TS, TSS	1L Nalgene	none
050110 site B SWQ	5/7/10 10:15	50031	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 site B SWQ	5/8/10 10:15	50032	WATER	TS, TSS	1L Nalgene	none
050110 QC Dup	na	50033	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 QC Dup	na	50034	WATER	TS, TSS	1L Nalgene	none
050110 QC Blank	na	50035	WATER	BOD, Ammonia-Nitrogen	1L Nalgene	none
050110 QC Blank	na	50036	WATER	TS, TSS	1L Nalgene	none

Relinquished by : ______________________ Accepted by : ______________________ Date : _________ Time : _________

Relinquished by : ______________________ Accepted by : ______________________ Date : _________ Time : _________

Relinquished by : ______________________ Accepted by : ______________________ Date : _________ Time : _________

NOTES :

Table A-4 Example of City of Omaha Escherichia coli Chain of Custody

Chain of Custody--City of Omaha

Project Number / Identification: Papio Basin Stream Sampling -- E. coli

GRAB SAMPLE I.D.	TIME AND DATE SAMPLED	CITY TAG #	SAMPLE MATRIX	ANALYSES REQUESTED	CONTAINER	FIELD PRESERVATION
050110 site D SWQ	5/1/10 8:40	50100	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate
050110 site F SWQ	5/3/10 9:07	50101	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate
050110 site S SWQ	5/5/10 9:35	501[illegible]	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate
050110 site B SWQ	5/7/10 10:15	50103	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate
050110 QC Dup	na	50104	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate
050110 QC Blank	na	50105	WATER	E. coli	120 mL plastic bottle	sodium thiosulfate

Relinquished by : ______________________________ Accepted by : ______________________________ Date : ________ Time : ________

Relinquished by : ______________________________ Accepted by : ______________________________ Date : ________ Time : ________

Relinquished by : ______________________________ Accepted by : ______________________________ Date : ________ Time : ________

NOTES :

A.2 City of Omaha Stream Sampling Procedures

Stream Sampling

Sampling Locations:
Site B: 168th & HWY 36 (Big Papio)
Site S: 78th & L Street (Big Papio)
Site F: 64th & L Street (Little Papio)
Site D: Capehart & Hwy 75 (Papillion Creek)

<u>Pre-Sampling Prep:</u>

- Go to Midwest Labs (136th & B St) – call ahead to make sure supplies ready [334-7770]:
    - collect cooler(s)
    - collect 12 Nalgene, 1L bottles
- Wash all bottles for next day:
    - 12 Nalgene bottles from Midwest Labs (MWL)
    - 12 Nalgene bottles from Environmental Quality Control Division (EQCD) Lab
- Gather 30 tags (and plenty of rubber bands)
    - Fill out known info
    - Record in log book
    - ✓ ***To save time in the field fill out tags and log book as much as possible before going out!***
    - ✓ ***Bring several pens that write well on the "water-proof" tags***
- Paperwork
    - Chain of Custody (CoCs) sheets (3)
    - Field Data Sheets (4)
    - ✓ ***Bring a clipboard for easier note-taking in the field***
- Equipment
    - Amphibian battery should be fully charged
    - Manta probe sensors should be inspected for last minute maintenance
    - Laptop should be fully charged
- Check that the Thermolyne I4300 incubator is at correct temperature [35°C ± 0.5] – adjust as needed

<u>Sampling Prep (Day of):</u>

- Refer to Supply Checklist for supplies needed
- Fill 2 – 1 gallon containers with deionized water (DI water)
- Organize all paperwork, tags, bottles, pens, rubber bands, and other supplies
- Calibrate Manta
    - Refer to Calibration Guide for procedures
    - turn off when finished to save battery
- Fill 1 small and 2 large coolers with ice – coolers should be labled for "MWL" and "EQCD"
- Review checklist again before leaving

Sampling Procedure - Overview:

- Wade to the deepest part of the stream and sample with the bottle opening away from the flow.
    - Each sample will need to be tagged and placed in a cooler with ice once you get back to vehicle.
- Take a duplicate set of samples at one site, varying the site week to week. The samples should be labeled as "duplicate" with no indication on tags or CoCs of which site was duplicated – do not put time on CoC and tags. Only field personnel's field notes should indicate which site was duplicated.
- At each site: take 4 readings with the Manta probe plus an additional 4 readings specifically for depth.
    - Transfer readings to **Field Data Sheets**.

  ✓ ***Tap Exit in the "PDA" pop-up menu to leave the Amphibian software; otherwise the Amphibian software will continue to run in the background and the Amphibian batteries will be consumed faster.***

- Complete the Field Data Sheet including the physical characteristic examination section before leaving the site.
- Download data from the ISCO 2150 Area Velocity Flow Meter.

Sampling Procedure (Continued) - Specifics:

- In a bucket, place 2 EQCD bottles, 2 MWL bottles, and 1 e-coli bottle (**NOTE**: if you are at the duplicate site, take twice as many bottles).
- Bring Field Data Sheet, Manta and Amphibian equipment, bucket with bottles, and any safety equipment to water's edge.

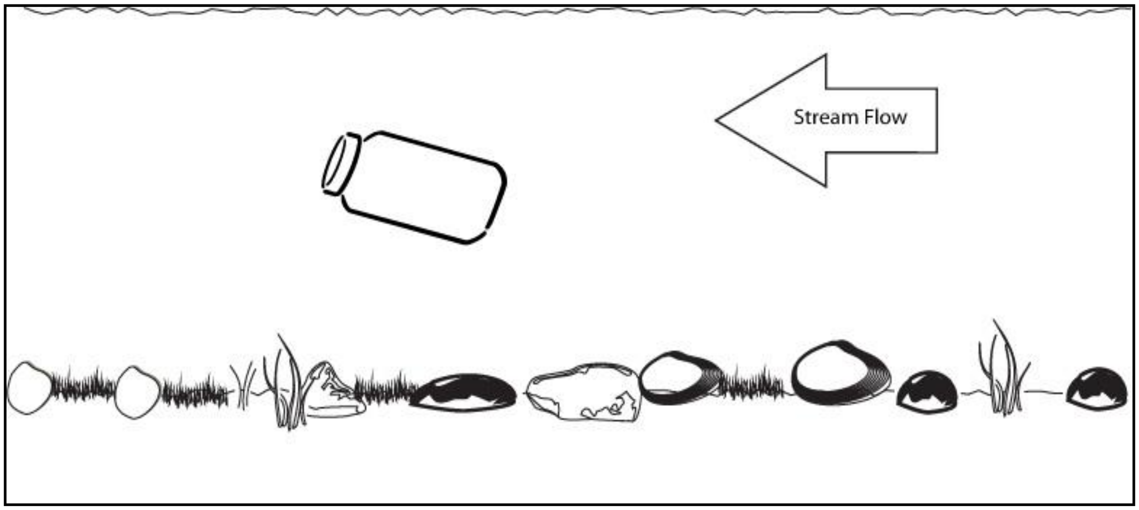
TIPS:

✓ **Keep the Manta upstream of you as you travel in the stream to minimize exposure of sensors to stirred sediment.**

✓ **While collecting samples or recording Manta snapshot data, minimize movement to avoid stirring up sediment.**

- While wearing appropriate safety equipment, wade into the deepest part of the creek; place the Manta probe in the water with the water guard in place to acclimate the sensors to the water conditions.
- "Rinse" the 1L bottles twice with the creek water. Place mouth of bottle facing downstream at about a 1/3 depth from the top of the water and fill the bottle almost to the top. See Figure below. (**NOTE:** Avoid placing fingers inside of the bottle when filling.) Due to the preservative in the e-coli bottles, they cannot be "rinsed" but need to be filled as full as possible to allow for dilutions when samples tested. (**NOTE:** These bottles are considered sterile – avoid touching the inside or mouth of the bottle to prevent contamination.)
    - Fill out the "In Situ" conditions of the Field Data sheet

   - Record time samples taken on sheet



- Near the same place as the samples were collected, hold the Manta probe at a depth of 1/3 to 1/2 from the water surface.
- Once numbers have stabilized, begin recording data on the Amphibian.
   - Refer to Snapshot Procedure
- After 4 snapshots have been saved, place the bottom of the Manta's weighted sensor guard on the bottom of streambed.
   - Allow numbers to stabilize, begin recording data on the Amphibian using the same procedures as above, annotating that the 4 additional readings are specifically for depth. The focus is to attain an accurate depth reading for comparison with the depth data from the ISCO 2150.
- Once all the samples and data snapshots have been taken, return to the vehicle to fill out remaining information on tags and attach tags to the corresponding bottle.
   - ✓ **To keep tags dry, leave in vehicle during sampling.**
- Place samples in appropriate cooler with ice.
- For duplicate: follow the same sampling procedure. (**NOTE:** water quality data needs to be taken only once)

   Reminder: do not put the time duplicate samples were collected on CoCs or tags.
- For field blank: fill 1 set of bottles with deionized water and place them in respective coolers with tags. (**NOTE:** try to disinfect your hands before you do this to avoid contamination.)
- Before leaving each site, download data from the ISCO 2150 Area Velocity Flow Meter, and any required maintenance (eg: changing batteries) is completed and annotated.

After All Sites Visited:

- Sampling personnel should check that all tags are complete and signed, and CoCs have also been signed before dropping off samples at labs.
- Drop off cooler at MWL; have MWL representative sign CoC and get a copy of the signed CoC to bring back with you.
- Return to plant with remaining 2 coolers and CoCs.
    - Bring large cooler up to lab - place bottles (with tags attached) on sample reception counter along with CoC.
    - Take remaining small cooler to the stream sampling field room – run e-coli tests on remaining samples. ***Reminder:*** e-coli samples need to be prepped and placed in incubator within 6 hours of being collected.
- Update the tag log book.
- Download Amphibian data to laptop.
- E-mail location of duplicate site to EQCD Lab Supervisor.
- Data Entry:
    - Enter data from Amphibian into **"Weekly Data" spreadsheet** – transfer the calculated averages to the **"Summary Analysis" spreadsheet**.
    - If not already done, get EQCD lab and MWL results for the previous week's sampling effort from the EQCD Lab Supervisor and record results in the **"Summary Analysis" spreadsheet**.
    - Update the **"Stream Meter Maintenance"** spreadsheet with field notes from ISCO 2150 data download.
- Manta equipment maintenance and cleaning:
    - Check for large debris caught amongst the sensors.
    - Clean sensors as described in the Manta Cleaning Guide.
    - Check for any damage of sensors.
    - Partially fill the cup with tap water and screw on cap.
    - ✓ **The Manta should be stored with basic tap water.**
- Charge equipment.

Follow Up:

- Read e-coli results 24-28 hours after test trays placed in incubator.
    - Record on bench sheet.
- Review ISCO monitoring data.

Appendix B. Water Quality Criteria and Recommendations for Selected Constituents for the State of Nebraska

			NDEQ Water Quality Standards					US EPA Proprosed Nutrient Criteria	
				Aquatic Life			Water Supply		
Constituent	Conditions	CAS Number	Recreation	General Criteria	Acute Toxicity	Chronic Toxicity	Agriculture	Aggregated Corn Belt and Northern Great Plains Nutrient Ecoregion	Western Cornbelt Plains Ecoregion
Water Properties and major ions									
Dissolved Oxygen	Class A warmwater stream (early life stages)				≥ 5 mg/L	≥ 6 mg/L			
Dissolved Oxygen	Class A warmwater stream (all life stages)				≥ 3 mg/L	≥ 4 mg/L			
Dissolved Oxygen	Class B warmwater stream (early life stages)				≥ 5 mg/L	≥ 6 mg/L			
Dissolved Oxygen	Class B warmwater stream (all life stages)				≥ 3 mg/L	≥ 4 mg/L			
E coli Bacteria			≤ 126 cfu/100 mL						
pH				6.5 to 9.0					
Specific Conductance							≤ 2000 µS/cm		
Water Temperature				Change ≤ 3^{0}C					

			NDEQ Water Quality Standards					US EPA Proprosed Nutrient Criteria	
				Aquatic Life			Water Supply		
Constituent	Conditions	CAS Number	Recreation	General Criteria	Acute Toxicity	Chronic Toxicity	Agriculture	Aggregated Corn Belt and Northern Great Plains Nutrient Ecoregion	Western Cornbelt Plains Ecoregion
Nutrients									
Nitrite plus Nitrate, as nitrogen							≤ 100 mg/L		
Ammonia, as nitrogen	Class A warmwater stream	7664417			a				
Ammonia, as nitrogen	Class B warmwater stream	7664417			a				
Total Nitrogen								≤ 2.2 mg/L	≤ 2.615 mg/L
Total Phosphorus		7723140						≤ 0.076 mg/L	≤ 0.118 mg/L

[a] Ammonia criteria is dependent upon pH.

Appendix C. 2010 Papillion Creek Monitoring Sampling Data

Table C-1 2010 Papillion Creek Monitoring Sampling Data

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (mg/L as N)	Biochemical Oxygen Demand (mg/L)	Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)	Escherichia Coli (cfu/100 mL)	Fecal Coliforms (cfu/100 mL)
Site B	3/10/2010	11:40	200	< 1.00	5.0	0.17		920.8	4,352.0
Site B	4/14/2010	10:55	48	< 1.00	< 2.0	0.07		122.3	1,391.0
Site B	5/12/2010	10:50	60	< 1.00	3.0	0.14		2,481.0	12,997.0
Site B	5/19/2010	10:20	44	< 1.00	< 2.0	0.17		579.4	4,352.0
Site B	5/26/2010	11:27	40	< 1.00	< 2.0	0.19		920.8	8,664.0
Site B	6/2/2010	10:50	120	< 1.00	8.0	0.21		2,419.6	> 24,196.0
Site B	6/9/2010	10:15	174	< 1.00	2.0	0.22		2,419.6	> 24,196.0
Site B	6/16/2010	10:30	182	< 1.00	< 2.0	0.20		1,553.1	> 24,196.0
Site B	6/23/2010	10:16	347	< 1.00	6.0	0.17		1,732.9	> 24,196.0
Site B	6/30/2010	9:40	87	< 1.00	< 2.0	0.16		727.0	1,299.7
Site B	7/7/2010	10:10	89	< 1.00	< 2.0	0.18		1,413.6	2,419.6
Site B	7/14/2010	9:30	115	< 1.00	< 2.0	0.20		2,419.6	> 24,196.0
Site B	7/21/2010	9:25	133	< 1.00	3.0	0.26		2,419.6	> 24,196.0
Site B	7/28/2010	9:55	62	< 1.00	< 2.0	0.18	8.61	2,419.6	> 24,196.0
Site B	8/4/2010	9:30	83	< 1.00	< 2.0	0.19	8.71	1,986.3	> 24,196.0
Site B	8/11/2010	9:10	49	1.40	< 2.0	0.20	8.58	1,553.1	> 24,196.0
Site B	8/18/2010	9:20	48	< 1.00	< 2.0	0.19		1,732.9	> 24,196.0
Site B	9/17/2010	9:43	30	< 1.00	< 2.0	0.15	10.20	613.1	> 24,196.0
Site B	10/8/2010	9:25	26	< 1.00	< 2.0	0.14	10.76	1,046.2	24,196.0
Site B	11/12/2010	11:20	44	< 1.00	7.0	0.14	12.57	2,909.0	> 24,196.0
Site B	12/17/2010	10:20	26	< 1.00	2.0	0.12		172.3	14,136.0

Site Name	Date	Time (CT)	Nitrite (mg/L as N)	Nitrite + Nitrate (mg/L as N)	pH (field)	pH (lab)	Specific Conductance (µS/cm)	Temperature (°C)	Total Dissolved Solids (mg/L)
Site B	3/10/2010	11:40	0.04	7.0	7.89	7.62	578.30	3.08	346
Site B	4/14/2010	10:55	0.07	8.3	8.12	7.87	670.10	13.62	447
Site B	5/12/2010	10:50	0.06	8.1	8.08	7.83	663.48	9.36	517
Site B	5/19/2010	10:20	0.09	8.3		7.83	692.58	13.39	446
Site B	5/26/2010	11:27	0.12	9.4		7.93			533
Site B	6/2/2010	10:50	0.14	10.3	7.89	7.52	544.75	15.73	580
Site B	6/9/2010	10:15	0.06	9.7	8.02	7.58	677.83	14.26	481
Site B	6/16/2010	10:30	0.05	10.2	8.00	7.69	689.93	15.35	586
Site B	6/23/2010	10:16	0.06	5.3	7.87	7.57	544.75	15.73	587
Site B	6/30/2010	9:40	0.07	11.8	8.00	7.74	682.03	17.00	465
Site B	7/7/2010	10:10	0.10	9.5	7.85	7.86	687.03	19.05	485
Site B	7/14/2010	9:30	0.10	9.6		7.81			424
Site B	7/21/2010	9:25	0.12	9.1	7.87	7.86	633.85	19.09	455
Site B	7/28/2010	9:55	0.07	9.9	8.09	7.85	698.19	26.43	469
Site B	8/4/2010	9:30	0.06	8.8	7.97	7.82	596.73	21.45	503
Site B	8/11/2010	9:10	0.04	5.2	8.22	7.97	701.80	21.99	469
Site B	8/18/2010	9:20	0.07	9.2		7.91			500
Site B	9/17/2010	9:43	0.04	8.5	8.32	7.92	707.00	15.31	493
Site B	10/8/2010	9:25	0.03	8.3	8.32	7.93	711.10	12.25	521
Site B	11/12/2010	11:20	0.04	7.2	8.52	7.80	671.70	6.06	445
Site B	12/17/2010	10:20	0.02	7.5		7.87			466

Site Name	Date	Time (CT)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
Site B	3/10/2010	11:40	2.67	9.67	1.28	1,218	872	
Site B	4/14/2010	10:55	< 0.50	< 8.80	0.16	493	46	41
Site B	5/12/2010	10:50	0.72	8.82	0.42	715	198	200
Site B	5/19/2010	10:20	< 0.50	< 8.80	0.36	592	146	47
Site B	5/26/2010	11:27	< 0.50	< 9.90	0.36	653	120	
Site B	6/2/2010	10:50	6.03	16.33	1.86	1,650	1,070	1,033
Site B	6/9/2010	10:15	1.75	11.45	1.10	1,399	918	409
Site B	6/16/2010	10:30	0.69	10.89	0.75	936	350	207
Site B	6/23/2010	10:16	4.62	9.92	1.90	1,852	1,265	1,033
Site B	6/30/2010	9:40	0.89	12.69	0.41	706	241	141
Site B	7/7/2010	10:10	0.62	10.12	0.43	702	217	123
Site B	7/14/2010	9:30	0.73	10.33	0.82	935	511	
Site B	7/21/2010	9:25	1.22	10.32	0.73	809	354	207
Site B	7/28/2010	9:55	0.62	10.52	0.41	728	259	131
Site B	8/4/2010	9:30	1.23	10.03	0.79	922	419	359
Site B	8/11/2010	9:10	0.61	5.81	0.25	507	38	141
Site B	8/18/2010	9:20	0.61	9.81	0.40	662	162	
Site B	9/17/2010	9:43	< 0.50	< 9.00	0.32	628	135	108
Site B	10/8/2010	9:25	< 0.50	< 8.80	0.25	633	112	135
Site B	11/12/2010	11:20	1.12	8.32	0.64	942	497	305
Site B	12/17/2010	10:20	< 0.50	< 8.00	0.20	544	78	

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (mg/L as N)	Biochemical Oxygen Demand (mg/L)	Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)	Escherichia Coli (cfu/100 mL)	Fecal Coliforms (cfu/100 mL)
Site S	3/10/2010	10:35	427	< 1.00	6.0	0.15		816.4	> 24,196.0
Site S	4/14/2010	9:55	97	< 1.00	< 2.0	0.07		133.3	2,035.0
Site S	5/12/2010	9:45	127	< 1.00	8.0	0.09		1,732.9	> 24,196.0
Site S	5/19/2010	9:20	92	< 1.00	< 2.0	0.15		344.8	24,196.0
Site S	5/26/2010	10:48	82	< 1.00	< 2.0	0.19		816.4	> 24,196.0
Site S	6/2/2010	10:18	263	< 1.00	8.0	0.13		2,419.6	> 24,196.0
Site S	6/9/2010	9:15	362	< 1.00	4.0	0.16		1,986.3	> 24,196.0
Site S	6/16/2010	9:30	373	< 1.00	< 2.0	0.17		1,553.1	> 24,196.0
Site S	6/23/2010	9:12	780	< 1.00	5.0	0.13		1,413.6	> 24,196.0
Site S	6/30/2010	8:55	177	< 1.00	< 2.0	0.16		1,203.3	> 24,196.0
Site S	7/7/2010	9:10	182	< 1.00	< 2.0	0.16		15,531.0	> 24,196.0
Site S	7/14/2010	8:40	236	2.90	2.0	0.16		12,997.0	> 24,196.0
Site S	7/21/2010	8:35	192	< 1.00	4.0	0.16		1,413.6	> 24,196.0
Site S	7/28/2010	9:00	127	< 1.00	2.0	0.17	8.30	2,419.6	> 24,196.0
Site S	8/4/2010	8:35	174	< 1.00	4.0	0.17	8.05	2,419.6	> 24,196.0
Site S	8/11/2010	8:35	174	2.40	< 2.0	0.21	8.15	1,413.6	> 24,196.0
Site S	8/18/2010	8:40	97	< 1.00	< 2.0	0.16		1,732.9	> 24,196.0
Site S	9/17/2010	8:50	62	< 1.00	2.0	0.14	9.70	1,986.3	> 24,196.0
Site S	10/8/2010	8:40	53	< 1.00	< 2.0	0.13	10.35	613.1	> 24,196.0
Site S	11/12/2010	10:20	90	< 1.00	14.0	0.18	12.82	2,419.6	> 24,196.0
Site S	12/17/2010	9:30	53	< 1.00	2.0	0.10		172.5	17,329.0

Site Name	Date	Time (CT)	Nitrite (mg/L as N)	Nitrite + Nitrate (mg/L as N)	pH (field)	pH (lab)	Specific Conductance (µS/cm)	Temperature (°C)	Total Dissolved Solids (mg/L)
Site S	3/10/2010	10:35	0.04	4.6	7.89	7.63	557.48	2.74	304
Site S	4/14/2010	9:55	0.05	6.6	8.23	8.01	682.50	15.35	487
Site S	5/12/2010	9:45	0.04	2.3	8.00	7.71	395.40	10.25	248
Site S	5/19/2010	9:20	0.08	6.6		7.89	734.11	15.00	471
Site S	5/26/2010	10:48	0.12	7.7		7.95			496
Site S	6/2/2010	10:18	0.11	10.0	7.36	7.29	366.32	17.17	646
Site S	6/9/2010	9:15	0.06	6.3	7.85	7.62	601.48	18.75	468
Site S	6/16/2010	9:30	0.05	7.6	7.94	7.84	634.41	18.56	553
Site S	6/23/2010	9:12	0.04	1.7	7.37	7.63	366.25	17.17	348
Site S	6/30/2010	8:55	0.07	9.9	8.00	7.92	703.83	18.82	468
Site S	7/7/2010	9:10	0.09	6.9	7.89	7.90	676.58	21.00	511
Site S	7/14/2010	8:40	0.07	6.7		7.93			447
Site S	7/21/2010	8:35	0.09	5.0	7.74	7.83	497.65	21.94	395
Site S	7/28/2010	9:00	0.06	8.0	8.14	8.00	718.11	26.42	504
Site S	8/4/2010	8:35	0.07	6.1	7.73	7.81	593.71	23.28	452
Site S	8/11/2010	8:35	0.07	7.5	8.22	8.01	722.90	24.24	466
Site S	8/18/2010	8:40	0.05	6.9		7.94			459
Site S	9/17/2010	8:50	0.03	6.2	8.19	7.99	710.20	10.09	510
Site S	10/8/2010	8:40	0.03	6.8	8.17	8.00	754.10	13.15	528
Site S	11/12/2010	10:20	0.02	1.5	7.90	7.62	317.40	5.66	222
Site S	12/17/2010	9:30	0.02	6.2		7.91			705

Site Name	Date	Time (CT)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
Site S	3/10/2010	10:35	4.39	8.99	1.67	1,538	1,234	
Site S	4/14/2010	9:55	0.54	7.14	0.12	507	20	18
Site S	5/12/2010	9:45	1.45	3.75	0.62	540	292	371
Site S	5/19/2010	9:20	< 0.50	< 7.10	0.28	535	64	31
Site S	5/26/2010	10:48	< 0.50	< 8.20	0.31	592	96	
Site S	6/2/2010	10:18	9.48	19.48	2.53	2,646	2,000	2,529
Site S	6/9/2010	9:15	2.86	9.16	1.50	2,162	1,694	913
Site S	6/16/2010	9:30	0.77	8.37	0.79	1,088	535	341
Site S	6/23/2010	9:12	2.15	3.85	0.92	803	455	2,507
Site S	6/30/2010	8:55	0.88	10.78	0.41	692	224	134
Site S	7/7/2010	9:10	0.84	7.74	0.43	667	156	136
Site S	7/14/2010	8:40	1.76	8.46	0.78	907	460	
Site S	7/21/2010	8:35	2.03	7.03	0.93	1,065	670	440
Site S	7/28/2010	9:00	0.67	8.67	0.40	700	196	138
Site S	8/4/2010	8:35	1.97	8.07	1.20	1,017	565	607
Site S	8/11/2010	8:35	0.83	8.33	0.40	647	181	138
Site S	8/18/2010	8:40	0.64	7.54	0.34	615	156	
Site S	9/17/2010	8:50	0.63	6.83	0.28	572	62	84
Site S	10/8/2010	8:40	< 0.50	< 7.30	0.23	582	54	73
Site S	11/12/2010	10:20	1.96	3.46	0.63	606	384	266
Site S	12/17/2010	9:30	< 0.50	< 6.70	0.18	741	36	

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (mg/L as N)	Biochemical Oxygen Demand (mg/L)	Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)	Escherichia Coli (cfu/100 mL)	Fecal Coliforms (cfu/100 mL)
Site F	3/10/2010	9:40	10	< 1.00	4.0	0.08		3,654.0	19,863.0
Site F	4/14/2010	9:05	16	< 1.00	2.0	< 0.05		201.4	3,968.0
Site F	5/12/2010	8:50	221	< 1.00	10.0	0.06		11,199.0	> 24,196.0
Site F	5/19/2010	8:50	23	< 1.00	< 2.0	0.07		387.3	17,329.0
Site F	5/26/2010	10:24	14	< 1.00	< 2.0	0.07		222.4	12,997.0
Site F	6/2/2010	9:35	40	1.00	9.0	0.12		1,119.9	> 24,196.0
Site F	6/9/2010	8:40	135	< 1.00	3.0	0.09		1,413.6	24,196.0
Site F	6/16/2010	8:50	77	< 1.00	3.0	0.07		1,986.3	> 24,196.0
Site F	6/23/2010	8:42	829	< 1.00	7.0	0.11		1,986.3	> 24,196.0
Site F	6/30/2010	8:25	82	< 1.00	< 2.0	0.06		435.2	19,863.0
Site F	7/7/2010	8:45	54	< 1.00	< 2.0	0.08		1,553.1	> 24,196.0
Site F	7/14/2010	8:10	7	< 1.00	< 2.0	0.10		1,119.9	2,419.6
Site F	7/21/2010	8:10	59	< 1.00	4.0	0.08		1,986.3	> 24,196.0
Site F	7/28/2010	8:35	50	< 1.00	4.0	0.06	7.86	224.7	> 24,196.0
Site F	8/4/2010	8:10	95	< 1.00	5.0	0.10	7.03	> 24,196.0	> 24,196.0
Site F	8/11/2010	8:15	42	< 1.00	2.0	0.10	7.45	517.2	24,196.0
Site F	8/18/2010	8:17	63	< 1.00	2.0	0.10		1,986.3	> 24,196.0
Site F	9/17/2010	8:30	30	< 1.00	2.0	0.08	8.78	1,119.9	> 24,196.0
Site F	10/8/2010	8:25	24	< 1.00	< 2.0	< 0.05	9.42	1,413.6	> 24,196.0
Site F	11/12/2010	9:58	319	1.40	18.0	0.19	12.59	12,303.0	> 24,196.0
Site F	12/17/2010	9:05	19	< 1.00	4.0	< 0.05		488.4	19,863.0

Site Name	Date	Time (CT)	Nitrite (mg/L as N)	Nitrite + Nitrate (mg/L as N)	pH (field)	pH (lab)	Specific Conductance (µS/cm)	Temperature (°C)	Total Dissolved Solids (mg/L)
Site F	3/10/2010	9:40	0.04	2.0	7.89	7.69	832.45	4.48	514
Site F	4/14/2010	9:05	0.04	1.8	8.04	7.74	764.40	14.97	504
Site F	5/12/2010	8:50	0.04	1.0	7.85	7.62	423.86	10.60	308
Site F	5/19/2010	8:50	0.06	1.6		7.69	790.21	15.48	497
Site F	5/26/2010	10:24	0.09	1.7		7.80			531
Site F	6/2/2010	9:35	0.11	6.2	7.38	7.36	409.94	17.82	571
Site F	6/9/2010	8:40	0.06	1.4	7.87	7.70	569.38	20.51	373
Site F	6/16/2010	8:50	0.07	1.7	7.97	7.86	598.23	21.57	380
Site F	6/23/2010	8:42	0.02	0.5	7.37	7.68	409.68	17.86	225
Site F	6/30/2010	8:25	0.04	2.2	7.80	7.83	647.65	21.36	405
Site F	7/7/2010	8:45	0.04	1.9	7.77	7.87	696.84	23.71	429
Site F	7/14/2010	8:10	0.06	2.0		7.86			412
Site F	7/21/2010	8:10	0.04	1.2	7.68	7.82	523.15	24.30	307
Site F	7/28/2010	8:35	0.03	1.8	7.98	7.85	700.68	26.43	458
Site F	8/4/2010	8:10	0.04	1.1	7.44	7.47	369.90	26.19	249
Site F	8/11/2010	8:15	0.02	1.6	8.01	7.83	713.38	25.64	438
Site F	8/18/2010	8:17	0.02	1.2		7.54			298
Site F	9/17/2010	8:30	0.03	1.6	7.72	7.61	657.90	16.52	420
Site F	10/8/2010	8:25	0.03	1.6	7.81	7.73	786.80	13.96	560
Site F	11/12/2010	9:58	0.02	0.7	8.09	7.59	237.90	5.31	185
Site F	12/17/2010	9:05	0.03	2.3		7.73			1,719

Site Name	Date	Time (CT)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
Site F	3/10/2010	9:40	1.15	3.15	0.30	653	139	
Site F	4/14/2010	9:05	0.68	2.48	0.08	508	4	5
Site F	5/12/2010	8:50	1.87	2.87	0.54	684	376	309
Site F	5/19/2010	8:50	0.66	2.26	0.10	499	2	76
Site F	5/26/2010	10:24	< 0.50	< 2.20	0.12	533	2	
Site F	6/2/2010	9:35	9.72	15.92	2.39	2,171	1,600	2,363
Site F	6/9/2010	8:40	1.52	2.92	0.38	587	214	134
Site F	6/16/2010	8:50	1.24	2.94	0.25	491	111	79
Site F	6/23/2010	8:42	3.79	4.29	0.67	635	410	2,384
Site F	6/30/2010	8:25	0.60	2.80	0.11	428	23	20
Site F	7/7/2010	8:45	< 0.50	< 2.40	0.15	455	26	23
Site F	7/14/2010	8:10	0.66	2.66	0.20	482	70	
Site F	7/21/2010	8:10	1.12	2.32	0.28	411	104	81
Site F	7/28/2010	8:35	0.89	2.69	0.17	482	24	24
Site F	8/4/2010	8:10	1.07	2.17	0.23	303	54	72
Site F	8/11/2010	8:15	1.03	2.63	0.20	472	34	26
Site F	8/18/2010	8:17	0.60	1.80	0.18	334	36	
Site F	9/17/2010	8:30	0.63	2.23	0.14	437	17	18
Site F	10/8/2010	8:25	< 0.50	< 2.10	< 0.05	564	4	6
Site F	11/12/2010	9:58	1.63	2.33	0.66	504	319	267
Site F	12/17/2010	9:05	0.63	2.93	0.07	1,724	5	

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (mg/L as N)	Biochemical Oxygen Demand (mg/L)	Dissolved Phosphorus (mg/L)	Dissolved Oxygen (mg/L)	Escherichia Coli (cfu/100 mL)	Fecal Coliforms (cfu/100 mL)
Site D	3/10/2010	8:12	432	< 1.00	6.0	0.12		1,616.0	12,997.0
Site D	4/14/2010	8:13	160	< 1.00	< 2.0	0.06		104.3	2,419.6
Site D	5/12/2010	8:00	481	< 1.00	6.0	0.09		2,419.6	> 24,196.0
Site D	5/19/2010	8:05	149	< 1.00	< 2.0	0.14		435.2	2,419.6
Site D	5/26/2010	8:35	122	< 1.00	< 2.0	0.17	5.86	816.4	24,196.0
Site D	6/2/2010	8:07	1,100	1.10	8.0	0.11		1,732.9	> 24,196.0
Site D	6/9/2010	8:00	445	< 1.00	4.0	0.14		1,986.3	> 24,196.0
Site D	6/16/2010	7:45	835	< 1.00	< 2.0	0.15		1,732.9	> 24,196.0
Site D	6/23/2010	7:40	870	< 1.00	8.0	0.10		> 24,196.0	> 24,196.0
Site D	6/30/2010	7:45	290	< 1.00	< 2.0	0.13		613.1	> 24,196.0
Site D	7/7/2010	8:00	110	< 1.00	< 2.0	0.14		2,419.6	> 24,196.0
Site D	7/14/2010	7:00	495	< 1.00	2.0	0.15		1,046.2	1,553.1
Site D	7/21/2010	7:25	822	< 1.00	5.0	0.13		24,196.0	> 24,196.0
Site D	7/28/2010	7:45	440	< 1.00	3.0	0.17	7.78	1,553.1	> 24,196.0
Site D	8/4/2010	7:35	910	< 1.00	4.0	0.13	6.20	2,419.6	> 24,196.0
Site D	8/11/2010	7:25	770	1.20	< 2.0	0.20	7.85	1,119.9	> 24,196.0
Site D	8/18/2010	7:40	476	< 1.00	2.0	0.14		1,553.1	> 24,196.0
Site D	9/17/2010	7:50	147	< 1.00	2.0	0.15	9.36	1,553.1	> 24,196.0
Site D	10/8/2010	7:45	220	< 1.00	< 2.0	0.11	10.11	162.4	11,199.0
Site D	11/12/2010	9:15	2,200	< 1.00	18.0	0.20	12.75	2,419.6	> 24,196.0
Site D	12/17/2010	8:20	178	< 1.00	3.0	< 0.05		272.3	17,329.0

Site Name	Date	Time (CT)	Nitrite (mg/L as N)	Nitrite + Nitrate (mg/L as N)	pH (field)	pH (lab)	Specific Conductance (µS/cm)	Temperature (°C)	Total Dissolved Solids (mg/L)
Site D	3/10/2010	8:12	0.03	3.1	7.87	7.58	594.33	3.57	272
Site D	4/14/2010	8:13	0.05	3.7	8.09	7.88	737.70	15.18	536
Site D	5/12/2010	8:00	0.03	2.5	7.87	7.71	595.98	10.96	362
Site D	5/19/2010	8:05	0.05	4.2		7.84	718.64	15.44	468
Site D	5/26/2010	8:35	0.08	4.3	8.36	7.85	563.85		517
Site D	6/2/2010	8:07	0.10	9.3		7.24			743
Site D	6/9/2010	8:00	0.05	3.5	7.56	7.49	510.75	19.54	357
Site D	6/16/2010	7:45	0.05	4.9	7.81	7.75	653.11	19.54	448
Site D	6/23/2010	7:40	0.04	1.3	7.23	7.50	270.00	22.88	884
Site D	6/30/2010	7:45	0.04	5.7	7.81	7.82	678.18	21.60	427
Site D	7/7/2010	8:00	0.04	4.0	7.71	7.84	645.94	22.56	392
Site D	7/14/2010	7:00	0.04	4.2		7.84			413
Site D	7/21/2010	7:25	0.07	2.4	7.40	7.63	443.44	23.21	291
Site D	7/28/2010	7:45	0.05	5.3	7.77	7.89	716.73	26.43	489
Site D	8/4/2010	7:35	0.05	2.3	7.56	7.52	430.90	25.88	260
Site D	8/11/2010	7:25	0.06	9.3	8.17	7.91	658.88	26.41	423
Site D	8/18/2010	7:40	0.02	2.7		7.60			294
Site D	9/17/2010	7:50	0.03	3.5	7.89	7.81	629.10	16.84	407
Site D	10/8/2010	7:45	0.02	4.0	8.22	7.99	756.60	14.33	507
Site D	11/12/2010	9:15	< 0.02	0.7	7.83	7.61	202.10	5.84	50
Site D	12/17/2010	8:20	< 0.02	2.8		7.80			1,091

Site Name	Date	Time (CT)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
Site D	3/10/2010	8:12	3.31	6.41	1.33	1,254	982	
Site D	4/14/2010	8:13	0.59	4.29	0.15	570	34	34
Site D	5/12/2010	8:00	0.99	3.49	0.40	532	170	193
Site D	5/19/2010	8:05	< 0.50	< 4.70	0.25	518	50	20
Site D	5/26/2010	8:35	< 0.50	< 4.80	0.27	587	70	49
Site D	6/2/2010	8:07	19.50	28.80	5.05	3,573	2,830	
Site D	6/9/2010	8:00	2.39	5.89	1.20	1,712	1,355	823
Site D	6/16/2010	7:45	0.84	5.74	0.39	588	140	119
Site D	6/23/2010	7:40	2.92	4.22	3.40	2,704	1,820	2,180
Site D	6/30/2010	7:45	0.60	6.30	0.23	469	42	42
Site D	7/7/2010	8:00	1.44	5.44	0.33	530	138	99
Site D	7/14/2010	7:00	1.16	5.36	0.58	752	339	
Site D	7/21/2010	7:25	2.34	4.74	0.80	788	497	401
Site D	7/28/2010	7:45	0.60	5.90	0.32	581	92	51
Site D	8/4/2010	7:35	1.73	4.03	0.59	424	164	363
Site D	8/11/2010	7:25	0.58	9.88	0.41	656	233	47
Site D	8/18/2010	7:40	0.93	3.63	0.34	434	140	
Site D	9/17/2010	7:50	1.02	4.52	0.29	502	95	88
Site D	10/8/2010	7:45	< 0.50	< 4.50	0.17	537	30	37
Site D	11/12/2010	9:15	2.21	2.91	1.27	1,328	1,278	695
Site D	12/17/2010	8:20	0.69	3.49	0.12	1,130	39	

Appendix D. 2010 Calculated Instantaneous Mass Loadings

Table D-1 2010 Calculated Instantaneous Mass Loadings

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (g/s as N)	Biochemical Oxygen Demand (g/s)	Dissolved Phosphorus (g/s)	Escherichia Coli (cfu/s)	Fecal Coliforms (cfu/s)	Nitrite (g/s as N)
Site B	3/10/2010	11:40	200	< 2.83	28.32	0.96	52,148,219	246,469,427	0.23
Site B	4/14/2010	10:55	48	< 0.68	< 1.36	0.10	1,662,309	18,906,561	0.10
Site B	5/12/2010	10:50	60	< 0.85	5.10	0.24	42,152,388	220,820,070	0.10
Site B	5/19/2010	10:20	44	< 0.62	< 1.25	0.21	7,218,972	54,223,274	0.11
Site B	5/26/2010	11:27	40	< 0.57	< 1.13	0.22	10,429,644	98,134,702	0.14
Site B	6/2/2010	10:50	120	< 1.70	27.18	0.71	82,218,395	> 822,183,951	0.48
Site B	6/9/2010	10:15	174	< 2.46	9.85	1.08	119,216,673	> 1,192,166,729	0.30
Site B	6/16/2010	10:30	182	< 2.58	< 5.15	1.03	80,041,456	> 1,246,978,993	0.26
Site B	6/23/2010	10:16	347	< 4.91	58.96	1.67	170,273,534	> 2,377,481,926	0.59
Site B	6/30/2010	9:40	87	< 1.23	< 2.46	0.39	17,910,093	32,018,910	0.17
Site B	7/7/2010	10:10	89	< 1.26	< 2.52	0.45	35,625,479	60,978,643	0.25
Site B	7/14/2010	9:30	115	1.63	3.26	0.65	78,792,629	787,926,287	0.33
Site B	7/21/2010	9:25	133	1.88	11.30	0.98	91,125,388	911,253,879	0.45
Site B	7/28/2010	9:55	62	0.88	1.76	0.32	42,479,504	424,795,042	0.12
Site B	8/4/2010	9:30	83	1.18	2.35	0.45	46,683,898	568,677,233	0.14
Site B	8/11/2010	9:10	49	1.94	1.39	0.28	21,549,623	335,725,113	0.06
Site B	8/18/2010	9:20	48	0.68	1.36	0.26	23,553,688	328,873,581	0.10
Site B	9/17/2010	9:43	30	0.42	0.85	0.13	5,208,309	205,545,988	0.03
Site B	10/8/2010	9:25	26	< 0.37	< 0.74	0.10	7,702,509	178,139,856	0.02
Site B	11/12/2010	11:20	44	< 0.62	8.72	0.17	36,244,371	> 301,467,449	0.05
Site B	12/17/2010	10:20	26	0.37	1.47	0.09	1,268,536	104,074,434	0.01

Site Name	Date	Time (CT)	Nitrite + Nitrate (g/s as N)	Total Dissolved Solids (g/s)	Total Kjeldahl Nitrogen (g/s as N)	Total Nitrogen (g/s)	Total Phosphorus (g/s)	Total Solids (g/s)	Total Suspended Solids (g/s)
Site B	3/10/2010	11:40	39.64	1,960	15.12	54.77	7.25	6,898	4,938
Site B	4/14/2010	10:55	11.28	608	< 0.34	11.62	0.22	670	63
Site B	5/12/2010	10:50	13.76	878	1.22	14.99	0.71	1,215	336
Site B	5/19/2010	10:20	10.34	556	< 0.31	10.65	0.45	738	182
Site B	5/26/2010	11:27	10.65	604	< 0.28	10.93	0.41	740	136
Site B	6/2/2010	10:50	35.00	1,971	20.49	55.49	6.32	5,607	3,636
Site B	6/9/2010	10:15	47.79	2,370	8.62	56.42	5.42	6,893	4,523
Site B	6/16/2010	10:30	52.57	3,020	3.56	56.12	3.87	4,824	1,804
Site B	6/23/2010	10:16	52.08	5,768	45.40	97.47	18.67	18,198	12,430
Site B	6/30/2010	9:40	29.07	1,146	2.19	31.26	1.01	1,739	594
Site B	7/7/2010	10:10	23.94	1,222	1.56	25.50	1.08	1,769	547
Site B	7/14/2010	9:30	31.26	1,381	2.38	33.64	2.67	3,045	1,664
Site B	7/21/2010	9:25	34.27	1,714	4.59	38.87	2.75	3,047	1,333
Site B	7/28/2010	9:55	17.38	823	1.09	18.47	0.72	1,278	455
Site B	8/4/2010	9:30	20.68	1,182	2.89	23.57	1.86	2,167	985
Site B	8/11/2010	9:10	7.22	651	0.85	8.06	0.35	703	53
Site B	8/18/2010	9:20	12.50	680	0.83	13.33	0.54	900	220
Site B	9/17/2010	9:43	7.22	419	0.21	7.43	0.27	533	115
Site B	10/8/2010	9:25	6.11	384	< 0.18	6.29	0.18	466	82
Site B	11/12/2010	11:20	8.97	554	1.40	10.37	0.80	1,174	619
Site B	12/17/2010	10:20	5.52	343	0.18	5.71	0.15	401	57

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (g/s as N)	Biochemical Oxygen Demand (g/s)	Dissolved Phosphorus (g/s)	Escherichia Coli (cfu/s)	Fecal Coliforms (cfu/s)	Nitrite (g/s as N)
Site S	3/10/2010	10:35	427	< 6.05	72.55	1.81	98,713,158	> 2,925,604,560	0.48
Site S	4/14/2010	9:55	97	< 1.37	< 2.75	0.19	3,661,391	55,895,947	0.14
Site S	5/12/2010	9:45	127	< 1.80	28.77	0.32	62,319,132	> 870,144,682	0.14
Site S	5/19/2010	9:20	92	< 1.30	< 2.61	0.39	8,982,542	630,341,029	0.21
Site S	5/26/2010	10:48	82	< 1.16	< 2.32	0.44	18,956,625	> 561,825,700	0.28
Site S	6/2/2010	10:18	263	< 3.72	59.58	0.97	180,195,316	> 1,801,953,160	0.82
Site S	6/9/2010	9:15	362	< 5.13	41.00	1.64	203,609,289	> 2,480,254,920	0.62
Site S	6/16/2010	9:30	373	5.28	10.56	1.80	164,041,006	2,555,621,782	0.53
Site S	6/23/2010	9:12	780	< 11.04	110.44	2.87	312,223,302	> 5,344,195,684	0.88
Site S	6/30/2010	8:55	177	< 2.51	< 5.01	0.80	60,310,282	> 1,212,721,328	0.35
Site S	7/7/2010	9:10	182	< 2.58	< 5.15	0.82	800,414,562	> 1,246,978,993	0.46
Site S	7/14/2010	8:40	236	19.38	13.37	1.07	868,558,941	1,616,961,771	0.47
Site S	7/21/2010	8:35	192	2.72	21.75	0.87	76,854,967	1,315,494,322	0.49
Site S	7/28/2010	9:00	127	1.80	7.19	0.61	87,014,468	870,144,682	0.22
Site S	8/4/2010	8:35	174	2.46	19.71	0.84	119,216,673	1,192,166,729	0.34
Site S	8/11/2010	8:35	174	11.83	4.93	1.03	69,649,814	1,192,166,729	0.34
Site S	8/18/2010	8:40	97	1.37	2.75	0.44	47,598,077	664,598,694	0.14
Site S	9/17/2010	8:50	62	0.88	3.51	0.25	34,872,309	424,795,042	0.05
Site S	10/8/2010	8:40	53	< 0.75	< 1.50	0.20	9,201,346	> 363,131,245	0.05
Site S	11/12/2010	10:20	90	< 1.27	35.68	0.46	61,663,796	> 616,637,964	0.05
Site S	12/17/2010	9:30	53	< 0.75	3.00	0.15	2,588,863	260,071,968	0.03

Site Name	Date	Time (CT)	Nitrite + Nitrate (g/s as N)	Total Dissolved Solids (g/s)	Total Kjeldahl Nitrogen (g/s as N)	Total Nitrogen (g/s)	Total Phosphorus (g/s)	Total Solids (g/s)	Total Suspended Solids (g/s)
Site S	3/10/2010	10:35	55.62	3,676	53.08	108.70	20.19	18,597	14,921
Site S	4/14/2010	9:55	18.13	1,338	1.48	19.61	0.33	1,393	55
Site S	5/12/2010	9:45	8.27	892	5.21	13.49	2.23	1,942	1,050
Site S	5/19/2010	9:20	17.19	1,227	< 0.65	17.85	0.73	1,394	167
Site S	5/26/2010	10:48	17.88	1,152	< 0.58	18.46	0.72	1,375	223
Site S	6/2/2010	10:18	74.47	4,811	70.60	145.07	18.84	19,706	14,895
Site S	6/9/2010	9:15	64.58	4,797	29.32	93.90	15.38	22,162	17,365
Site S	6/16/2010	9:30	80.27	5,841	8.13	88.41	8.34	11,492	5,651
Site S	6/23/2010	9:12	37.55	7,686	47.49	85.04	20.32	17,736	10,050
Site S	6/30/2010	8:55	49.62	2,346	4.41	54.03	2.05	3,468	1,123
Site S	7/7/2010	9:10	35.56	2,634	4.33	39.89	2.22	3,438	804
Site S	7/14/2010	8:40	44.77	2,987	11.76	56.54	5.21	6,061	3,074
Site S	7/21/2010	8:35	27.18	2,148	11.04	38.22	5.06	5,790	3,643
Site S	7/28/2010	9:00	28.77	1,813	2.41	31.18	1.44	2,517	705
Site S	8/4/2010	8:35	30.06	2,227	9.71	39.76	5.91	5,011	2,784
Site S	8/11/2010	8:35	36.95	2,296	4.09	41.04	1.97	3,188	892
Site S	8/18/2010	8:40	18.95	1,261	1.76	20.71	0.93	1,689	428
Site S	9/17/2010	8:50	10.89	895	1.11	11.99	0.49	1,004	109
Site S	10/8/2010	8:40	10.21	792	< 0.38	10.58	0.35	873	81
Site S	11/12/2010	10:20	3.82	566	5.00	8.82	1.61	1,544	979
Site S	12/17/2010	9:30	9.30	1,058	< 0.38	9.68	0.27	1,112	54

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (g/s as N)	Biochemical Oxygen Demand (g/s)	Dissolved Phosphorus (g/s)	Escherichia Coli (cfu/s)	Fecal Coliforms (cfu/s)	Nitrite (g/s as N)
Site F	3/10/2010	9:40	10	< 0.14	1.13	0.02	10,346,959	56,245,660	0.01
Site F	4/14/2010	9:05	16	< 0.23	0.91	< 0.01	912,481	17,977,770	0.02
Site F	5/12/2010	8:50	221	< 3.13	62.58	0.38	700,834,853	> 1,514,188,777	0.25
Site F	5/19/2010	8:50	23	< 0.33	< 0.65	0.05	2,522,432	112,861,420	0.04
Site F	5/26/2010	10:24	14	< 0.20	< 0.40	0.03	881,672	51,524,683	0.04
Site F	6/2/2010	9:35	40	1.13	10.19	0.14	12,684,794	> 274,061,317	0.12
Site F	6/9/2010	8:40	135	< 1.91	11.47	0.34	54,038,648	924,956,945	0.23
Site F	6/16/2010	8:50	77	< 1.09	6.54	0.15	43,309,158	> 527,568,035	0.15
Site F	6/23/2010	8:42	829	11.74	164.32	2.58	466,276,520	> 5,679,920,797	0.47
Site F	6/30/2010	8:25	82	< 1.16	< 2.32	0.14	10,105,247	461,214,411	0.09
Site F	7/7/2010	8:45	54	< 0.76	< 1.53	0.12	23,748,564	> 369,982,778	0.06
Site F	7/14/2010	8:10	7	< 0.10	< 0.20	0.02	2,219,839	4,796,073	0.01
Site F	7/21/2010	8:10	59	< 0.84	6.68	0.13	33,184,939	> 404,240,443	0.07
Site F	7/28/2010	8:35	50	< 0.71	5.66	0.08	3,181,392	> 342,576,646	0.04
Site F	8/4/2010	8:10	95	< 1.35	13.45	0.27	> 650,895,628	> 650,895,628	0.11
Site F	8/11/2010	8:15	42	< 0.59	2.38	0.12	6,151,089	287,764,383	0.02
Site F	8/18/2010	8:17	63	< 0.89	3.57	0.18	35,434,766	> 431,646,574	0.04
Site F	9/17/2010	8:30	30	< 0.42	1.70	0.07	9,513,595	> 205,545,988	0.03
Site F	10/8/2010	8:25	24	< 0.34	< 0.69	< 0.02	9,686,928	> 165,807,097	0.02
Site F	11/12/2010	9:58	319	12.63	162.44	1.71	1,110,292,129	> 2,183,583,544	0.18
Site F	12/17/2010	9:05	19	< 0.27	2.14	< 0.01	2,613,856	106,304,297	0.02

Site Name	Date	Time (CT)	Nitrite + Nitrate (g/s as N)	Total Dissolved Solids (g/s)	Total Kjeldahl Nitrogen (g/s as N)	Total Nitrogen (g/s)	Total Phosphorus (g/s)	Total Solids (g/s)	Total Suspended Solids (g/s)
Site F	3/10/2010	9:40	0.57	146	0.33	0.89	0.08	185	39
Site F	4/14/2010	9:05	0.82	228	0.31	1.12	0.04	230	2
Site F	5/12/2010	8:50	6.26	1,927	11.70	17.96	3.38	4,281	2,353
Site F	5/19/2010	8:50	1.04	324	0.43	1.47	0.07	325	1
Site F	5/26/2010	10:24	0.67	211	< 0.10	0.77	0.05	211	1
Site F	6/2/2010	9:35	7.02	647	11.01	18.03	2.71	2,459	1,812
Site F	6/9/2010	8:40	5.35	1,426	5.81	11.16	1.45	2,244	818
Site F	6/16/2010	8:50	3.71	829	2.70	6.41	0.55	1,071	242
Site F	6/23/2010	8:42	11.74	5,282	88.97	100.71	15.73	14,906	9,625
Site F	6/30/2010	8:25	5.11	940	1.39	6.50	0.26	994	53
Site F	7/7/2010	8:45	2.91	656	< 0.38	3.29	0.23	696	40
Site F	7/14/2010	8:10	0.40	82	0.13	0.53	0.04	96	14
Site F	7/21/2010	8:10	2.00	513	1.87	3.88	0.47	687	174
Site F	7/28/2010	8:35	2.55	648	1.26	3.81	0.24	682	34
Site F	8/4/2010	8:10	2.96	670	2.88	5.84	0.62	815	145
Site F	8/11/2010	8:15	1.90	521	1.22	3.13	0.24	561	40
Site F	8/18/2010	8:17	2.14	532	1.07	3.21	0.32	596	64
Site F	9/17/2010	8:30	1.36	357	0.54	1.89	0.12	371	14
Site F	10/8/2010	8:25	1.10	384	< 0.17	< 1.27	< 0.02	386	3
Site F	11/12/2010	9:58	6.32	1,670	14.71	21.03	5.96	4,548	2,879
Site F	12/17/2010	9:05	1.23	920	0.34	1.57	0.04	923	3

Site Name	Date	Time (CT)	Discharge (cfs)	Ammonia (g/s as N)	Biochemical Oxygen Demand (g/s)	Dissolved Phosphorus (g/s)	Escherichia Coli (cfu/s)	Fecal Coliforms (cfu/s)	Nitrite (g/s as N)
Site D	3/10/2010	8:12	432	< 6.12	73.40	1.47	197,682,979	1,589,904,502	0.37
Site D	4/14/2010	8:13	160	< 2.27	< 4.53	0.27	4,725,508	109,624,527	0.23
Site D	5/12/2010	8:00	481	< 6.81	81.72	1.23	329,558,734	> 3,295,587,338	0.41
Site D	5/19/2010	8:05	149	< 2.11	< 4.22	0.59	18,361,972	102,087,841	0.21
Site D	5/26/2010	8:35	122	< 1.73	< 3.45	0.59	28,203,759	835,887,017	0.28
Site D	6/2/2010	8:07	1,100	34.26	249.19	3.43	539,772,010	> 7,536,686,221	3.11
Site D	6/9/2010	8:00	445	< 6.30	50.40	1.76	250,293,186	> 3,048,932,153	0.63
Site D	6/16/2010	7:45	835	< 11.82	< 23.64	3.55	409,736,026	> 5,721,029,995	1.18
Site D	6/23/2010	7:40	870	< 12.32	197.09	2.46	> 5,960,833,647	> 5,960,833,647	0.99
Site D	6/30/2010	7:45	290	< 4.11	< 8.21	1.07	50,346,987	> 1,986,944,549	0.33
Site D	7/7/2010	8:00	110	< 1.56	< 3.11	0.44	75,366,862	> 753,668,622	0.12
Site D	7/14/2010	7:00	495	< 7.01	28.03	2.10	146,643,929	217,695,169	0.56
Site D	7/21/2010	7:25	822	< 11.64	116.38	3.03	5,631,960,067	> 5,631,960,067	1.63
Site D	7/28/2010	7:45	440	< 6.23	37.38	2.12	193,506,817	> 3,014,674,488	0.62
Site D	8/4/2010	7:35	910	< 12.88	103.07	3.35	623,489,496	> 6,234,894,964	1.29
Site D	8/11/2010	7:25	770	26.16	< 21.80	4.36	244,182,279	> 5,275,680,355	1.31
Site D	8/18/2010	7:40	476	< 6.74	26.96	1.89	209,339,193	> 3,261,329,674	0.27
Site D	9/17/2010	7:50	147	< 2.08	8.33	0.62	64,648,868	> 1,007,175,340	0.12
Site D	10/8/2010	7:45	220	< 3.11	< 6.23	0.69	10,117,026	697,663,655	0.12
Site D	11/12/2010	9:15	2,200	< 31.15	1121.35	12.46	1,507,337,244	> 15,073,372,442	< 0.62
Site D	12/17/2010	8:20	178	< 2.52	15.12	< 0.13	13,724,983	873,449,252	< 0.05

Site Name	Date	Time (CT)	Nitrite + Nitrate (g/s as N)	Total Dissolved Solids (g/s)	Total Kjeldahl Nitrogen (g/s as N)	Total Nitrogen (g/s)	Total Phosphorus (g/s)	Total Solids (g/s)	Total Suspended Solids (g/s)
Site D	3/10/2010	8:12	37.92	3,327	40.49	78.41	16.27	15,340	12,013
Site D	4/14/2010	8:13	16.76	2,428	2.67	19.44	0.68	2,583	154
Site D	5/12/2010	8:00	34.05	4,931	13.48	47.54	5.45	7,246	2,315
Site D	5/19/2010	8:05	17.72	1,975	< 1.05	18.78	1.05	2,186	211
Site D	5/26/2010	8:35	14.86	1,786	< 0.86	15.72	0.93	2,028	242
Site D	6/2/2010	8:07	289.68	23,143	607.40	897.08	157.30	111,294	88,151
Site D	6/9/2010	8:00	44.10	4,499	30.12	74.22	15.12	21,573	17,074
Site D	6/16/2010	7:45	115.86	10,593	19.86	135.72	9.22	13,903	3,310
Site D	6/23/2010	7:40	32.03	21,778	71.94	103.96	83.76	66,615	44,837
Site D	6/30/2010	7:45	46.81	3,506	4.93	51.74	1.89	3,851	345
Site D	7/7/2010	8:00	12.46	1,221	4.49	16.94	1.03	1,651	430
Site D	7/14/2010	7:00	58.87	5,789	16.26	75.13	8.13	10,541	4,752
Site D	7/21/2010	7:25	55.86	6,773	54.47	110.33	18.62	18,342	11,568
Site D	7/28/2010	7:45	66.04	6,093	7.48	73.51	3.99	7,239	1,146
Site D	8/4/2010	7:35	59.27	6,700	44.58	103.85	15.20	10,926	4,226
Site D	8/11/2010	7:25	202.78	9,223	12.65	215.42	8.94	14,303	5,080
Site D	8/18/2010	7:40	36.39	3,963	12.54	48.93	4.58	5,850	1,887
Site D	9/17/2010	7:50	14.57	1,694	4.25	18.81	1.21	2,090	395
Site D	10/8/2010	7:45	24.92	3,158	< 1.56	26.48	1.06	3,345	187
Site D	11/12/2010	9:15	43.61	3,115	137.68	181.29	79.12	82,731	79,616
Site D	12/17/2010	8:20	14.11	5,499	3.48	17.59	0.60	5,696	197