# WATER QUALITY MONITORING IN THE HOOVER CREEK WATERSHED 2004-2006

Iowa Geological Survey
Technical Information Series No. 53

Iowa Department of Natural Resources
Richard Leopold, Director
September 2007

COVER

Hoover Creek as it flows through
Herbert Hoover National Historic Site.

*photo by*
Katie Foreman

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# WATER QUALITY MONITORING
# IN THE HOOVER CREEK WATERSHED
# 2004-2006

**Iowa Geological Survey**
**Technical Information Series 53**

Prepared by

K. L. Foreman

The work on which this report is based
was performed in accordance with a cooperative agreement
between the Iowa Department of Natural Resources
and United States National Park Service.

September 2007

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# INTRODUCTION

The unnamed tributary of the west branch of Wapsinonoc Creek that runs through the Herbert Hoover National Historic Site in eastern Iowa is referred to by project coordinators as "Hoover Creek." The Hoover Creek watershed has historically been dominated by agricultural landuse. However, in recent years, agricultural landuse has declined as the city of West Branch expands into the western section of the watershed. Approximately 250 acres of agricultural land have been replaced by an urban landscape in the last 65 years. It is likely that such landuse changes have dramatically altered the water quality and stream hydrology throughout the watershed by creating more dynamic surface water flow regimes.

Under Section 303(d) of the Clean Water Act, the State of Iowa is required to submit a list of all waters that do not meet state water quality standards. This list is known as the 303(d) list of impaired waters. Waterbodies on this list are considered "impaired" and steps to improve their water quality must be undertaken. Periodic sampling of Hoover Creek indicates that the creek has elevated bacteria and nitrate+nitrite-nitrogen concentrations with a maximum bacteria level of 39,000 colony forming units (CFU) / 100 milliliters (ml) and nitrate+nitrite-nitrogen concentrations that exceed 20 milligrams/liter (mg/L). Although Hoover Creek is not a designated stream, and therefore is not in violation of state water quality standards for bacteria and nitrate+nitrite-nitrogen, these elevated levels are a potential water quality concern.

This cooperative project involves the National Park Service, Iowa Department of Natural Resources (IDNR) – Watershed Monitoring and Assessment Program, the University of Iowa Hygienic Lab (UHL), and the United States Geological Survey (USGS). The goal of this project is to characterize the biological, chemical, and physical health of the stream. This information will be critical for setting priorities in stream restoration plans that will have the potential to improve water quality within Hoover Creek.

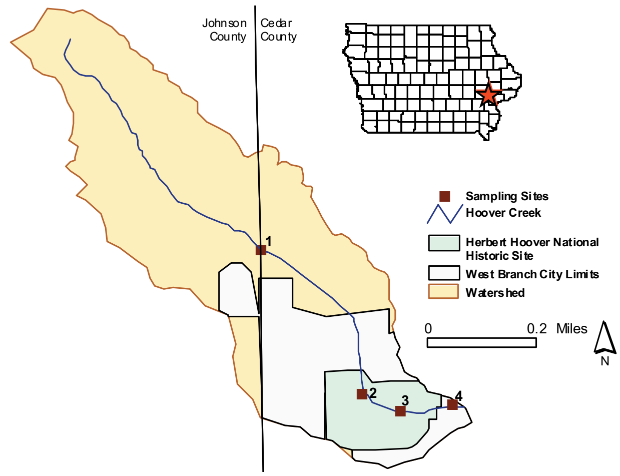


**Figure 1.** Location of monthly monitoring sites in the Hoover Creek watershed.

Project objectives include:

- Monitor and characterize patterns in bacteria, nutrient, and total suspended solids concentrations within the creek
- Measure temperature, dissolved oxygen, and turbidity to establish baseline water quality conditions
- Determine nutrient and bacteria pollution loads
- Determine the sources of bacteria in the watershed
- Characterize the biological and physical integrity of Hoover Creek

Four monthly sampling locations were identified in the Hoover Creek watershed for water quality monitoring. All four sites are located on the western tributary of the west branch of the Wapsinonoc Creek. Sites are denoted as 1, 2, 3, and 4 (Figure 1). Monthly sampling occurred at all four sites from June 8, 2004, to October 25, 2006. The Hoover Creek watershed experienced an extreme drought in the spring and summer of 2005 that eliminated flow in all of the sampling locations, therefore, sampling did not occur from August 4, 2005, through spring 2006. This report summarizes all data collected from June 8, 2004, to October 25, 2006.

## PROJECT SETTING

The Hoover Creek watershed is a small watershed that encompasses 1,752 acres in Cedar and Johnson counties in east-central Iowa. The Hoover Creek watershed is located within the Southern Iowa Drift Plain landform region. This landform region is composed primarily of pre-Illinoian glacial drift with a relatively thick loess mantle. The land surface is characterized by steep rolling hills and well integrated drainage systems (Prior 1991).

Landuse within the watershed is dominated by agriculture. Thirty-seven and a half percent of the landuse is grassland, 52.6% is row crop, while 7.5% is urban, and only a small percentage is wetland, forest, or other landuses (Figure 2). The data represented in the figure are from a calculation based on the 2002 Land Cover Grid of Iowa, which is available at: http://www.igsb.uiowa.edu/nrgislibx/. In general, landuse in the upper reaches of the watershed is primarily agricultural. Further downstream, there is a small golf course that separates the agricultural and urban parts of the watershed. The western portion of the urban section of the watershed is expanding rapidly, such that the percentage of the watershed that is characterized as urban is steadily increasing. The lower portion of the watershed consists of the Herbert Hoover National Historic Site.

## CLIMATIC CONDITIONS

Climate data for east-central Iowa was obtained from the Iowa State University Department of Agronomy, Iowa Environmental Mesonet (http://mesonet.agron.iastate.edu/index.phtml). Conditions in 2004 were characterized by warmer temperatures and more precipitation than normal in east-central Iowa. Total precipitation was 4.0 inches higher than the long-term average. Drought conditions impacted east-central Iowa in 2005 with above normal temperatures and precipitation was 13.2 inches below the long-term average. Drought conditions persisted in 2006, although not as severely as the year before with only an 8 inch divergence from the average amount of precipitation and above normal temperatures.

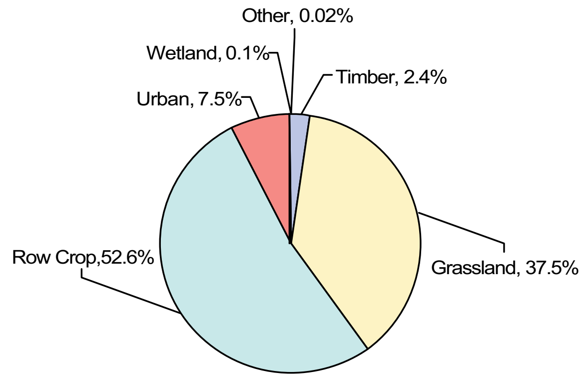


**Figure 2.** 2002 landuse in the Hoover Creek watershed.

## STREAM DISCHARGE

A USGS stream gage at monitoring site 3 (Figure 1) provided continuous stream discharge measurements on Hoover Creek. This stream gage has been operational since April 2000, and real-time stream discharge data is available online at: http://waterdata.usgs.gov/nwis/uv?05464942.

Mean daily discharge measurements for Hoover Creek during the sampling period are shown in Figure 3. Differences in long-term daily mean discharge (six years of data) and daily discharge are plotted in Figure 4 to demonstrate the departure of daily mean from long-term mean discharge. This discharge graph reiterates the previously stated climatic conditions; discharge was higher than the long-term mean in 2004 and less than the long-term mean in 2005 and 2006.

In general, stream flow in Hoover Creek is flashy with baseflow conditions interrupted by brief, high-flow events. The maximum daily mean discharge in 2004 was 12 cubic feet per second (cfs) on March 26, 11 cfs on February 13, 2005, and 2.8 cfs on April 14, 2006.

## WATER QUALITY RESULTS

Water quality was monitored monthly at four sites in the Hoover Creek watershed (Figure 1).

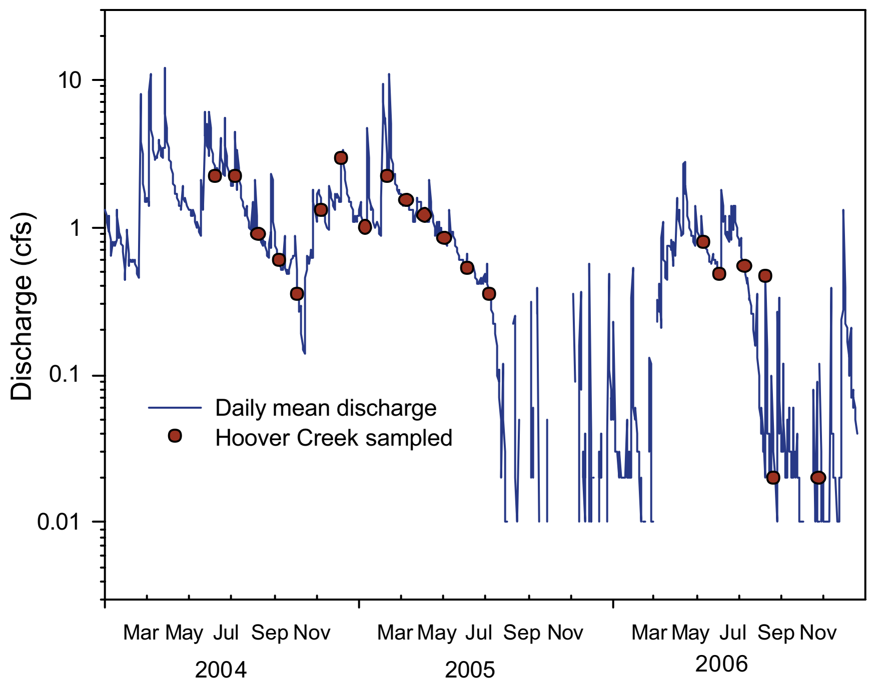


**Figure 3.** Discharge on Hoover Creek at the gaging station in the Herbert Hoover National Historic Site, 2004 through 2006. Dates for monthly sampling are plotted on the discharge graph.

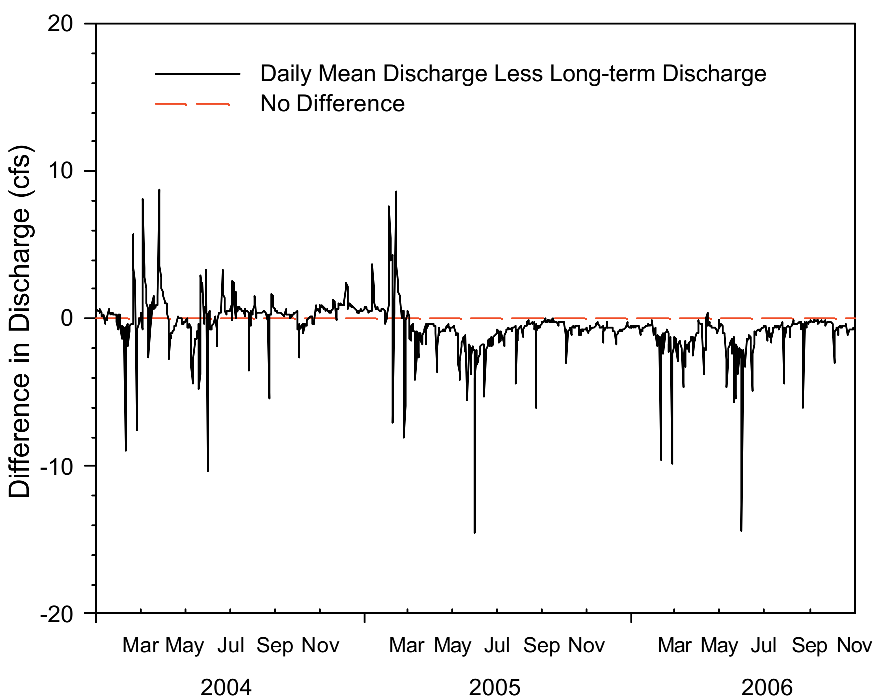


**Figure 4.** Departure of discharge from long term average on Hoover Creek at gaging station, 2004 through 2006.

Iowa Department of Natural Resources staff conducted the monitoring following methods outlined by the UHL's standard operating procedures (UHL 2001). The following on-site field parameters were measured: turbidity, dissolved oxygen, and water temperature (using a Hach 2100 P Turbidimeter and a YSI 55 dissolved oxygen and temperature meter). Water samples were analyzed by the UHL, a U.S. Environmental Protection Agency (EPA) certified lab, for the following parameters: total Kjeldahl nitrogen (TKN), ammonia nitrogen, nitrate+nitrite-nitrogen, *Escherichia coli (E. coli)*, and total suspended solids (beginning in 2005). All water quality monitoring results were uploaded into the EPA water quality database, STORET, and can be accessed at: http://wqm.igsb.uiowa.edu/iastoret/

Summaries of the water quality results can be found in appendices A through E. Appendices A and B are tables that summarize the basic statistical distribution of each monitoring parameter by year and by site. Appendix C includes boxplots of the data by year and appendix D includes boxplots of the data by site. Appendix E includes line plots illustrating the spatial and temporal trends of the data.

## Nitrate+Nitrite as N

Nitrate+nitrite-N is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth, however, too much nitrogen in surface waters can contribute to nutrient enrichment. This causes excess algal growth, oxygen depletion and eutrophication, all of which negatively impact aquatic communities. Sources of nitrogen include soils, human and animal wastes, decomposing plants, and fertilizer runoff.

During 2004-2006, nitrate+nitrite-N ranged from 0.2 mg/L to 15.0 mg/L (Appendices A and C). Concentrations of nitrate+nitrite-N were generally higher in 2004 than in 2005 and 2006. The maximum level of nitrate+nitrite-N measured in 2004 was 15 mg/L on June 8, and the median for all sites that year was 9.0 mg/L. Meanwhile, the lowest value of 0.2 mg/L was measured on October 25, 2006, and the median for all sites that year was 4.4 mg/L. Reasons for these differences could be attributed to the higher rainfall in 2004 that increased the potential for nitrate+nitrite-N transport across the landscape, while 2005 and 2006 were much drier years with less potential for nitrate+nitrite-N transport to the creek. Although 2004 and 2005 nitrate+nitrite-N data are fairly comparable, Hoover Creek was dry from July 2005 until spring 2006.

Spatial patterns can be seen in the data (Appendices B and D). Nitrate+nitrite-N values decrease from upstream (site 1 - having a median of 10.5 mg/L) to downstream (site 4 - with a median of 7.4 mg/L). This trend is consistent across years. There also appears to be a seasonal variation in nitrate+nitrite-N values. Nitrogen values peak in the spring and summer and tend to be lower during the winter months when potential for nitrate+nitrite-N availability and transport decreases (Appendix E).

The State of Iowa currently does not have a water quality standard for nitrate+nitrite-N. However, the EPA has published recommendations to assist states in setting nutrient standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's nitrate+nitrite-N criteria recommendation is 1.965 mg/L. Approximately 84% of the samples from Hoover Creek exceeded this recommended level.

### *Nitrate+Nitrite-N Loads*

Nitrogen loads were unable to be calculated using traditional computer programs such as ESTIMATOR and AutoBeale due to the small size of the dataset. However, a load duration curve was calculated for nitrogen at site 3, where the gaging station is located (Figure 1). This load duration curve is perhaps more useful than a sole load value, as it evaluates where in the hydrological cycle the highest loads are occurring. Figure 5 shows the load duration curve that uses the EPA nutrient standard recommendation as the threshold. All sampling points above the curve shown are exceeding that nutrient standard (1.965 mg/L). Flows are characterized as high, moist,

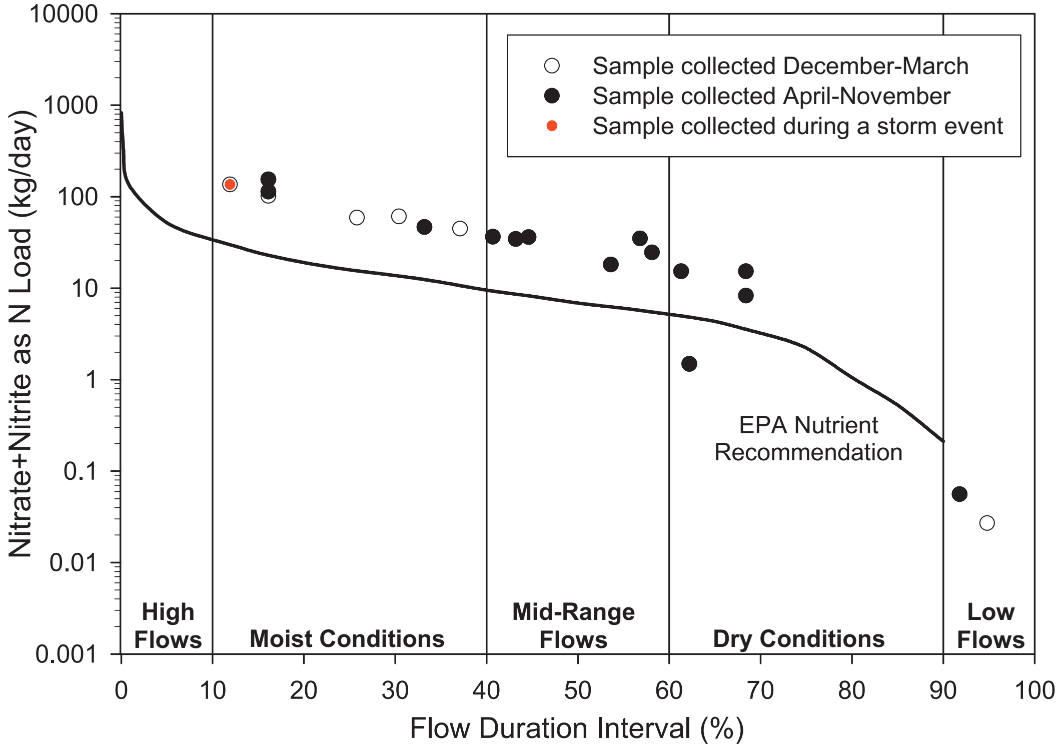


**Figure 5.** Nitrate+nitrite-N load duration curve for Hoover Creek at the gaging station in the Herbert Hoover National Historic Site, 2004 though 2006.

mid-range, dry, and low. The load duration curve suggests that Hoover Creek consistently exceeds the EPA recommended level of nitrate+nitrite-N. Eighty-three percent of the nutrient standard exceedances occur in moist and mid-range flows, suggesting that the majority of these high values are associated with nonpoint sources (Cleland 2004). This supports the previous discussion that high nutrient values in Hoover Creek are driven by high flow conditions.

## Ammonia-N

Ammonia-N is an inorganic, dissolved form of nitrogen in water. Ammonia-N is the concentration of ionized and un-ionized ammonia, both products of the decomposition of organic matter in water. The most common sources of ammonia include fertilizers and human and animal waste.

During 2004-2006, ammonia-N ranged from <0.05 mg/L to 0.7 mg/L (Appendices A and C). Ammonia-N levels were generally lower in 2004 and 2005 than in 2006. The maximum level of 0.7 mg/L was measured in 2006 with multiple other detects throughout that year. However, during 2004 and 2005, ammonia-N was rarely detected in Hoover Creek.

There was not much variation in ammonia levels in different sections of the creek (Appendix D). The upper-most point in the watershed (site 1) had the highest detected value of ammonia-N; otherwise, ammonia levels were relatively low in the watershed. Only one sampling event in 2006 had detections for ammonia-N at all four sites (Appendix E). This occurred following a strong rain storm, which caused turbidity and bacteria numbers to be high at all sites. These elevated values in conjunction with the large rain storm can probably be attributed to fecal matter entering the stream from the watershed and/or stormwater inputs.

The State of Iowa has an ammonia standard that is dependent on the pH value of the water (IAC 2002). Hoover Creek monitoring did not include monitoring for pH, thus information on violations of the state standard for ammonia is not available.

## Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is nitrogen in the form of organic proteins or their decomposition product ammonia, as measured by the Kjeldahl Method. Sources of TKN are animal and human wastes and organic matter.

During 2004-2006, TKN concentrations in Hoover Creek ranged from 0.1 mg/L to 5.4 mg/L with median values ranging from 0.3 to 0.4 mg/L. TKN values were generally higher in 2006 with a maximum level of 5.4 mg/L than in 2004 and 2005, when maximum levels were 0.5 mg/L (Appendices A and C). Site 1 tends to have higher values of TKN versus sites further downstream (Appendices B and E). The highest levels of TKN occurred during high flow events in the upstream portion of the watershed, where agricultural nonpoint source pollution is more likely.

The State of Iowa currently does not have a water quality standard for TKN. However, the EPA has published recommendations to assist states in setting nutrient standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's TKN criteria recommendation is 0.65 mg/L. Approximately 17% of the samples from Hoover Creek exceeded this recommended level.

## Turbidity

Turbidity is a measure of the cloudiness of water caused by suspended particles within the water column. Sources of high turbidity include organic matter, algae, sediment, and other suspended solids in the water column. Turbidity usually increases after storm events, when streams carry more sediment as a result of increased erosion.

During 2004-2006, the turbidity values in Hoover Creek ranged from 2 Nephelometric Turbidity Units (NTU) to greater than 1,000 NTU (Appendices A and C). Median turbidity ranged from 11 to 17 NTU. In general, turbidity was highest at site 1 (Appendices B and D). Statistics show that turbidity was higher in 2006 than in 2004 or 2005 (Appendix A). This is a skewed view of turbidity in the stream, as the largest rainstorm monitored during the sampling project was monitored in 2006. In general, turbidity in the creek was relatively low (less than 25 NTU) with increases for short periods of time right after large storm events when runoff increased. The highest turbidity recorded at most sites was associated with a heavy rainstorm that occurred on August 9, 2006.

The State of Iowa currently does not have a water quality standard for turbidity. However, the EPA has published recommendations to assist states in setting turbidity standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's turbidity criteria recommendation is 15 NTU. Approximately 35% of the samples from Hoover Creek exceeded this recommended level.

## Dissolved Oxygen

Dissolved oxygen (DO) is a measure of oxygen gas ($O_2$) in water and is crucial for the support of aquatic communities. Almost all aquatic plants and animals need DO in the water to survive. Dissolved oxygen is produced by diffusion from the atmosphere, aeration of water, and is a waste product of photosynthesis. Dissolved oxygen levels are affected by temperature, salinity, atmospheric pressure, and oxygen demand from aquatic plants and animals. Oxygen in a stream can be consumed through respiration by aquatic plants and animals and by the decomposition of organic matter.

Dissolved oxygen was measured in the field at all sites during each sampling event. During 2004-2006, DO levels ranged from 2.6 mg/L to 11.1 mg/L. Median DO levels ranged from 7.5 mg/L at site 1 to 8.1 mg/L at site 3 (Appendices A, B, C, D). Dissolved oxygen showed little variation from 2004-2006. However, there was a higher median value in 2005 due to the fact that samples were only collected in the winter months, when DO levels tend to be higher. There was also very little variation in DO levels from upstream sites to downstream sites (Appendix D). Dissolved oxygen levels exhibit a seasonal pattern with levels highest in the winter months and lowest during the summer months, since colder water can hold more oxygen than can warmer water (Appendix E). Had DO been measured on a real-time basis, diurnal patterns would have inevitably been observed as well.

The DO standard for the State of Iowa is a minimum of 5 mg/L in a warm water stream (IAC 2002). Hoover Creek sites violated this standard 14% of the time, usually following large rain events or during times when flow was low and water temperatures were high. Such conditions increase the biological oxygen demand and decrease available oxygen in the stream.

## Water Temperature

Water temperature is a measure of the thermal energy of water. Water temperature can influence the species of plants and animals that can survive in the water.

During 2004-2006, water temperatures in Hoover Creek ranged from 1.0 to 21.9 degrees Celsius. In general, water temperatures were higher in 2006 than in 2004 and 2005 and were more variable in 2005 (Appendices A and C). Temperature did not vary much from upstream to downstream sites. As to be expected, water temperature is linked to season with higher temperatures in the summer months than in the winter months (Appendix E).

## Total Suspended Solids

Total suspended solids (TSS) quantify the total amount of substances that are in suspension in a stream channel. The suspended substances include silt, clay, fine sand, and other organic matter. Larger particles can be carried during floods or when water volumes and velocities are high. Total suspended solids are related to stream flow; the higher the velocity of the water, the higher the TSS. Total suspended solids concentrations are a good indicator of both land surface erosion and streambank erosion. Higher levels of TSS usually imply high velocities of water (rainfall events) which increase erosion and channel incision.

Total suspended solids were monitored from 2005 to 2006. Total suspended solids concentrations ranged from 2 mg/L to 4400 mg/L. Median values ranged from 10 mg/L at site 3 to 29 mg/L at site 1 (Appendices A, B, C, D). Total suspended solids concentrations were highest at site 1. In general, TSS in the creek was relatively low (less than 15 mg/L) with increases for short periods immediately following large storm events, when runoff increases. The highest TSS recorded at most sites was associated with a heavy rainstorm that occurred on August 9, 2006, when TSS peaked at 4400 mg/L (Appendix E).

## *Escherichia coli* Bacteria

*Escherichia coli (E. coli)* are bacteria that indicate the presence of pathogenic bacteria. *E. coli* are necessary bacteria that promote digestion in humans and other warm-blooded animals. High levels of *E. coli* in stream water typically indicate greater levels of fecal contamination and thus a greater chance that pathogenic microbes may be present in the water. Pathogenic organisms are a health risk to humans; they can cause illness in people and adversely impact aquatic ecosystems. The most frequent sources of bacteria in water are sewage overflows, malfunctioning septic systems and sewer lines, animal waste, and polluted storm water runoff.

During 2004-2006, *E. coli* values ranged from less than 10 to 29,000 colony forming units (CFU)/100 ml. Median concentrations ranged from 425 CFU/100 ml at site 2 to 650 CFU/100 ml at site 4 (Appendices A, B, C, D). Generally, *E. coli* was higher in 2006 than in 2004-2005 (Appendices A and C). Spatial patterns exist in *E. coli* concentrations; site 4 consistently had the highest levels of bacteria, while median values were consistently lower for sites 1 through 3.

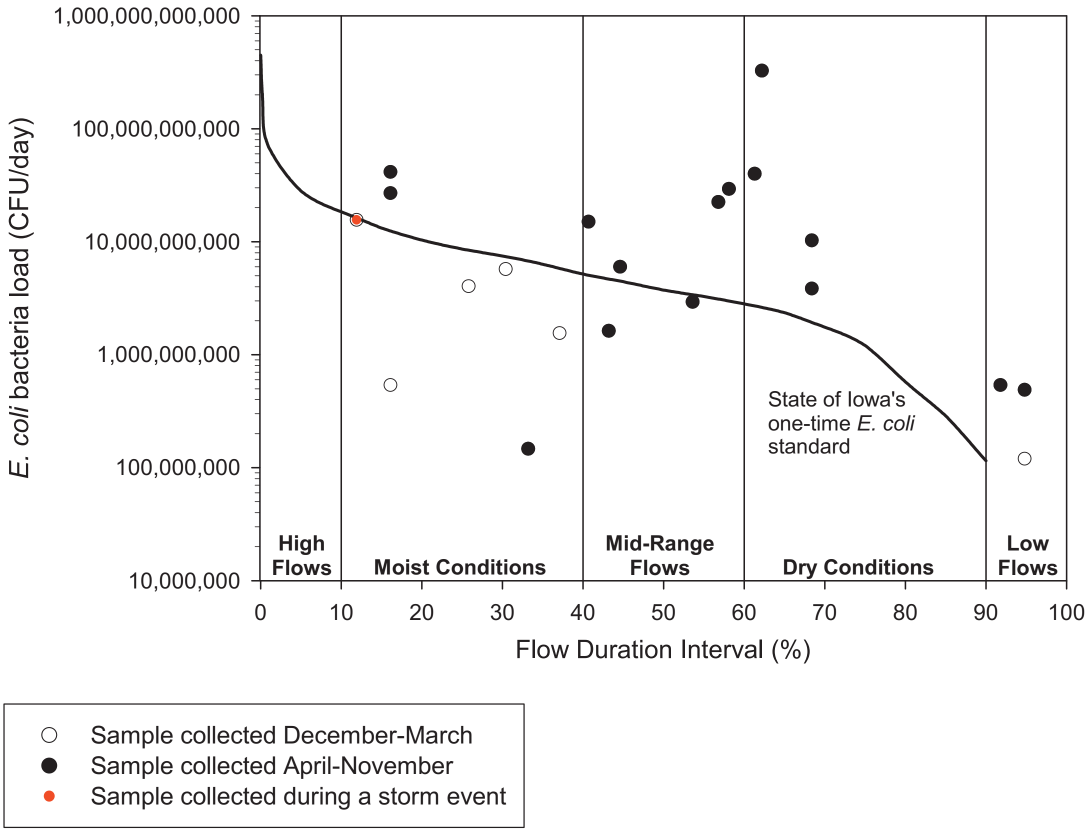


**Figure 6.** *E. coli* load duration curve for Hoover Creek at the gaging station in the Herbert Hoover National Historic Site, 2004 through 2006.

There were some seasonal patterns in *E. coli* concentrations with some of the highest *E. coli* levels occurring during rain events. All sites had *E. coli* concentrations greater than 20,000 CFU/100 ml following a heavy rainfall event on August 9, 2006.

*E. coli* values were relatively high throughout the entire sampling period with many water samples exceeding the Class A1 one-time maximum standard for *E. coli* of 235 CFU/100 ml (Appendix E). A new State of Iowa rule mandates that *E. coli* concentrations not exceed the Class A1 standard in all streams determined to be perennial or intermittent with perennial pools. Hoover Creek is not classified as a perennial stream and has not undergone proper assessment to determine its designation. Therefore, there are no *E. coli* standards that are applicable to Hoover Creek. However, the Class A1 standard is used as a benchmark for evaluation of bacteria contamination in the creek. Sixty-nine percent of the samples collected in Hoover Creek violated that one time maximum standard, as did 85% of the samples collected at site 4.

### *Escherichia coli Bacteria Loads*

To further understand patterns of bacteria in Hoover Creek, a load duration curve was generated. This load duration curve is perhaps more useful than a sole load value, as it evaluates where in the hydrological cycle the highest loads are occurring. Figure 6 shows the load duration curve that uses the State of Iowa Class A1 *E. coli* standard as the threshold. Although this standard does not apply to Hoover Creek, it provides a benchmark for evaluation of bacteria contamination in the creek. All sampling points above the curve shown are violating the 235 CFU/100 ml bacteria standard. Flows are characterized as high, moist, mid-range, dry, and low. The load duration curve suggests that over 60% of water samples exceeded that bacteria standard. Sixty-two percent of the bacteria standard exceedances occur in midrange and dry conditions, suggesting that these high values are likely associated with both nonpoint and point sources of pollution (Cleland 2004). However, even though the highest concentrations of bacteria occurred during a high flow event, the largest load of bacteria occurred during dry conditions. The next chapter entitled "Targeted Bacteria Sampling," further investigates the sources of bacteria within the creek.

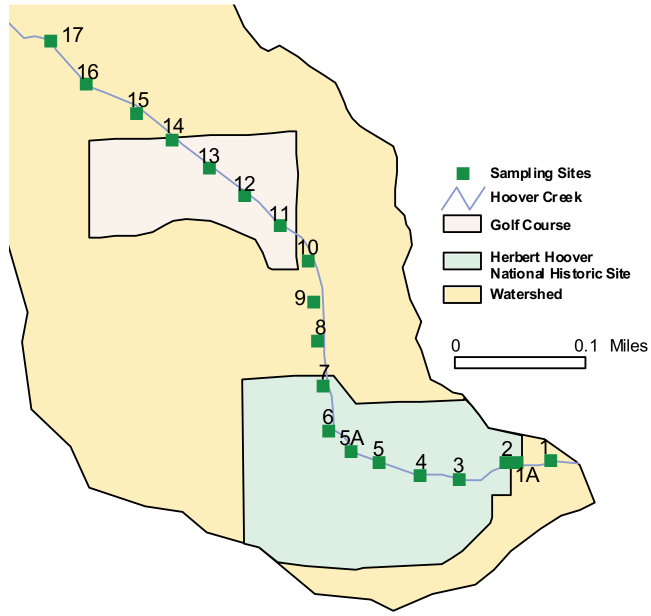


**Figure 7.** Location of targeted bacteria sampling sites, August 2006 through October 2006.

## TARGETED BACTERIA SAMPLING

### Bacteria Source Tracking

The presence of *E. coli* bacteria in a stream suggests a relatively fresh fecal source entering the water. Although monitoring indicated that bacteria concentrations tended to be high in Hoover Creek, the monitoring did not identify the sources of these elevated bacteria levels. Rather than conduct expensive microbial source tracking studies in the watershed, a targeted sampling approach was conducted. This approach entailed taking numerous samples along the stretch of the stream to determine locations with elevated bacteria concentrations. Two sampling events occurred in August and September of 2006 during which 14-17 samples were collected and analyzed for bacteria. Fluorometry was then used to sample the levels of optical brighteners in the water. Samples were taken at a rate of one sample per 150 meters of stream length or where tile lines were flowing. Sites were numbered 1 through 17 and are mapped and described in Figure 7 and Table 1. Additionally, a smaller sampling event was conducted on a subset of these sites in October. The presence of optical brighteners and bacteria in water is a good indication of a human source of bacteria via a failed or inadequate sewage treatment system.

#### *Fluorometry*

Fluorometry can be used to detect optical brighteners from laundry detergents, dishwashing detergents, and toilet paper, which fluoresce when exposed to ultraviolet radiation. Optical brighteners break down when exposed to ultraviolet radiation (UV), whereas most naturally occurring organics which fluoresce at the same wavelength do not. Optical brightener dyes are generally found in domestic waste waters, because the main commercial use of these dyes is in laundry detergents and textile finishing. The brighteners can enter a waterway via leaking sewer pipes, sewer lines improperly cross-connected to storm drains, and malfunctioning on-site waste disposal systems. In the past, fluorometry has not worked well in tracking potential human waste contamination when it was used alone. However, fluorometry combined with bacteria analysis, is an inexpensive method to detect human waste

**Table 1.** Universal Transverse Mercator coordinates of fluorometric monitoring locations.

| Sites | UTM X coordinates (meters) | UTM Y coordinates (meters) |
|---|---|---|
| 1 | 637828 | 4614468 |
| 1A | 637693 | 4614460 |
| 2 | 637653 | 4614461 |
| 3 | 637462 | 4614392 |
| 4 | 637308 | 4614411 |
| 5 | 637143 | 4614460 |
| 5A | 637034 | 4614504 |
| 6 | 636938 | 4614587 |
| 7 | 636924 | 4614767 |
| 8 | 636899 | 4614944 |
| 9 | 636883 | 4615103 |
| 10 | 636858 | 4615264 |
| 11 | 636748 | 4615404 |
| 12 | 636604 | 4615520 |
| 13 | 636463 | 4615634 |
| 14 | 636319 | 4615749 |
| 15 | 636178 | 4615853 |
| 16 | 635975 | 4615967 |
| 17 | 635828 | 4616142 |

in waterways. Table 2 shows the relationship between levels of bacteria, levels of optical brighteners, and sources of bacteria in waterways (Hartel *et al*. 2005).

***Sample Collection and Analysis.*** Water samples for fluorometric analysis were collected in 125 ml sterilized and acid-washed bottles. Samples were stored in a cool, dark place following collection to prevent further breakdown of the optical brightening agents in the field. Bacteria samples were collected in 100 ml bottles and were analyzed by UHL.

Samples for fluorometric analysis were then placed in 30 ml acid-washed borosilicate test tubes. Using a Turner Designs 10-AU Field Fluorometer, the level of fluorescence of each sample at 436 nanometer (nm) was determined and recorded. These samples were then exposed to UV for at least six hours. Samples were analyzed prior to and following UV exposure to assess the influence of background interference from organic compounds present in the water. Differences in the level of fluorescence of each sample were compared to the previous reading. The decline in fluorescence from the first reading to the second indicates the presence of optical brighteners and their concentration in each sample.

## Results

Spatial patterns exist in the presence of bacteria and optical brighteners in Hoover Creek. In all three sampling events, bacteria levels generally increased from the upstream section of the stream to the downstream section (Figure 8 and Table 3). There were only a few exceptions to this trend: the October sampling of site 16 and the September sampling of sites 8 through 10. Spatial trends in optical brighteners are more complex. The concentration of optical brighteners generally increased from site 17 to site 10 or 11 and then declined until site 7, when concentration increased and peaked at site 3 or 4 before decreasing again (Figure 9 and Table 3). The patterns in optical brightener levels tended to follow landuse characteristics in the watershed (Figure 7). Optical brighteners were in relatively low numbers around site 17, an area that is characterized by agricultural land. The concentration of optical brighteners increased through the golf course and then decreased downstream of site 11 within residential neighborhoods. Optical brightener levels began to increase as the stream flowed through Herbert Hoover National Historic Site, peaking within the national historic site and it decreased as it flowed out of Herbert Hoover National Historic Site at site 1.

The optical brightener concentration and bacteria levels for all three sampling events were categorized as low or high (Table 3). Thresholds

**Table 2.** Relationship between levels of bacteria, levels of optical brighteners, and sources of bacteria in waterways.

| Fecal Bacterial Numbers | Optical Brightener Values | Potential Bacteria Sources |
|---|---|---|
| High | High | Failing on-site waste disposal system or leaking sewer pipe |
| High | Low | Human (e.g., outhouse) or other warm-blooded animals |
| Low | High | Gray water in storm water system |
| Low | Low | No evidence of fecal contamination |

for these categories varied between samplings as background conditions were taken into account. Table 2 shows the relationship between levels of bacteria, levels of optical brighteners, and sources of bacteria (Hartel *et al.* 2005). As adapted from Table 2, the combination of bacteria levels and optical brighteners fell into one of three potential sources of bacteria: 1.) failing on-site waste disposal system or leaking sewer pipe/gray water from stormwater, 2.) human or other warm-blooded animals, and 3.) no evidence of fecal contamination. Table 4 summarizes the potential sources of bacteria for each site. Some sites were consistent in their potential source of bacteria for all of the sampling events, while others had differing potential sources for events. Differences were taken into account during data analysis and interpretation.

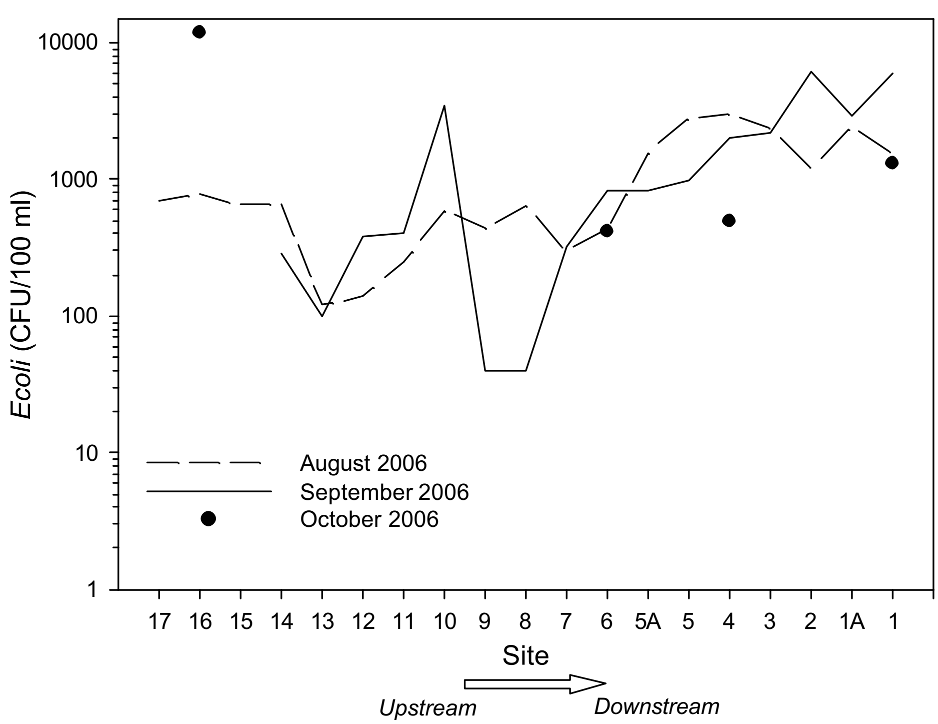


**Figure 8.** *E. coli* concentrations from targeted bacteria sampling, August 2006 through October 2006.

**Table 3.** Results from fluorometric investigation, August 2006 through October 2006.

| Date (2006) | Site | Optical Brightener Change (OBU) | *E. coli* (CFU/100 ml) | Level Optical Brightener Change* | Level *E. coli** |
|---|---|---|---|---|---|
| 8/23 | 1 | 196 | 1500 | Low | High |
| ↓ | 2 | 261 | 1200 | High | High |
| | 3 | 277 | 2400 | High | High |
| | 4 | 274 | 3000 | High | High |
| | 5 | 271 | 2800 | High | High |
| | 6 | 237 | 430 | Low | Low |
| | 7 | 184 | 300 | Low | Low |
| | 8 | 166 | 640 | Low | Low |
| | 9 | 236 | 440 | Low | Low |
| | 10 | 263 | 600 | High | Low |
| | 11 | 311 | 250 | High | Low |
| | 12 | 275 | 140 | High | Low |
| | 13 | 301 | 120 | High | Low |
| | 14 | 208 | 650 | Low | Low |
| | 15 | 209 | 650 | Low | Low |
| | 16 | 159 | 780 | Low | Low |
| | 17 | 132 | 690 | Low | Low |
| | 1A | 230 | 2500 | Low | High |
| | 5A | 254 | 1600 | High | High |
| 9/29 | 1 | 37 | 5900 | Low | High |
| ↓ | 2 | 87 | 6100 | High | High |
| | 3 | 119 | 2200 | High | High |
| | 4 | 126 | 2000 | High | High |
| | 5 | 119 | 970 | High | High |
| | 6 | 62 | 820 | Low | Low |
| | 7 | 32 | 320 | Low | Low |
| | 8 | 31 | 40 | Low | Low |
| | 9 | 77 | 40 | High | Low |
| | 10 | 101 | 3500 | High | High |
| | 11 | 89 | 410 | High | Low |
| | 12 | 42 | 380 | Low | Low |
| | 13 | 65 | 100 | Low | Low |
| | 14 | 13 | 290 | Low | Low |
| | 1A | 56 | 2900 | Low | High |
| | 5A | 103 | 840 | High | Low |
| 10/25 | 1 | 165 | 1300 | High | High |
| ↓ | 4 | 170 | 490 | High | Low |
| | 6 | 157 | 420 | High | Low |
| | 16 | 206 | 12000 | High | High |

| ***Thresholds** | | |
|---|---|---|
| Date | High, Low *E. coli* (CFU/100 ml) | High, Low Optical Brighteners (OBU) |
| 8/23/2006 | >900, <900 | >250, <250 |
| 9/29/2006 | >900, <900 | >75, <75 |
| 10/25/2006 | >900, <900 | >100, <100 |

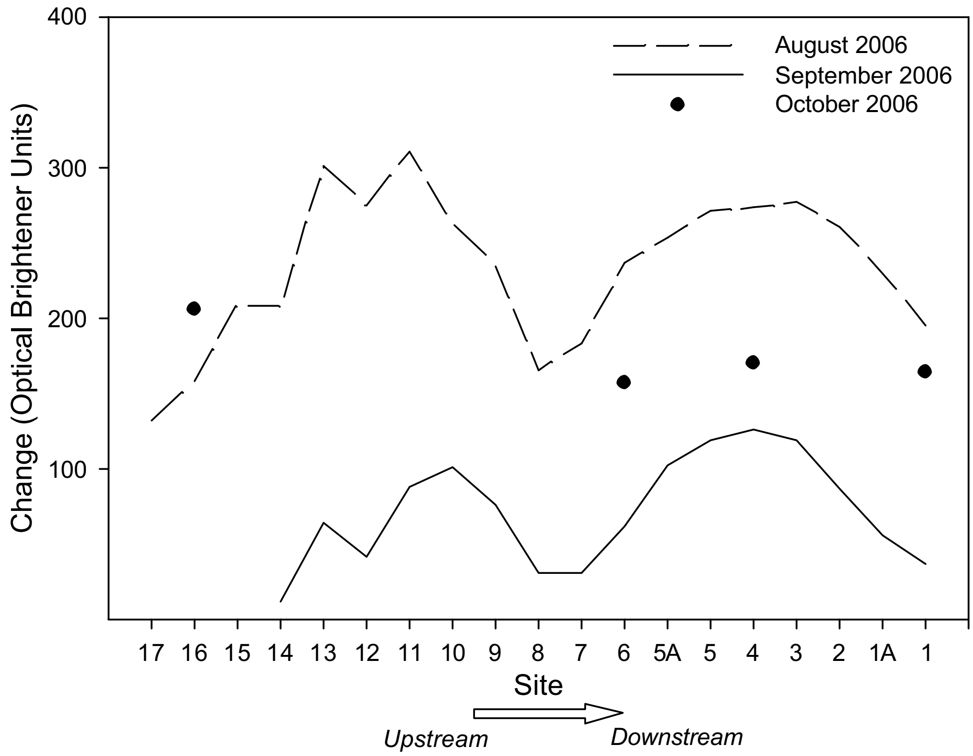


**Figure 9.** Changes in optical brightener indicators in Hoover Creek from targeted bacteria sampling, August 2006 through October 2006.

Results show that there is no evidence of human fecal pollution in the upper reaches of the watershed, where landuse is dominated by agriculture (Figure 10). The one exception is site 16 where one sampling indicated that bacteria was coming from a failing on-site waste disposal system but later sampling indicated no human fecal contamination. Potential human sources of bacteria occur in the sites on the golf course and just downstream of the golf course – likely resulting from gray water from storm water systems. The sites within the golf course showed relatively higher optical brightener levels but not necessarily high bacteria concentrations. This inconsistency could indicate a chemical additive to the golf course turf that causes higher optical brightener levels in the stream. Some of the sources of bacteria within Herbert Hoover National Historic Site are likely human. Nearly all sites within the park had been classified as contaminated by bacteria as a result of a failing on-site disposal system, a leaking sewer pipe, or gray water (Figure 11). Sites outside of the park boundaries are characterized as having bacteria that is potentially from humans or other warm-blooded animals as well as failing waste disposal systems.

## Discussion

Results from the targeted sampling suggest that some of the bacteria in Hoover Creek are likely from humans. Areas that suggest potentially strong indications of human fecal contamination are sites within Herbert Hoover National Historic Site, where sites consistently indicate that high bacteria levels result from failing on-site waste disposal systems, leaking sewer pipes, or gray water. This is not surprising considering the large number of tile lines that are present in this section

**Table 4.** Potential sources of bacteria in Hoover Creek based on targeted bacteria sampling results.

| Sites | Potential Sources of Bacteria |
|---|---|
| 1 | Failing on-site waste disposal system/human or other warm-blooded animals |
| 1A | Human or other warm-blooded animals |
| 2 | Failing on-site waste disposal system or leaking sewer pipe |
| 3 | Failing on-site waste disposal system or leaking sewer pipe |
| 4 | Failing on-site waste disposal system or leaking sewer pipes/gray water |
| 5 | Failing on-site waste disposal system or leaking sewer pipe |
| 5A | Failing on-site waste disposal system or leaking sewer pipes/gray water |
| 6 | Gray water/no evidence of fecal contamination |
| 7 | No evidence of fecal contamination |
| 8 | No evidence of fecal contamination |
| 9 | Gray water/no evidence of fecal contamination |
| 10 | Failing on-site waste disposal system or leaking sewer pipes/gray water |
| 11 | Gray water |
| 12 | Gray water/no evidence of fecal contamination |
| 13 | Gray water/no evidence of fecal contamination |
| 14 | No evidence of fecal contamination |
| 15 | No evidence of fecal contamination |
| 16 | Failing on-site waste disposal system or leaking sewer pipes/no evidence of fecal contamination |
| 17 | No evidence of fecal contamination |

of the stream. This portion of the stream is the most impacted by urban infrastructure that has the potential to be inadequate or to fail. Other areas of concern include sites within and just downstream of the golf course, where high optical brightener values could be the result of chemical additives applied to the golf course turf.

Although the fluorometry results are not conclusive about the exact source of elevated bacteria levels, they help identify potential sources and their locations. Further bacteria and fluorometric monitoring investigations would be particularly beneficial within Herbert Hoover National Historic Site in order to expand understanding of bacteria levels and sources.

## BENTHIC MACROINVERTEBRATE SAMPLING

### Methods

A benthic macroinvertebrate study was conducted on all four Hoover Creek sites (Figure 1) in August of 2006 to assess the biological integrity of Hoover Creek. Sampling benthic macroinvertebrates is the most common method of assessing the biological health of a stream. As water conditions change, so does the presence and diversity of benthic macroinvertebrate communities in that stream. The number and kinds of organisms collected are a relatively good indicator of the health of the stream. This is because benthic macroinvertebrates are stable in their range (they do not migrate long distances), are easy to collect and identify, and much is known of their tolerance to different pollutants. Only one benthic study was conducted during the study period, so the information gathered provides a small picture of the overall biological integrity of the stream. In order to determine trends and changes in the biological health of the stream, more frequent studies would need to be conducted.

The benthic macroinvertebrate study was conducted using IOWATER Advanced Benthic Macroinvertebrate Indexing methods.

The IOWATER method is a modified version of the Regional Environmental Monitoring and Assessment Program (REMAP) method developed by the IDNR in cooperation with the UHL (IDNR 2001 and 2005). Three quantitative sub-samples were collected at each of the four Hoover Creek sampling sites using dip nets. Surber and Hess samplers that are commonly used in benthic macroinvertebrate sampling were deemed inappropriate for this study because of the narrow width and shallow water depth of the stream. Benthic macroinvertebrates were collected for a period of 90 minutes utilizing a multihabitat approach (Barbour *et al.* 1999). Proportional abundance sampling of multiple microhabitats was conducted over a sampling area consisting of at least 100 meters of streambed length. Observational data, including clarity (transparency), DO, level of flow, and the number and types of macro and microhabitats sampled, were recorded for each site.

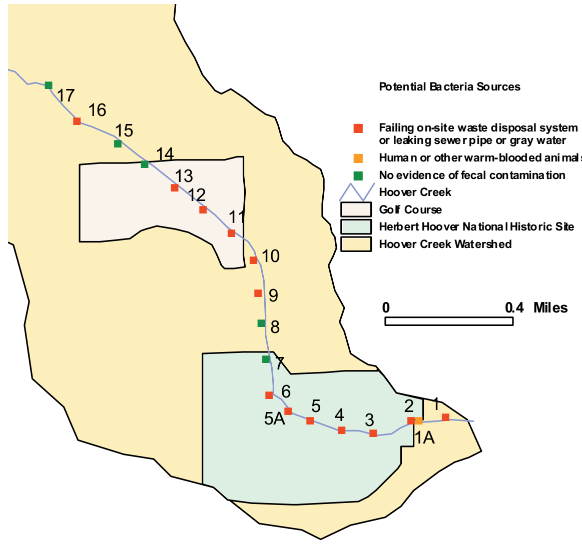


**Figure 10.** Potential sources of bacteria in the Hoover Creek watershed based on targeted bacteria sampling results.

***Metrics***

The sub-samples from each site were consolidated and macroinvertebrates were sorted in the lab and identified to family level. Five metrics were used to interpret macroinvertebrate populations in relationship to biological integrity: Macroinvertebrate Biotic Index (MBI); taxa richness; percent of families identified in Ephemeroptera, Plecoptera, and Trichoptera (EPT) orders; and the percentage of the three most dominant taxa. Benthic macroinvertebrates were also classified into categories that indicate low, medium and high quality water as a way of generalizing the water quality of the stream.

A family-level macroinvertebrate biotic index value was calculated using the following formula:

MBI = ((∑ (count in each family x family tolerance value))/total count collected)

An individual family's tolerance value (TV) indicates their relative tolerance to organic pollution on a scale of 0 to 10. Macroinvertebrates with the least tolerance to organic pollution have a TV of 0. Intolerant macroinvertebrates often have specific habitat requirements, such as high DO, low amount of organic pollutants, and coarse substrates. Macroinvertebrate families that have the most tolerance to organic pollution are assigned a TV of 10. These macroinvertebrates can survive in conditions with relatively lower amounts of dissolved oxygen, higher organic pollution, and habitats that are embedded with fine sediment. Tolerance values allow for a qualitative analysis of the water quality based on the overall index score. Higher MBI values indicate water that may be more impacted by pollution, habitat destruction, or adverse environmental conditions than water that has a lower MBI.

Taxa richness represents the overall number of different taxa identified. Generally, the more diverse the taxa is, the healthier the system. The percent of organisms within Ephemeroptera, Plecoptera, and Trichoptera orders represents the percent of organisms found to inhabit streambeds with coarse substrates. The absence of these organisms from a stream is strong evidence of


**Figure 11.** Potential sources of bacteria in Hoover Creek as it flows into the Herbert Hoover National Historic Site based on targeted bacteria sampling results. Results plotted over a digital orthophoto quadrangle (DOQ).

a water quality or stream habitat problem. The percent composition of the three most dominant taxa provides important information on family diversity and dominant feeding groups and can be an indicator of water quality.

## Results

The benthic macroinvertebrate population in Hoover Creek is dominated by organisms that indicate mostly fair or poor water quality based on MBI values. This poor/fair categorization suggests substantial water pollution or habitat deterioration is likely based on the pollution tolerance levels of the existing benthic macroinvertebrate population (Hilsenhoff 1988).

There was not much variation in the MBI values between sites (Table 5). The MBI values range from 6.0-7.1. Site 3 had the lowest index value, and site 1 had the highest value. All index values within this range indicate poor/fair water quality. Reasons for differences in MBI values likely have to do with macro and microhabitat types. Site 1 had the least amount of micro and macrohabitats available to organisms, as well as the lowest dissolved oxygen and transparency values. Site 1 was only comprised of a run and a limited number of microhabitats, such as muck, silt, and overhanging vegetation. Sites 2 through 4 had higher DO and transparency, as well as significantly higher numbers of macro and microhabitats available to organisms, and therefore, a lower MBI. These sites were comprised of a run and at least one other habitat type. They also had many types of high quality microhabitats, such as leaf packs, fallen trees, root wads, and rocks.

Although taxa richness was relatively high throughout the stream (ranging from 10-14), the diversity within the stream was low as the three most dominate taxa often comprised more than three-fourths of the population. The three most dominate taxa in all sections of the creek were macroinvertebrates that indicated low or medium water quality (left spiral snails, true bugs, sowbugs, beetles). The percent of EPT was very low throughout the stream with the highest percentage found at site 4 at only 3.9% and no EPT orders found at site 1.

Organisms were categorized individually as indicating low, medium and high water quality based on their known tolerance to pollution (Gautsch 2006) (Table 6). All Hoover Creek sites had small quantities of high quality organisms. These results are consistent with the MBI values. The majority of the macroinvertebrates in Hoover Creek are relatively pollution tolerant, indicating low or medium water quality (Figure 12). This pattern is consistent throughout the reach of the stream; although results suggest that biotic integrity may be the lowest in the upper reaches of the watershed.

**Table 5.** Metrics and results from benthic macroinvertebrate investigation, August 2006.

| Characteristic | Site 1 | Site 2 | Site 3 | Site 4 |
|---|---|---|---|---|
| Taxa Richness (# of organisms) | 11.0 | 13.0 | 14.0 | 10.0 |
| EPT Taxa Richness (# of organisms) | 0.0 | 1.0 | 1.0 | 1.0 |
| Percent EPT | 0.0 | 1.1 | 1.3 | 3.9 |
| Macroinvertebrate Biotic Index | 7.1 | 6.8 | 6.0 | 7.0 |
| Percent 3 Most Dominant Taxa | 76.7 | 71.6 | 73.7 | 84.5 |
| # of Habitat Types | 1 | 3 | 2 | 3 |
| # of Microhabitats | 4 | 10 | 8 | 11 |
| Dissolved Oxygen (mg/L) | 4 | 6 | 8 | 6 |
| Transparency (cm) | 11 | 52 | 39 | 24 |

## Discussion

The high MBI values, along with visual observations from the stream, indicate a great deal of sedimentation throughout Hoover Creek. This sedimentation depletes the quality, quantity, and diversity of microhabitats. Two weeks prior to the benthic macroinvertebrate study, Hoover Creek watershed experienced a large rainfall event that significantly increased flow in the stream. This rainfall event had the potential to disturb and deteriorate the majority of macroinvertebrates and their habitats. The populations that were found in the study are populations that could have easily reestablished themselves within a couple of weeks or were organisms that are well adapted to flashy flow regimes. Although these circumstances are specific to this particular sampling event, if Hoover Creek regularly experiences such flashy flow regimes, the increased sedimentation would decrease the stability, quality, quantity, and diversity of microhabitats, and therefore decrease the diversity of organisms found within the stream. Further investigations of benthic macroinvertebrates would be beneficial to determine trends in the biological integrity of the creek and how those trends are related to the physical and chemical health of the stream.

# PHYSICAL ASSESSMENT

## Stream Visual Assessment Protocol

A physical assessment of Hoover Creek was performed in August 2006 in order to determine the physical integrity of the stream. The Natural Resources Conservation Service's Stream Visual

**Table 6.** Categorization of benthic macroinvertebrates in Hoover Creek as indicators of water quality.

| Characteristic | Site 1 | Site 2 | Site 3 | Site 4 |
|---|---|---|---|---|
| % Low Quality Organisms | 30.7 | 35.8 | 29.6 | 44.7 |
| % Medium Quality Organisms | 69.3 | 62.1 | 69.1 | 51.5 |
| % High Quality Organisms | 0.0 | 2.1 | 1.3 | 3.9 |
| # of Habitat Types | 1 | 3 | 2 | 3 |
| # of Microhabitats | 4 | 10 | 8 | 11 |
| Dissolved Oxygen (mg/L) | 4 | 6 | 8 | 6 |
| Transparency (cm) | 11 | 52 | 39 | 24 |

Assessment Protocol was used to measure the physical health of Hoover Creek (USDA 1998). This assessment provides a basic level of stream health evaluation by assessing multiple stream characteristics and combining all the assessments into an overall score that rates the physical integrity of the stream.

Fifteen stream reaches were analyzed along the stretch of Hoover Creek from monitoring site 1 to site 4 (Figure 1). A stream reach was defined as 12 times the active channel width; if conditions changed drastically within the allotted stretch of stream, the stream reach was divided further into two segments in order to capture that diversity in the assessment. Nine to eleven characteristics were looked for and assessed, if found, in each reach. The following characteristics were assessed: channel condition, hydrologic alteration (channel incision, flooding regimes), riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, in-stream fish cover, pools, canopy cover, and riffle embeddedness. Each assessment element was rated with a value of 1 to 10, 1 indicating poorer physical health and 10 indicating better physical health. Reaches were scored based on qualitative descriptions of the conditions associated with each score for each assessment element. The overall assessment score was determined by adding values for each element and dividing by the number of elements assessed. This quantitative score was then applied to a rating scale that rates the physical integrity of the stream as either poor, fair, good, or excellent.

## Results

Overall stream condition scores for Hoover Creek ranged from 2.1 to 6.1 (Table 7). All but one of the fifteen stream reaches assessed were rated as having poor physical integrity (scores less than or equal to 6.0) and that was assessed as having merely a fair physical quality. There

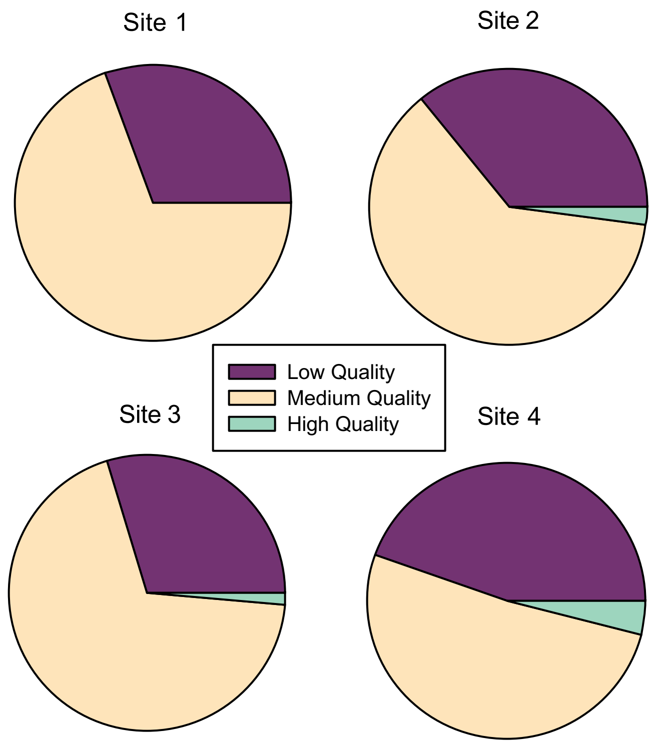


**Figure 12.** Distribution of the type of benthic macroinvertebrates present in Hoover Creek, August 2006.

was not a significant spatial pattern to the ratings of these reaches as scores were not particularly variable. The assessment factors that have the most influence on the poor physical rating (the elements with the lowest scores) tended to be the amount of hydrologic alteration, absence of pools and canopy cover, and the embeddedness of the substrate within the stream. Table 7 summarizes the different scores for each of the elements.

The scores offer important information about the physical health of the stream. The stream is generally characterized as having a low diversity of in-stream habitat with most of the stream being characterized by runs. Riffle and pool habitats are less frequently found, and where present, much of them are highly embedded with sediment. The majority of substrate is composed of mud and silt. These factors indicate that there is a lot of erosion in the stream that has caused streambeds to become embedded with sediment. Many of the stream reaches are also characterized by banks that are actively eroding. Bank height ranged from 2 feet to 15 feet with an average bank height of 6.5 feet. This average bank height usually characterizes vertical banks that are not stable. Further evidence of erosion was relatively wide stream channels with the maximum channel width of 24 feet. Most of the reaches were surrounded by small riparian areas with low growing and shallow rooted plants. The lack of a natural riparian area with a diverse plant community facilitates increases in sediment loading and erosional processes that negatively impact the physical integrity of Hoover Creek.

## Discussion

The rating of poor physical health for Hoover Creek indicates a stream that has dynamic surface water flow regimes. The higher speed and volume of water entering the stream during rainfall events generally creates poor physical integrity by causing channel and streambed erosion,

**Table 7.** Ranking of physical integrity of Hoover Creek via Stream Visual Assessment Protocol.

| Statistic | Channel Condition | Hydrologic Alteration | Riparian Zone | Bank Stability | Water Appearance | Nutrient Enrichment |
|---|---|---|---|---|---|---|
| Minimum | 1 | 1 | 1 | 1 | 3 | 3 |
| Median | 3 | 1 | 3 | 3 | 7 | 7 |
| Maximum | 7 | 1 | 10 | 7 | 7 | 7 |

| Statistic (con't) | Barriers to fish movement | In-stream fish cover | Pools | Canopy Cover | Riffle embedded-ness | Overall Score* |
|---|---|---|---|---|---|---|
| Minimum | 1 | 1 | 1 | 1 | 1 | 2.1 |
| Median | 10 | 3 | 1 | 1 | 5 | 5.1 |
| Maximum | 10 | 8 | 7 | 10 | 5 | 6.1 |

***Overall score values:**

≤6.0 Poor
6.1-7.4 Fair
7.5-8.9 Good
≥9.0 Excellent

sedimentation, channel widening, and destruction of macro and microhabitats. These physical characteristics of the stream have implications for degrading water quality by potentially increasing nutrient, sediment, and bacteria loads. Flashy flow regimes, sedimentation and erosion also can decrease biological integrity by decreasing quality and quantity of habitat available to aquatic life.

## CONCLUSIONS

Above normal temperatures and dry conditions characterized the Hoover Creek watershed through the duration of the monitoring project. Sampling ceased for a large portion of 2005 as a result of the stream running dry. Hoover Creek can be characterized as having a very flashy flow regime with generally baseflow conditions that are interrupted by brief, high-flow events. The consequence of such a flashy system is reflected in low biological and physical integrity. A physical assessment of the stream characterized the creek as having poor physical integrity because of hydrologic alteration, absence of pools and canopy cover, and the embeddedness of the substrate within the stream. This embeddedness decreases the stability, quality, quantity, and diversity of microhabitats available to aquatic life. As such, the diversity of benthic macroinvertebrate populations found in Hoover Creek was low, and most of the organisms found were pollution tolerant and able to adapt to extreme changes in their physical environment.

Water monitoring results indicate elevated nitrate+nitrite-N, bacteria, turbidity, and total suspended solids concentrations. Many of the results exceeded current and recommended water quality standards for these parameters. Nutrients and suspended solids were particularly high in the upstream portion of the watershed, where landuse is predominantly agricultural and the potential for nonpoint source pollution is high. Nutrient load duration calculations suggest that the flashy system has a considerable impact on water quality by significantly increasing nutrient loads following large rain events.

Results from the targeted bacteria sampling suggest that some of the bacteria in Hoover

Creek is likely from humans. Areas that suggest potentially strong indications of human fecal contamination are sites within Herbert Hoover National Historic Site. These sites consistently indicate that high bacteria levels likely result from failing on-site waste disposal systems, leaking sewer pipes, or gray water. Additional sampling is suggested within the park in order to improve understanding of bacteria levels and sources.

Under Section 303(d) of the Clean Water Act, the State of Iowa is required to submit a list of all waters that do not meet state water quality standards. Data collected as part of this project indicates that Hoover Creek, if it did fall under the new rules for water quality standards, would be violation of the bacteria standard 69% of the time and in violation of the recommended nitrate+nitrite-N standard 84% of the time. Non-point source and point source pollution are both contributing to these high values. Further bacteria monitoring in the watershed is recommended, as well as riparian restoration and erosion mitigation within and around the creek.

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# APPENDIX A.

Water quality results statistics for all sites
for each year from 2004 through 2006.

| 2004 Statistics | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 28 | 28 | 28 | 28 | 28 | 24 | 24 | 0 |
| Minimum | 180 | 4.4 | <0.05 | 0.2 | 7 | 2.6 | 8.7 | * |
| 10th Percentile | 200 | 5.4 | <0.05 | 0.3 | 8 | 3.1 | 8.8 | * |
| 25th Percentile | 260 | 7.3 | <0.05 | 0.3 | 10 | 3.3 | 9.2 | * |
| 50th Percentile | 460 | 9.0 | <0.05 | 0.3 | 11 | 6.8 | 13.5 | * |
| 75th Percentile | 650 | 11.5 | <0.05 | 0.4 | 15 | 8.0 | 16.5 | * |
| 90th Percentile | 858 | 13.0 | <0.05 | 0.5 | 23 | 8.3 | 19.1 | * |
| Maximum | 2,900 | 15.0 | 0.07 | 0.5 | 31 | 9.4 | 20.1 | * |
| | | | | | | | | ** Not Sampled* |

| 2005 Statistics | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 28 | 28 | 28 | 28 | 28 | 24 | 28 | 16 |
| Minimum | <10 | 6.8 | <0.05 | 0.1 | 3 | 6.4 | 1.0 | 2 |
| 10th Percentile | <10 | 7.3 | <0.05 | 0.2 | 3 | 6.9 | 2.8 | 4 |
| 25th Percentile | 25 | 7.9 | <0.05 | 0.2 | 6 | 7.9 | 4.5 | 6 |
| 50th Percentile | 110 | 8.6 | <0.05 | 0.3 | 11 | 8.6 | 16.4 | 9 |
| 75th Percentile | 1,013 | 9.6 | <0.05 | 0.3 | 17 | 10.0 | 17.7 | 12 |
| 90th Percentile | 1,880 | 11.0 | <0.05 | 0.4 | 27 | 10.8 | 18.9 | 25 |
| Maximum | 4,300 | 11.0 | 0.1 | 0.5 | 30 | 11.1 | 20.3 | 47 |

| 2006 Statistics | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 24 | 24 | 24 | 24 | 24 | 16 | 24 | 24 |
| Minimum | 50 | 0.2 | <0.05 | 0.2 | 2 | 4.3 | 4.0 | 2 |
| 10th Percentile | 343 | 0.4 | <0.05 | 0.3 | 6 | 5.5 | 4.6 | 8 |
| 25th Percentile | 598 | 0.6 | <0.05 | 0.5 | 10 | 6.3 | 13.7 | 10 |
| 50th Percentile | 1,600 | 4.4 | <0.05 | 0.7 | 18 | 7.5 | 18.7 | 26 |
| 75th Percentile | 3,475 | 8.6 | 0.1 | 0.9 | 35 | 9.4 | 20.5 | 42 |
| 90th Percentile | 22,700 | 9.2 | 0.1 | 2.2 | 887 | 10.5 | 21.1 | 626 |
| Maximum | 29,000 | 12.0 | 0.7 | 5.4 | >1,000 | 11.1 | 21.9 | 4,440 |

# APPENDIX B.

Water quality results statistics at each site
from 2004 through 2006.

| Site 1 Statistic | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 20 | 20 | 20 | 20 | 20 | 16 | 19 | 10 |
| Minimum | <10 | 0.4 | <0.05 | 0.1 | 2 | 2.6 | 3.2 | 2 |
| 10th Percentile | 9 | 3.4 | <0.05 | 0.2 | 6 | 3.8 | 4.5 | 7 |
| 25th Percentile | 160 | 9.1 | <0.05 | 0.3 | 8 | 5.6 | 9.9 | 11 |
| 50th Percentile | 460 | 10.5 | <0.05 | 0.4 | 17 | 7.5 | 16.2 | 29 |
| 75th Percentile | 1,400 | 11.3 | <0.05 | 0.5 | 26 | 9.6 | 17.8 | 46 |
| 90th Percentile | 5,040 | 12.1 | <0.05 | 1.7 | 39 | 10.7 | 20.1 | 570 |
| Maximum | 22,000 | 15.0 | 0.7 | 5.4 | >1,000 | 11.1 | 21.1 | 4,440 |

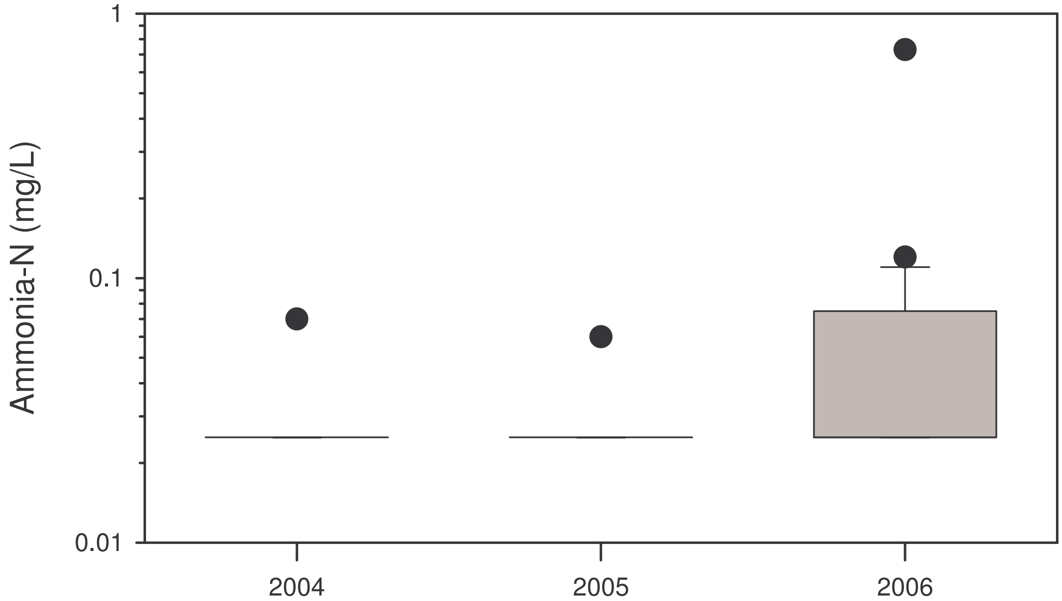
| Site 2 Statistic | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 20 | 20 | 20 | 20 | 20 | 16 | 19 | 10 |
| Minimum | <10 | 0.6 | <0.05 | 0.2 | 4 | 2.7 | 1.9 | 6 |
| 10th Percentile | 28 | 1.2 | <0.05 | 0.3 | 6 | 4.6 | 4.5 | 9 |
| 25th Percentile | 175 | 6.4 | <0.05 | 0.3 | 10 | 6.3 | 9.4 | 11 |
| 50th Percentile | 425 | 8.6 | <0.05 | 0.4 | 13 | 7.7 | 16.5 | 13 |
| 75th Percentile | 760 | 9.6 | <0.05 | 0.5 | 16 | 8.7 | 19.1 | 24 |
| 90th Percentile | 1,950 | 10.0 | <0.05 | 0.7 | 22 | 9.9 | 20.3 | 67 |
| Maximum | 24,000 | 14.0 | 0.1 | 2.2 | 623 | 9.9 | 21.3 | 360 |

| Site 3 Statistic | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 20 | 20 | 20 | 20 | 20 | 16 | 19 | 10 |
| Minimum | <10 | 0.5 | <0.05 | 0.2 | 3 | 3.2 | 1.7 | 3 |
| 10th Percentile | 53 | 0.6 | <0.05 | 0.3 | 5 | 4.6 | 4.2 | 6 |
| 25th Percentile | 145 | 5.8 | <0.05 | 0.3 | 8 | 7.0 | 9.1 | 8 |
| 50th Percentile | 450 | 7.9 | <0.05 | 0.4 | 11 | 8.1 | 16.5 | 10 |
| 75th Percentile | 1,150 | 8.7 | <0.05 | 0.4 | 17 | 9.3 | 18.6 | 21 |
| 90th Percentile | 2,520 | 9.8 | 0.1 | 0.5 | 27 | 10.5 | 20.3 | 105 |
| Maximum | 29,000 | 13.0 | 0.1 | 2.2 | >1,000 | 11.1 | 21.9 | 810 |

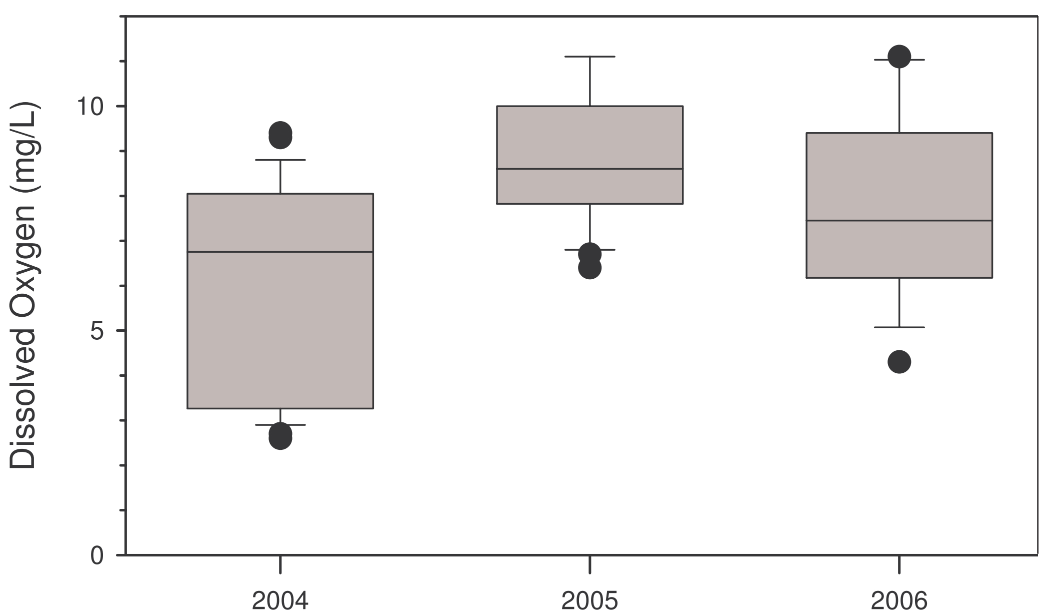
| Site 4 Statistic | *E. coli* (CFU/100 ml) | Nitrate+Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Water Temperature (℃) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Count | 20 | 20 | 20 | 20 | 20 | 16 | 19 | 10 |
| Minimum | 64 | 0.2 | <0.05 | 0.2 | 3 | 3.1 | 1.0 | 2 |
| 10th Percentile | 158 | 0.5 | <0.05 | 0.2 | 7 | 4.5 | 4.4 | 5 |
| 25th Percentile | 405 | 5.3 | <0.05 | 0.3 | 9 | 6.8 | 8.7 | 6 |
| 50th Percentile | 650 | 7.4 | <0.05 | 0.3 | 13 | 8.0 | 16.3 | 11 |
| 75th Percentile | 2,600 | 8.3 | <0.05 | 0.5 | 21 | 9.2 | 18.5 | 28 |
| 90th Percentile | 3,820 | 9.0 | 0.05 | 0.7 | 28 | 9.7 | 19.6 | 112 |
| Maximum | 23,000 | 12.0 | 0.1 | 1.9 | >1,000 | 11.1 | 20.5 | 740 |

# APPENDIX C.

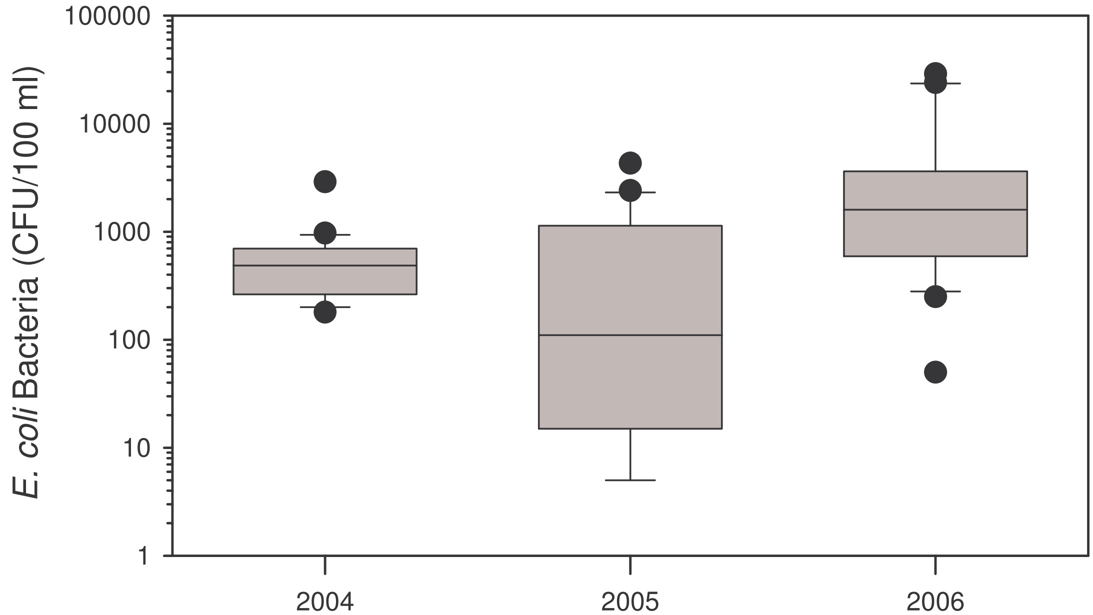
Box plots of water quality results
for each year from 2004 through 2006.

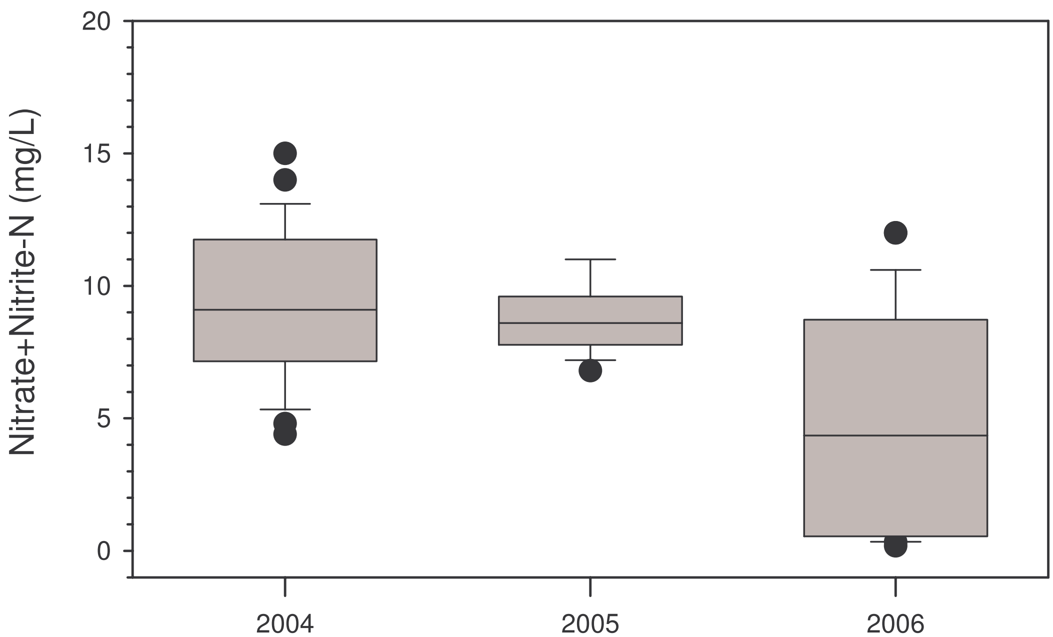


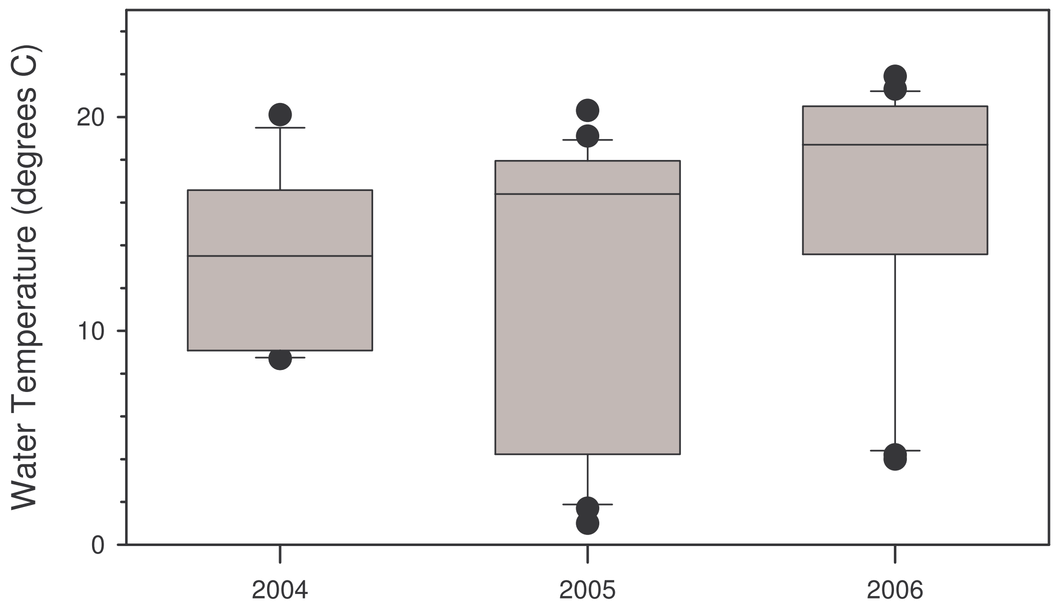
Ammonia-N (mg/L)
1
0.1
0.01
2004
2005
2006

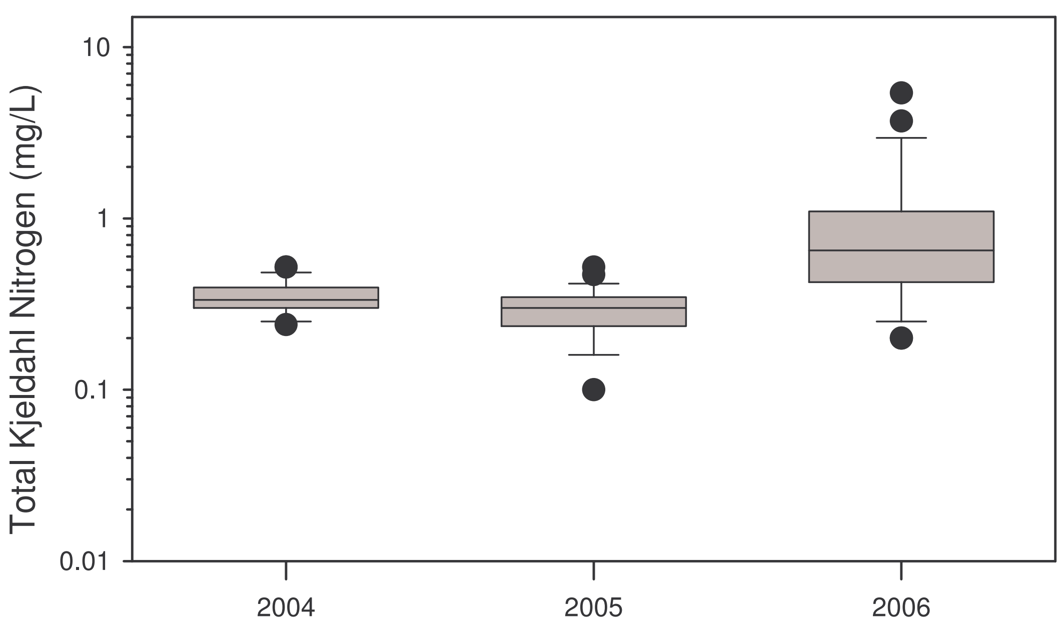



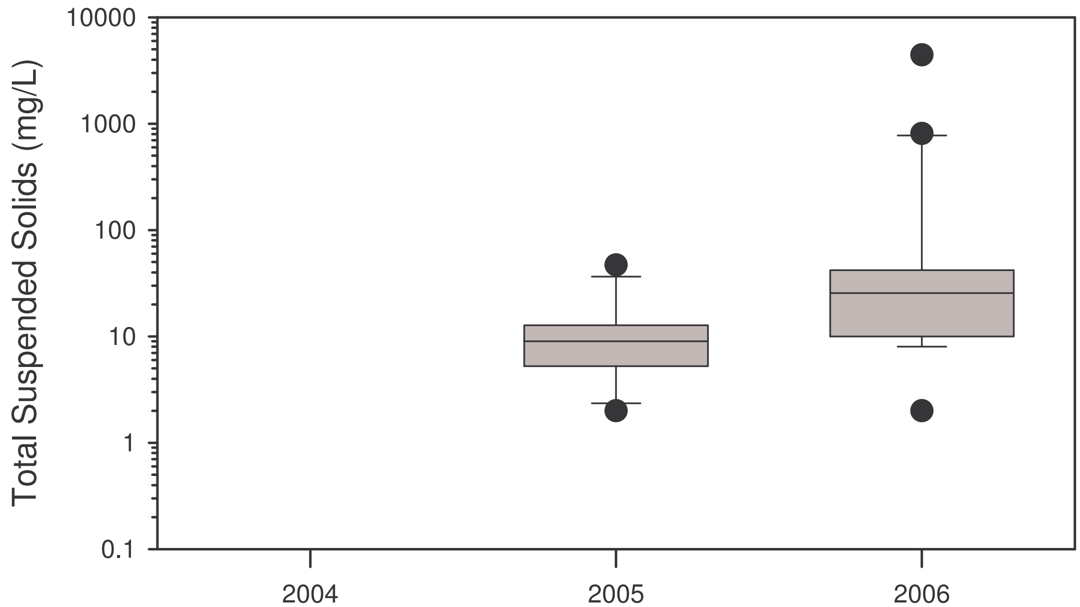
Dissolved Oxygen (mg/L)
10
5
0
2004
2005
2006

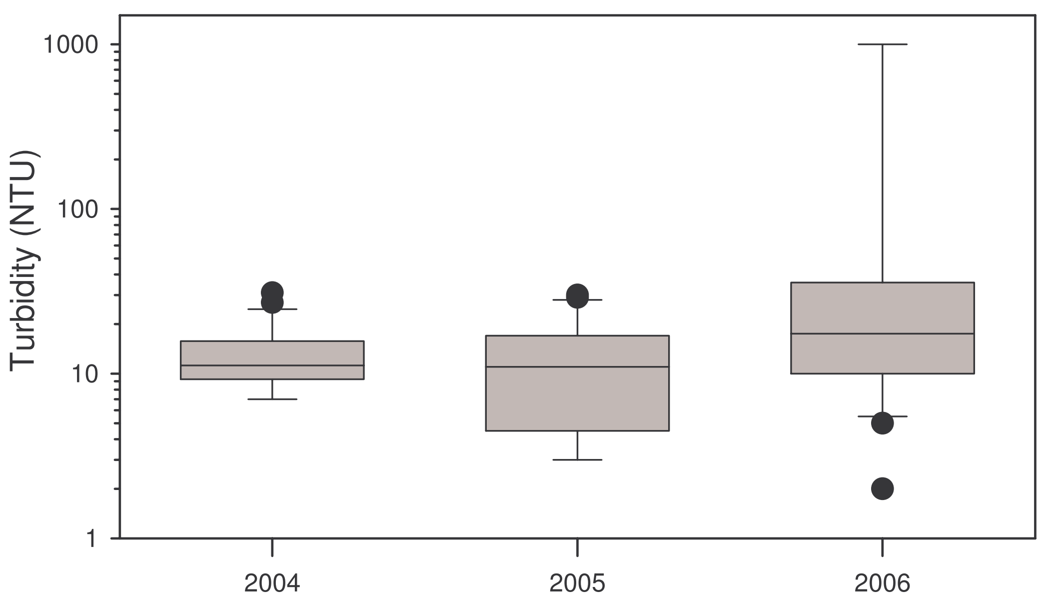

E. coli Bacteria (CFU/100 ml)
100000
10000
1000
100
10
1
2004
2005
2006


Nitrate+Nitrite-N (mg/L)
20
15
10
5
0
2004
2005
2006


Water Temperature (degrees C)
20
10
0
2004
2005
2006

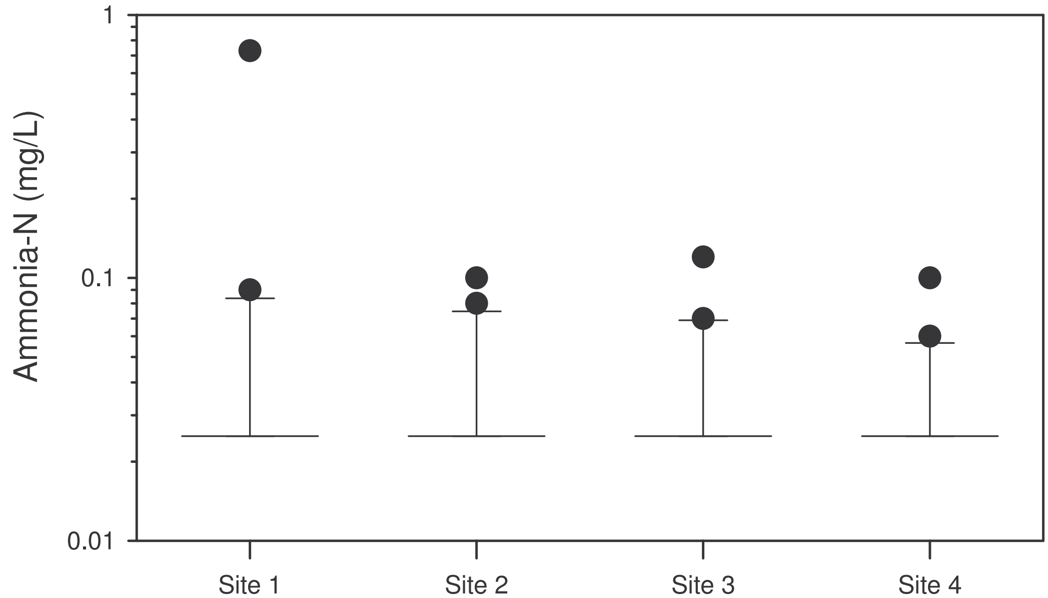

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
2004
2005
2006


10000
1000
100
10
1
0.1
Total Suspended Solids (mg/L)
2004
2005
2006

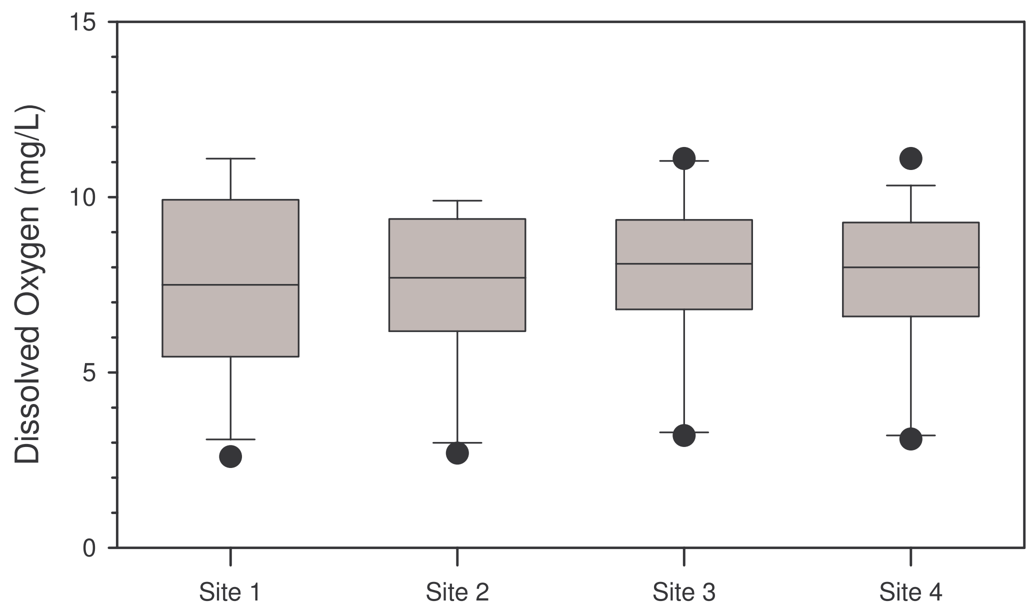

1000
100
10
1
Turbidity (NTU)
2004
2005
2006

# APPENDIX D.

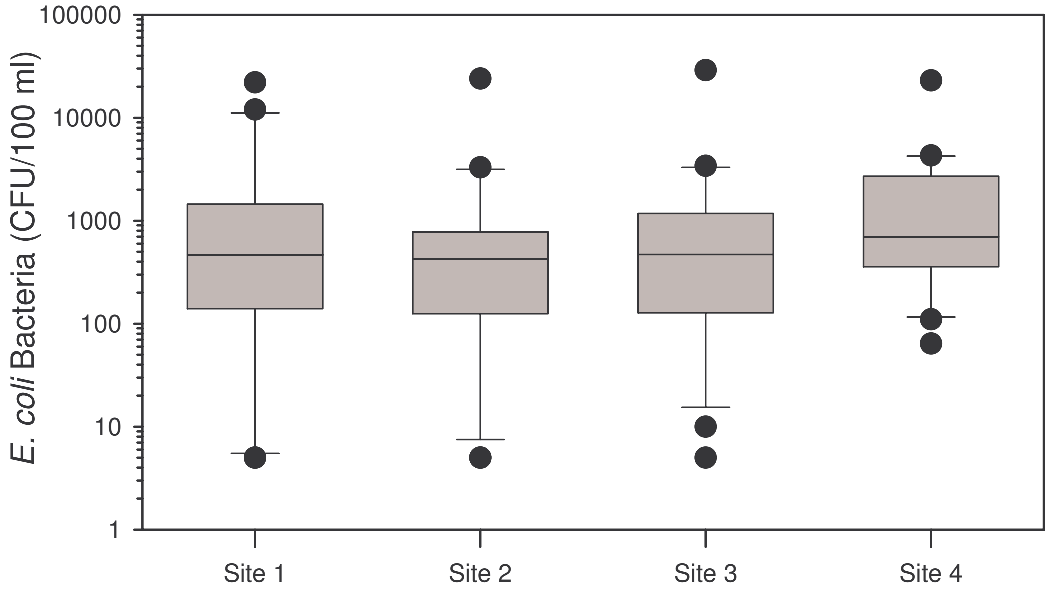
Box plots of water quality results
for each site from 2004 through 2006.

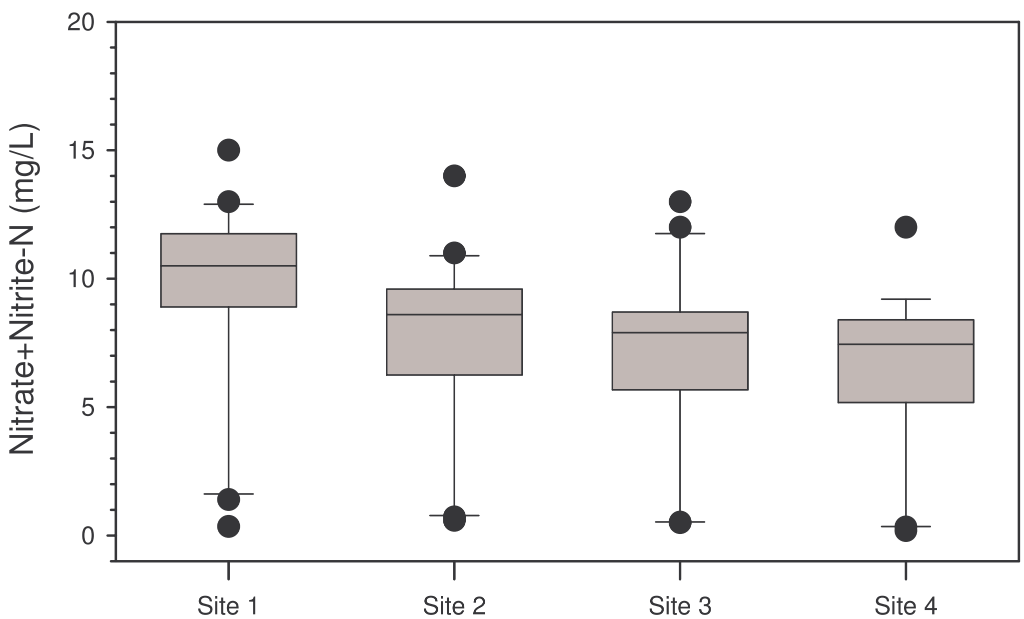


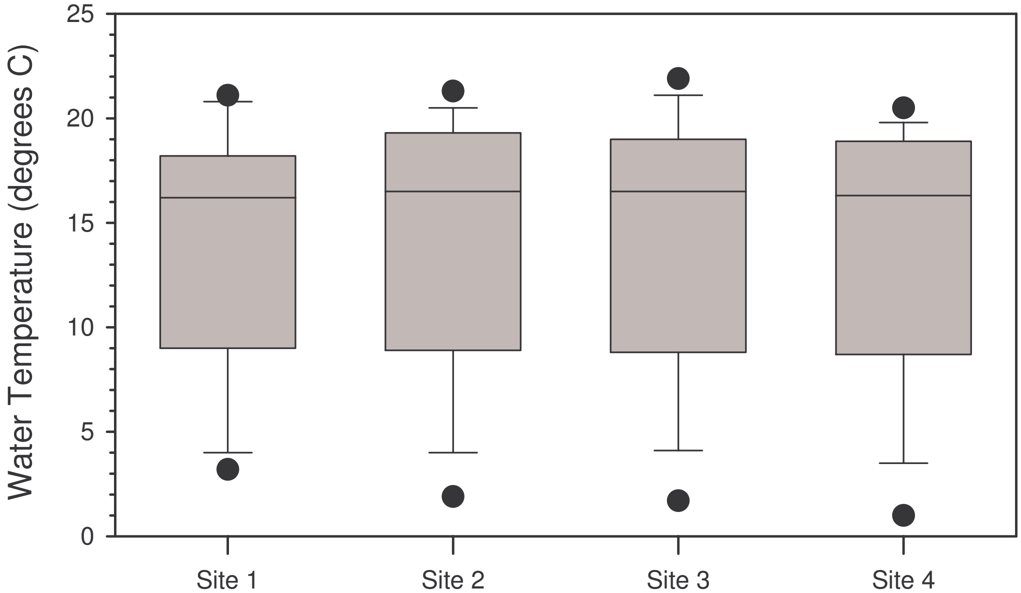
Ammonia-N (mg/L)
1
0.1
0.01
Site 1
Site 2
Site 3
Site 4

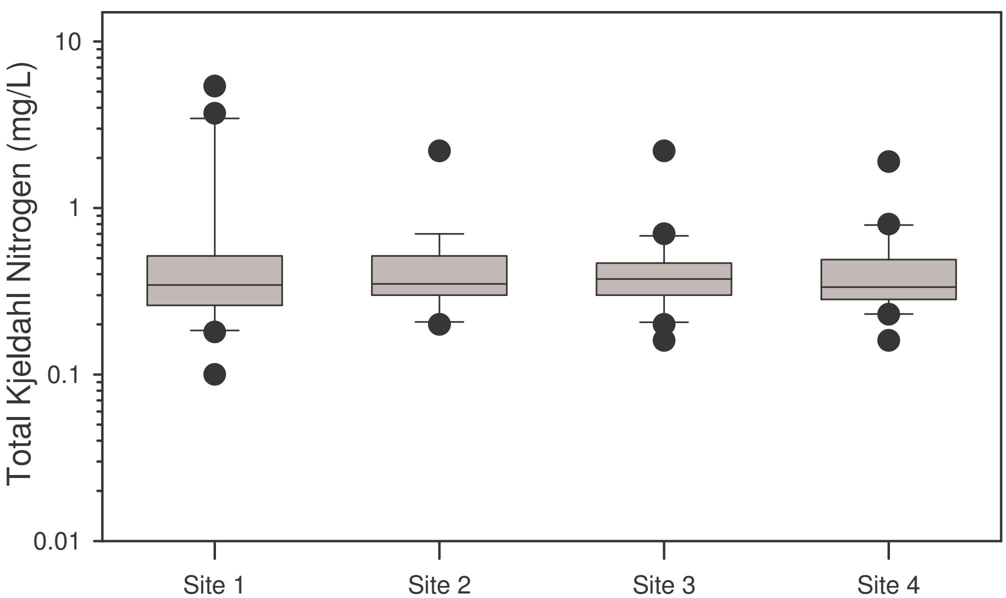



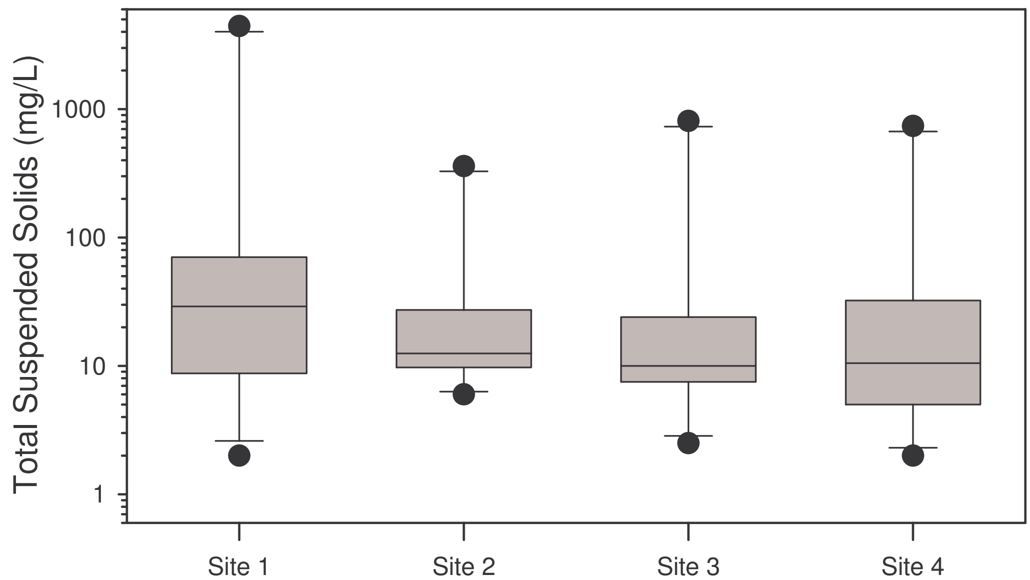
Dissolved Oxygen (mg/L)
15
10
5
0
Site 1
Site 2
Site 3
Site 4

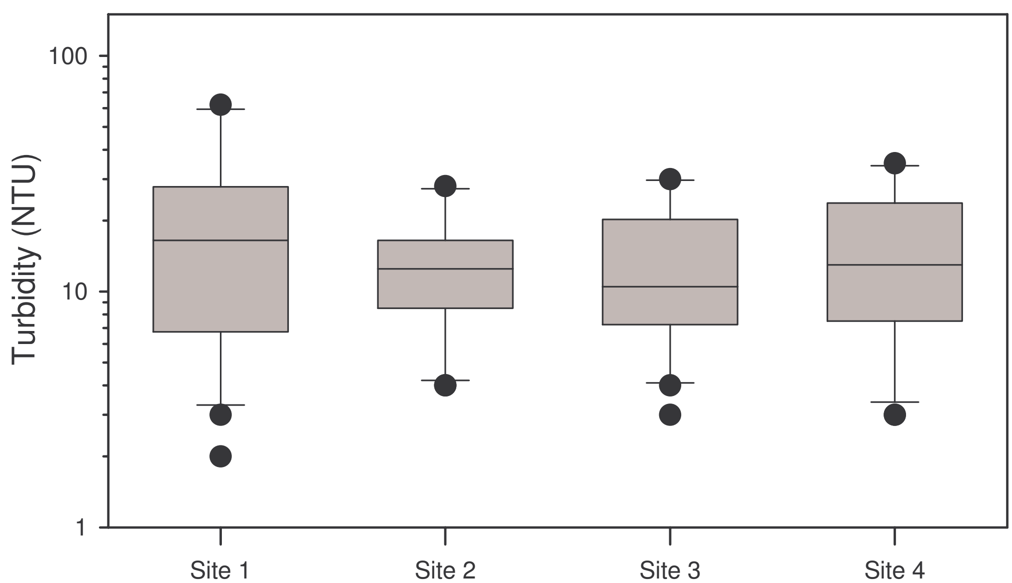

100000
10000
1000
100
10
1
E. coli Bacteria (CFU/100 ml)
Site 1
Site 2
Site 3
Site 4


20
15
10
5
0
Nitrate+Nitrite-N (mg/L)
Site 1
Site 2
Site 3
Site 4


Water Temperature (degrees C)
25
20
15
10
5
0
Site 1
Site 2
Site 3
Site 4

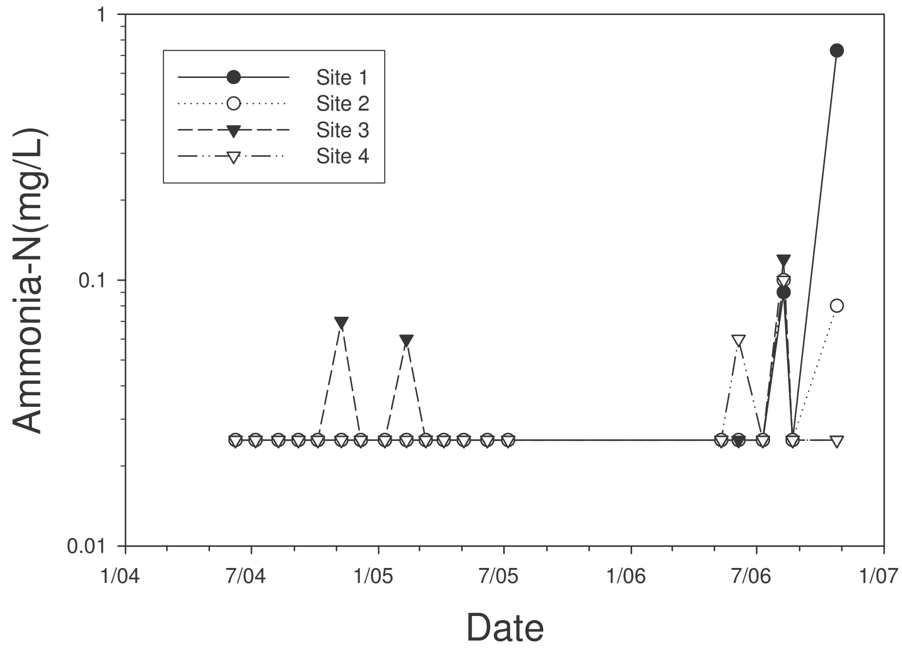

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
Site 1
Site 2
Site 3
Site 4


Total Suspended Solids (mg/L)
1000
100
10
1
Site 1
Site 2
Site 3
Site 4

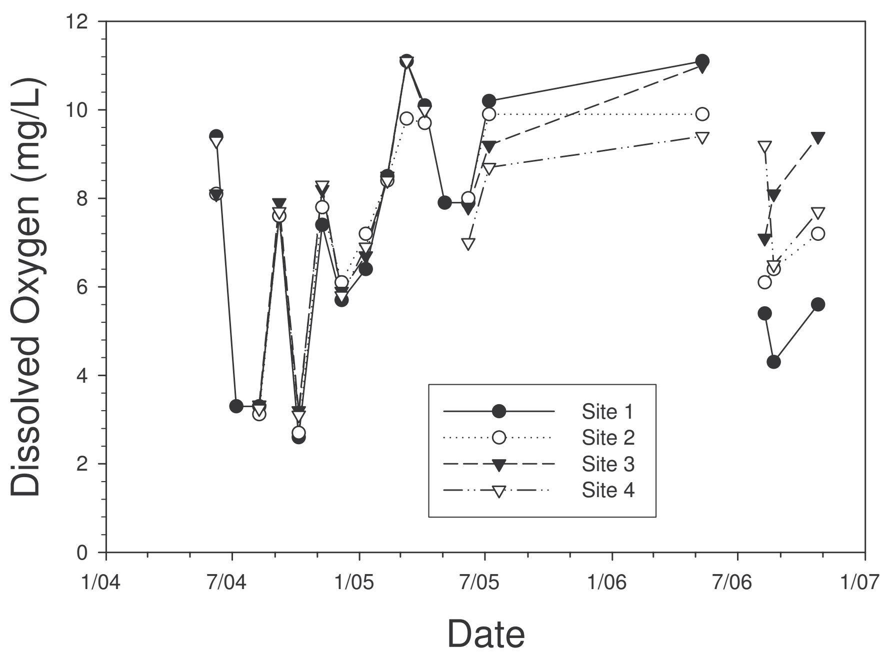

Turbidity (NTU)
100
10
1
Site 1
Site 2
Site 3
Site 4

# APPENDIX E.

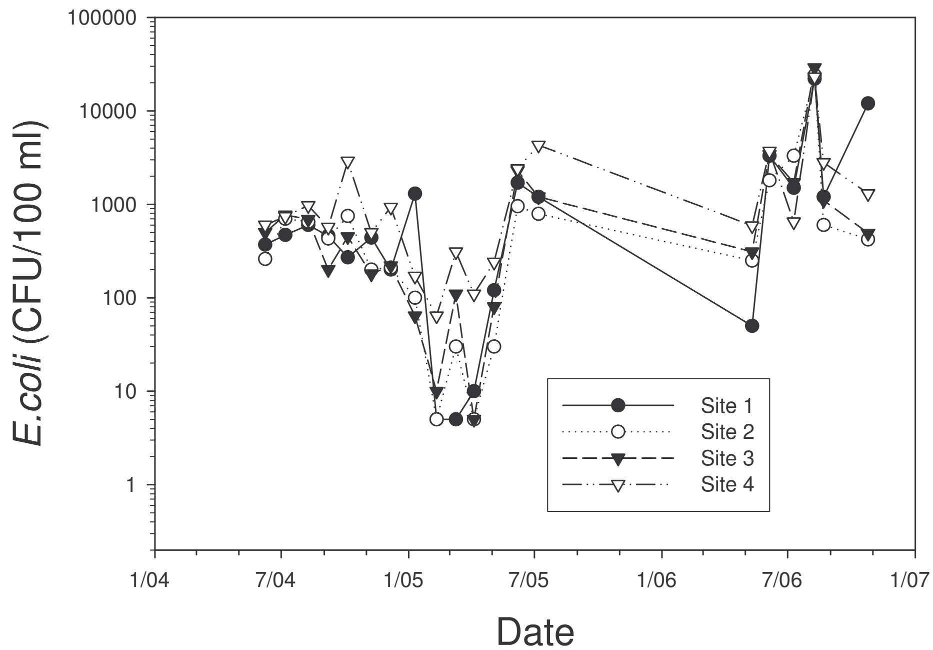
Temporal variations in water quality results
from 2004 through 2006.

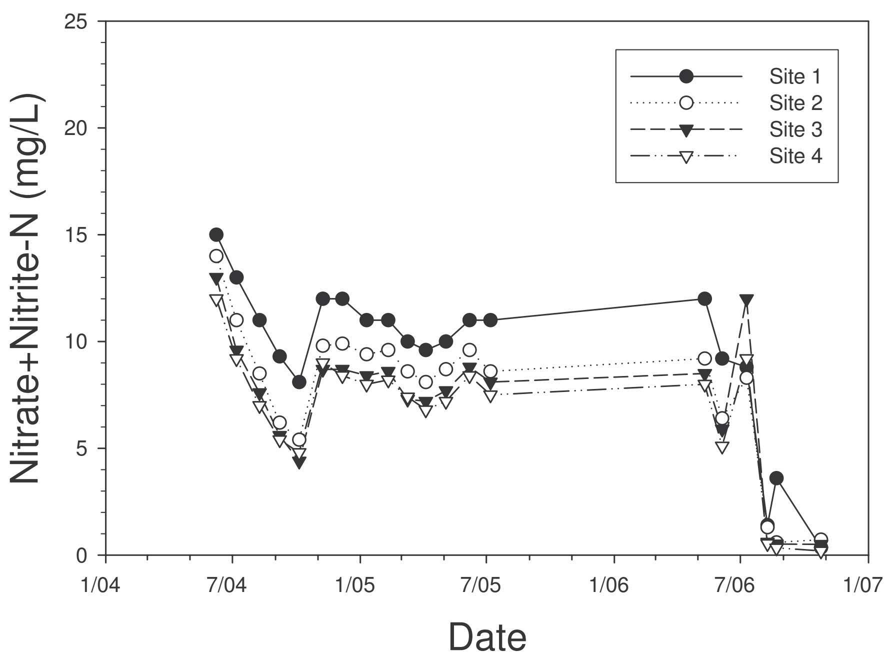


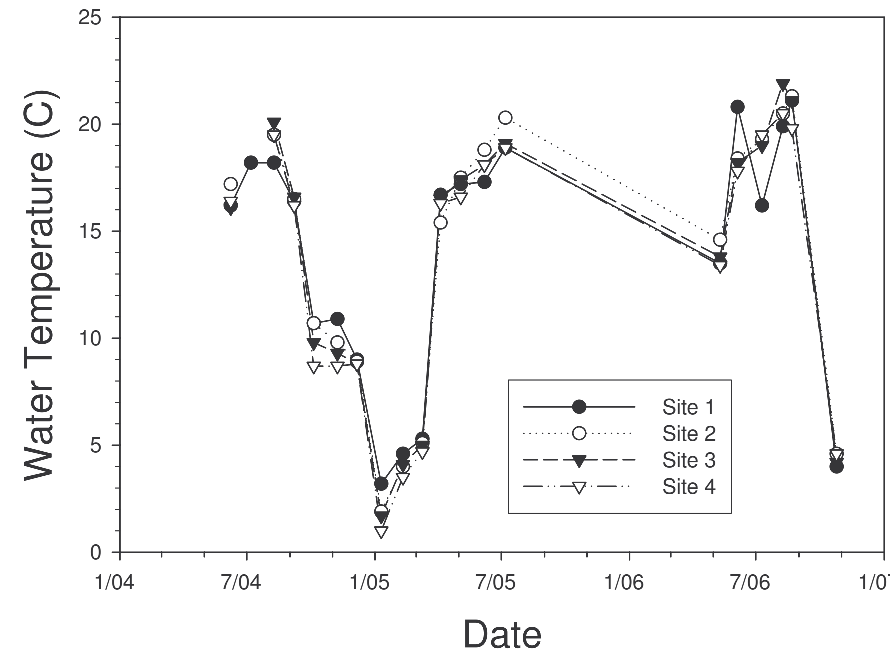
Ammonia-N(mg/L)
1
0.1
0.01
Site 1
Site 2
Site 3
Site 4
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date

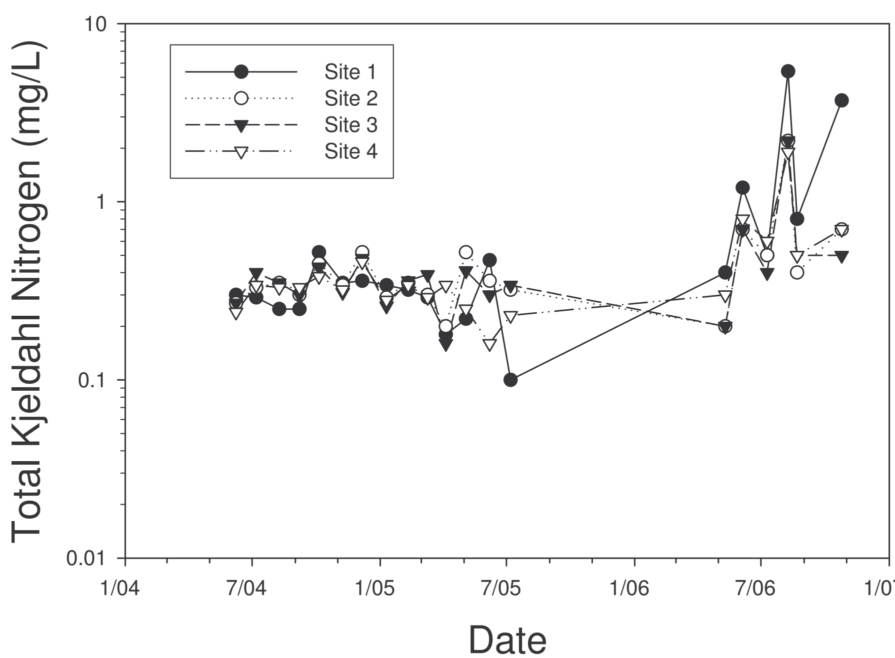
Dissolved Oxygen (mg/L)
12
10
8
6
4
2
0
Site 1
Site 2
Site 3
Site 4
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date


100000
10000
1000
100
10
1
E.coli (CFU/100 ml)
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date
Site 1
Site 2
Site 3
Site 4

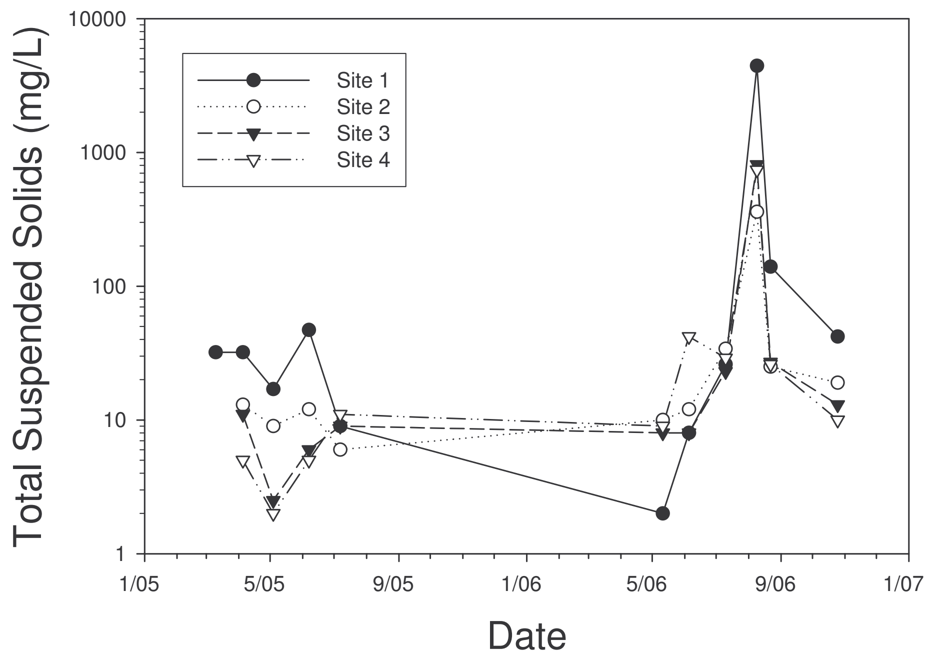

25
20
15
10
5
0
Nitrate+Nitrite-N (mg/L)
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date
Site 1
Site 2
Site 3
Site 4

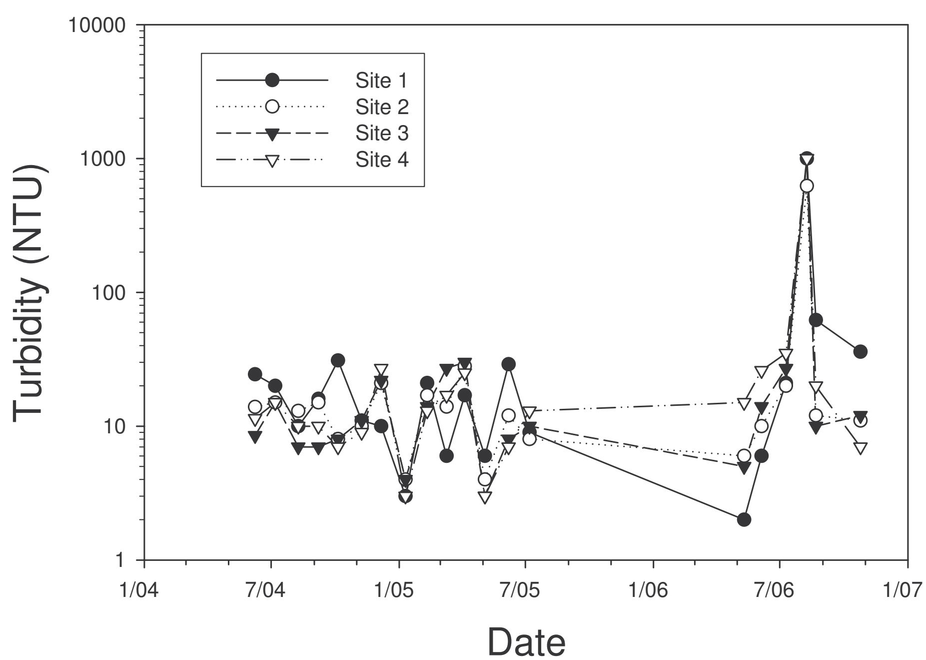


Water Temperature (C)
25
20
15
10
5
0
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date
Site 1
Site 2
Site 3
Site 4

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date
Site 1
Site 2
Site 3
Site 4


Total Suspended Solids (mg/L)
10000
1000
100
10
1
Site 1
Site 2
Site 3
Site 4
1/05
5/05
9/05
1/06
5/06
9/06
1/07
Date


Turbidity (NTU)
10000
1000
100
10
1
Site 1
Site 2
Site 3
Site 4
1/04
7/04
1/05
7/05
1/06
7/06
1/07
Date

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