NUTRIENTS, CHLOROPHYLL AND BACTERIAL FECAL INDICATORS IN COVES AND OPEN WATER AREAS OF LAKE OF THE OZARKS, MISSOURI

A Thesis presented to the Faculty of the Graduate School at the

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In Partial Fulfillment of the Requirements for the Degree

Master of Science

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by

REBECCA O'HEARN

Dr. John R. Jones, Thesis Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

NUTRIENTS, CHLOROPHYLL AND BACTERIAL FECAL INDICATORS IN COVES AND OPEN WATER AREAS OF LAKE OF THE OZARKS, MISSOURI

presented by Rebecca O'Hearn,

a candidate for the degree of master of science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor John R. Jones

Professor Matthew F. Knowlton

Professor Robert J. Kremer

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Rebecca O'Hearn

Dr. John R. Jones, Thesis Supervisor

ABSTRACT

Lake of the Ozarks was constructed for hydropower and has become a popular recreational river-reservoir in the Ozark Plateau of Missouri. Wide spread use of septic tanks in porous soils of the region poses a threat to public health via leaching into drinking wells and coves used for whole body contact. During summers 2007 and 2008, phosphorus (TP), nitrogen (TN), chlorophyll (Chl), fecal coliform (FC), and *Escherichia coli* (EC) were measured in 35 coves and 3 main channel sites in the Grand Glaize-Turkey Bend area of the reservoir to assess anthropogenic influences on water quality in coves. *Bacteroides thetaiotaomicron* (BT), an obligate human gut anaerobic bacterium, was concurrently monitored to determine the specificity of conventional fecal indicators (FC and EC). Record discharges were recorded for both summers and relationships between anthropogenic metrics and water quality variables (TP, TN, Chl, FC and EC) were not apparent. Steady increases in pool level throughout sampling created backflow from the main channel into coves and likely diluted local anthropogenic influences among coves. In a cross-cove regression on the main-stem of the study reach (28 coves), location of a cove relative to the dam accounted for 74% of the variation in TP, about half the variation in TN (48%) and Chl (50%), 29% of the variation in FC and 21% of the variation in EC. Among these coves, TP, TN, Chl, FC and EC declined from up- to down-reservoir, which reflected basin sedimentary processes typical of large riverine reservoirs. In a regression analysis of daily means, local wind speed accounted for a large percentage of the variation in FC (69%) and EC (86%), and a local rain event elevated site means for FC and EC. The obligate human gut anaerobe (BT) did not decline from up- to down-reservoir, was not positively related to wind speed, and was not influenced by the rain event. Unlike TP, TN, Chl, and conventional fecal indicators, BT was positively related to a surrogate for anthropogenic activity among daily means. These results indicate 1) conventional fecal indicators (FC and EC) often represent bacteria from soil erosion and sediment resuspension. Factors controlling these processes often dilute or obscure anthropogenic influences, and 2) relationships between BT and anthropogenic factors are not obscured by hydrologic and climatic processes, which allows detection of anthropogenic influences during circumstances when conventional fecal indicators (FC and EC) fail to detect them.

INTRODUCTION

Lake of the Ozarks is a 24,100 ha river-reservoir located in west-central Missouri in the Ozark Highlands (Jones and Novak 1981, Figure 1). The basin is composed of soluble dolomite bedrock with numerous springs, caves, and sinkholes in porous karst topography. Flow is west to east along the Osage River, the main stem. Lake of the Ozarks was formed in 1931 with the completion of Bagnell Dam, a hydro-electric facility. Flooding of the steep valleys in the basin created a highly convoluted shoreline (shoreline development index=38, Mitzelfelt 1985) with hundreds of coves branching off the main stem. The large watershed drains two major physiographic regions; the agricultural Osage Plains are located in the headwaters, and the forested Ozark Highlands surround the basin (Jones et al. 2008a). Lake of the Ozarks ranges from mesotrophic to eutrophic, which is consistent with trophic state characteristics of impoundments in the Osage Plains and Ozark Highlands (Perkins and Jones 2000, Jones et al. 2008b).

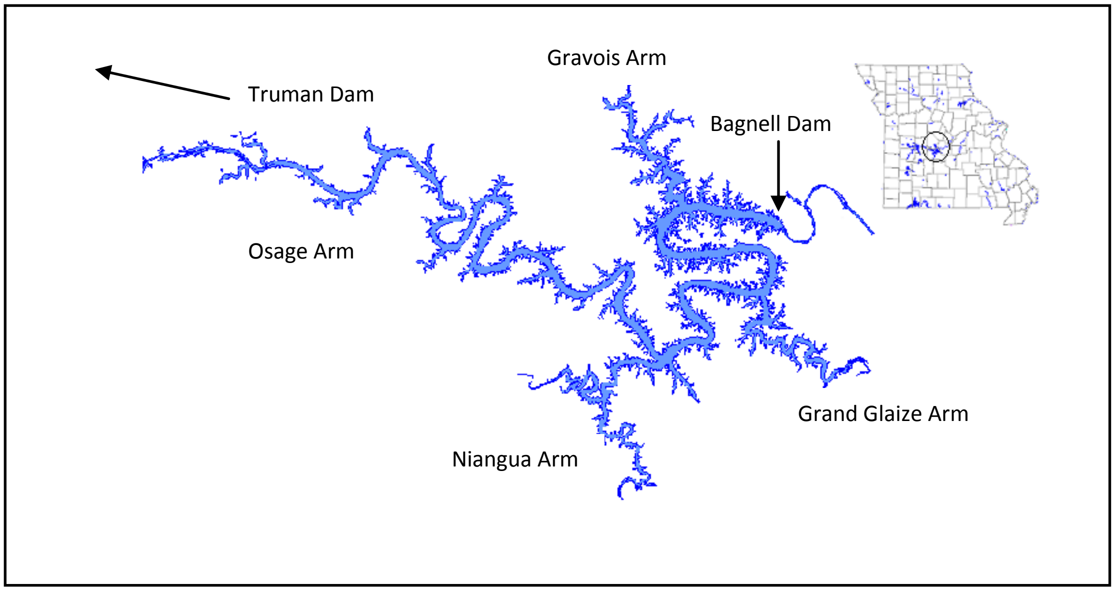


Figure 1. Map of Lake of the Ozarks and respective arms; Osage Arm, Niangua Arm, Grand Glaize Arm, and Gravois Arm. Bagnell Dam is located down-reservoir on the Osage Arm and Truman Dam is located up-reservoir on the Osage Arm.

The first comprehensive limnological studies on Lake of the Ozarks assessed the effects of Truman Dam (completed in 1979) on water quality. Prior to completion of Truman Dam, Walker (1974) reported phosphorus concentrations in sediments were larger near Bagnell Dam than up-reservoir. Crisp (1977) found total and dissolved phosphorus, total and dissolved nitrogen, chlorophyll, and turbidity in sites closer to Bagnell Dam were lower than sites up-reservoir. Jones and Novak (1981) used data from 1976-1979 to describe this pattern as a longitudinal gradient from the headwaters to Bagnell Dam, with the headwaters most turbid and nutrient rich. Jones and Novak (1981) also described the main stem as more turbid and nutrient rich than arms formed by minor tributaries. Pamperl (1980) collected baseline data on diatoms before construction of Truman Dam, and found the diatom community also varied in conjunction with nutrients and turbidity. Diversity and diatom richness decreased with distance down-reservoir. Pamperl (1980) also described the influence of flow on water quality and diatom communities in the reservoir; the longitudinal trends were obscured in 1977 when flushing rate was about 10 times greater than normal. After construction of Truman Dam, phosphorus decreased and chlorophyll increased (Jones and Kaiser 1988), suggesting productivity of Lake of the Ozarks increased in response to reduced suspended solids, which were settling in Truman Lake. This reduction in suspended material increased water clarity and light availability for algal cells (Perkins and Jones 2000).

While most research on Lake of the Ozarks quantified trophic state and temporal patterns, one study conducted in the early 1980s focused on local anthropogenic impacts within the reservoir watershed (Mitzelfelt 1985). By the early 1980s, the Lake of the Ozarks region had become a popular Midwest vacation destination and a valued source of tourist income. Shoreline property developed over time for residential and commercial use.

Historically, the region had no central sewage treatment facilities for lakeshore housing. Most sewage treatment was accomplished by on site septic systems (Mitzelfelt 1985), with leachate fields in porous soils and steep topography. Sewage pollution from poorly placed septic tanks can promote eutrophication (Edmondson 1961) which degrades aesthetic value and the ecological health of fisheries

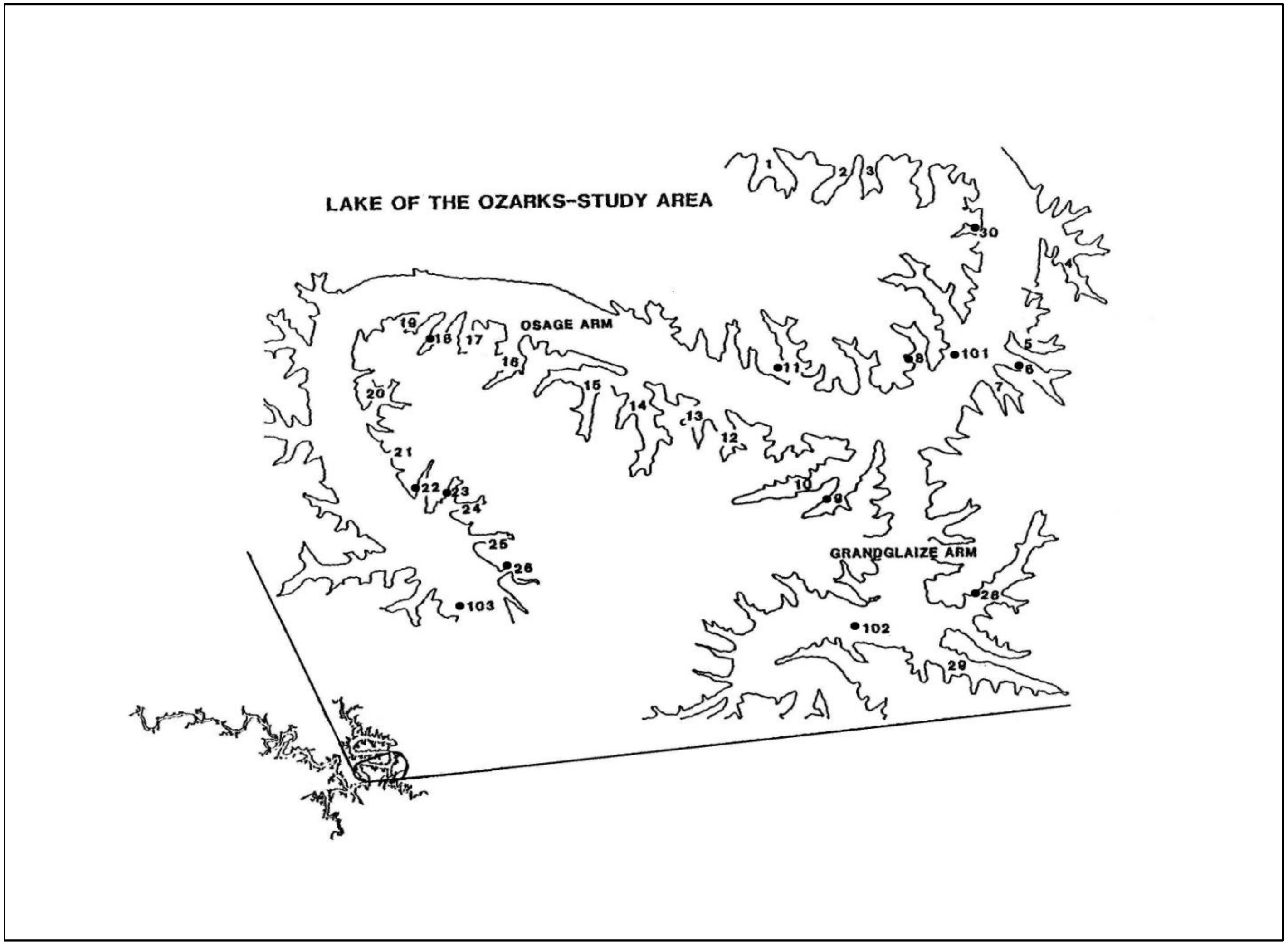
(Mason 2002). Septic systems contribute to nutrient enrichment of groundwater, which promotes subsequent enrichment of receiving waters (Loeb and Goldman 1979, Lapointe et al. 1999) and increases in littoral benthic algal and bacterial productivity (Loeb et al. 1984). Sewage pollution decreases invertebrate species diversity and may increase the biological oxygen demand of ambient waters (Hynes 1960). It also degrades bacteriological quality of water, which increases the risk of potential swimming-acquired microbial infections (Dufour 1984). In regions with porous soils, such as the Lake of the Ozarks region, pollution from this source increases the risk of drinking well contamination (Gagliardi and Karns 2000). Concerns about these potential problems prompted Mitzelfelt (1985) to study the relationship between anthropogenic development and water quality in coves of Lake of the Ozarks.

From 1981 to 1984, Mitzelfelt intensely studied 29 coves and three main channel sites in the Grand Glaize-Turkey bend region of the reservoir (Figure 2). A subset of ten coves was sampled for fecal coliform (Figure 2). During this period, all main channel sampling sites and coves were mesotrophic. Mitzelfelt (1985) found no statistically significant difference in mineral ion content (alkalinity and conductivity) between main channel sites and coves. Coves, however, generally had greater total phosphorus, algal biomass, fecal coliform, chemical oxygen demand, and lower Secchi transparency than main channel sites. Among coves these variables increased with development in the adjacent watershed. Development was measured by a development value index:

$$DV = HU / LA / WA$$

DV is the development value, HU is the number of housing units within the cove watershed
LA is the land area in the cove watershed (ha), and WA is cove water area (ha).

Figure 2. Coves and main channel sites sampled by Mitzelfelt (1985). Sites 101-103 are located in open waters. Black dots indicate sites and coves where fecal coliforms were sampled.



The study also linked fecal coliform concentrations with local traffic activity and recreational use in the region. Fecal coliform concentrations increased following holidays, and were five times greater on weekends compared to weekdays.

By 2007, 79% of cove watersheds monitored in the 1980s (Table 1) had increased in housing units (on average, by 40%, from 107-150 housing units), and all coves increased in percent urban cover (on average, by 47%). With increased development, municipalities initiated waste water treatment in a few areas in the Lake Ozark region, and several treatment facilities obtained Environmental Protection Agency (EPA) permits to discharge effluents into the reservoir. Most treatment, however, was still accomplished by on-site septic systems or lagoons. In 2007, comprehensive fecal coliform data in coves and main channel sites sampled by Mitzelfelt (1985) had not been updated in 22-26 years, and visitors and residents were concerned about degrading water quality in the reservoir (Lake of the Ozarks Watershed Alliance, personal communication).

Table 1. Percent urban area and number of housing units in cove watersheds in 1980 and 2007 on both Osage and Grand Glaize Arms. *Data from Mitzelfelt (1985).

		1980		2007			
Reservoir Arm	**Cove**	**% Urban**	**Housing Units***	**% Urban**	**Housing Units**	**Δ % Urban**	**Δ HU**
Osage	1	0	0	23	50	23	50
	2	0	0	21	46	21	46
	3	0	0	23	33	23	33
	4	24	108	37	213	13	105
	5	21	43	32	148	11	105
	6	44	218	59	210	15	-8
	7	90	142	96	199	6	57
	8	0	39	20	101	20	62
	9	41	339	57	326	15	-13
	10	23	166	38	601	16	435
	11	0	0	12	38	12	38
	12	1	64	37	256	35	192
	13	40	91	60	259	20	168
	14	10	134	26	228	16	94
	15	0	261	15	463	15	202
	16	0	72	13	176	13	104
	17	14	49	40	77	27	28
	18	16	53	23	62	6	9
	19	28	40	33	29	5	-11
	20	4	51	19	36	15	-15
	21	92	42	92	185	0	143
	22	86	82	88	282	2	200
	23	15	689	26	327	11	-362
	24	0	13	15	83	15	70
	25	0	50	11	199	11	149
	26	3	61	13	45	10	-16
	30	0	0	42	19	42	19
	31	0	----	3	0	3	----
Grand Glaize	28	5	303	13	514	8	211
	29	0	2	2	24	2	22
	32	0	----	0	17	0	----
	33	0	----	1	0	1	----
	34	0	----	5	3	5	----
	35	0	----	0	0	0	----
	36	0	----	0	0	0	----

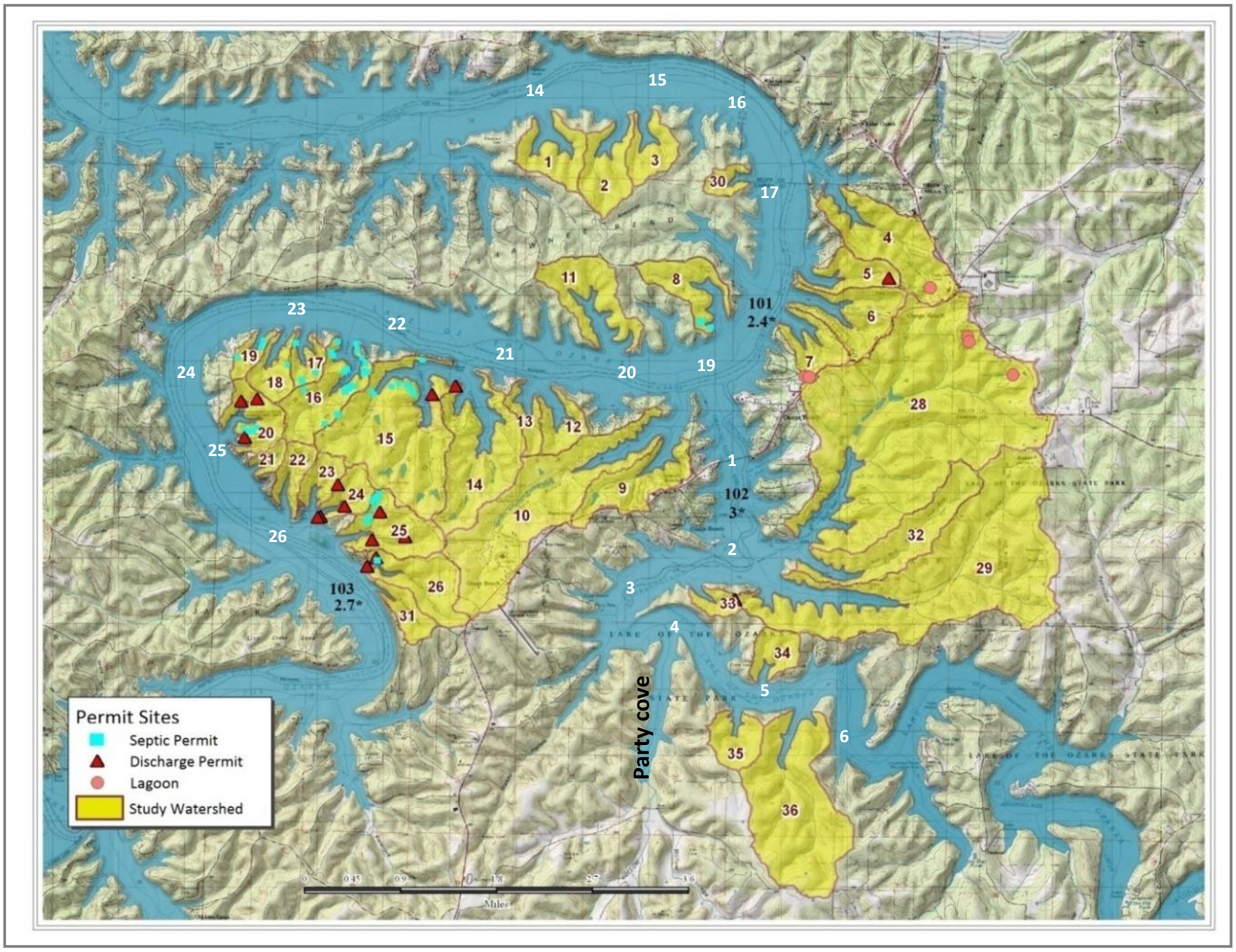


Figure 3. Locations of cove sites are labeled in black font: coves 1-26, 28-36; and main channel sites 101-103. Main channel sites with "*" were sampled by Jones and Novak (1981), Jones and Kaiser (1988), and Perkins and Jones (2000), and are sampled in a long-term monitoring project at the University of Missouri (J. R. Jones, unpublished data). All three main channel sites and most coves were also sampled by Mitzelfelt (1985). Coves not sampled by Mitzelfelt (1985) were coves 31-36. Cove watersheds are highlighted in yellow-green. Locations of septic tank permits (small blue squares), permitted point discharges at the outfall point (red triangles), and visible lagoons (peach circles). Reservoir mile makers in white font: 14-27 on the Osage Arm and 1-6 on the Grand Glaize Arm.

In response to increased development, continued use of septic systems, and concerns of reservoir users, two main objectives of this study were to 1) measure water quality in main channel sampling sites and coves, and compare current conditions with those in the 1980s to assess potential changes over time and 2) assess the relationship between watershed development and water quality using development value (Mitzelfelt 1985) and updated development metrics. Plant-growth nutrients (phosphorus and nitrogen), biological responses to nutrients (algal biomass measured by chlorophyll), suspended solids, and fecal indicator bacteria (fecal coliform, *Escherichia coli*, and *Bacteroides thetaiotaomicron*) were the pollutants and/or indicators monitored. Transport of nutrients, sediments, and bacteria to and within the reservoir, was central to this study.

The third objective focused on specificity of the three fecal indicators. The coliform index was originally intended to indicate the possible presence of anthropogenic fecal pollution and the potential for infection by enteric microbes (Gleeson and Gray 1997). Numerous studies, however, have documented that total coliform bacteria and fecal coliform bacteria are correlated with abundance of animals (Hussong et al. 1979, Hoyer et al. 2006, Ricca and Cooney 1998), are natural inhabitants of soil and sediments (Gleeson and Gray 1997), and reproduce in aquatic environments (Dutka 1979, Ellis 1989). To identify human sources of fecal contamination, researchers have used other microbial indicators that are more specific to human fecal matter.

E. coli[1] is an indicator that is more specific to human gut flora than the total coliform and fecal coliform groups, and has been adopted as the primary fecal indicator for whole body contact waters in many states. As of January 2009, Missouri stopped using the fecal coliform group as indicators in whole body contact standards, and fully adopted the *E. coli* standard (Missouri Department of Natural Resources 2007). Thus another purpose of this project was to generate *E. coli* data for coves in Lake of the Ozarks[2].

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[1] Only certain bacteria of the fecal coliform group and certain strains of *E. coli* cause disease in humans.

[2] Coincidently, in the summer of 2007 Missouri Department of Natural Resources began sampling *E. coli* in coves in the Osage Arm of the reservoir; however, Missouri Department of Natural Resources sampling and planning was not affiliated with the current study.

Regardless, there are numerous records documenting replication of *E. coli* in soils and sediments (Gagliardi and Karns 2000, Solo-Gabriele et al. 2000, Whitman and Nevers 2003, Ishii et al. 2006), and wide acceptance that *E. coli* inhabit the guts of other animals (Hoyer et al. 2006, Meyer et al. 2006, Carson et al. 2001). New research has documented *Bacteroides thetaiotaomicron* is largely an exclusive human gut resident (Teng et al. 2004, Carson et al. 2005) and does not replicate in external environments (Fiksdal et al. 1985, Allsop and Stickler 1985, Pan and Imlay 2001). Carson et al. (2005) determined the presence of *B. thetaiotaomicron* indicates recent anthropogenic fecal pollution. Thus, this objective was to assess the degree to which environmental factors influenced the 3 bacteria and the human-specificity of the conventional fecal indicator bacteria (fecal coliform and *E. coli*) in Lake of the Ozarks when monitored in conjunction with *B. thetaiotaomicron*. A history and more detailed description of the coliform index and fecal bacterial indicators are included in a literature review in appendix.

METHODS

Sampling Design

Thirty-five coves and 3open water reference sites in the Osage and Grand Glaize Arms of Lake of the Ozarks were sampled in 2007 (Figure 3). Among coves, total watershed area ranged from 19-883 ha (median=76 ha), water area ranged from 2-52 ha (median=11 ha), and adjacent drainage area ranged from 17-842 ha (median=65 ha). Most coves and all main channel sites had been previously monitored in the 1980s (Mitzelfelt 1985). Six additional coves (coves 31-36) were included to characterize undeveloped reference conditions. In 2007, 16 facilities had discharge effluent permits in 8 coves within the study area (coves 5, 14, 15, 20, 24-26, and 33, Figure 3). All but 3 of these discharges were located within the lower 3 km of the Osage Arm study reach. Seventy-four permitted and inspected septic tanks were on file at Camden County Waste Water in Camdenton, Missouri. These were dispersed throughout 11 coves in the Osage Arm (coves 8, 11, 14-20, 25, and 26, Figure 3), and were most concentrated between kilometers 34-40 (mile markers 21-25). Five lagoons dispersed in 3 coves were also visible in aerial photos, but were not listed as permitted discharge facilities.

Sites were sampled every other Monday or Tuesday beginning in mid-May 2007 and continuing through August 2007. As part of the first August trip, 9 coves on the Osage Arm and 1 cove on the Grand Glaize Arm were sampled the previous Friday to compare pre- and post- weekend measurements of fecal indicators resulting from increased anthropogenic activity. A cove of interest to Lake of the Ozarks residents and vacationers, “Party Cove”, in the Grand Glaize Arm, was also sampled over this weekend. A subset of thirteen coves and two main channel sites were identified based on high fecal bacterial counts or *B. thetaiotaomicron* detections during summer 2007. This subset was sampled in 2008 the day prior to and the day following three major holiday weekends (Memorial Day, Independence Day, and Labor Day). These collections were intended to assess further relationships between fecal indicators and increased anthropogenic activity.

In each cove, surface samples were collected from mid-cove. The back and mouth of 17 coves, spanning the study area, were sampled once to check for longitudinal variation within coves (Figure 4). Surface dissolved oxygen (DO), specific conductivity, and temperature were measured in the field using a YSI 85 dissolved oxygen and conductivity meter. Secchi depth and water column depth were also recorded in the field. Two types of water samples were collected for subsequent analysis in the lab. For nutrient and sediment analysis, a 2-L Nalgene bottle was rinsed 3 times with surface water, then inverted and plunged beneath the air-water interface to a depth of about 0.25 m. For bacterial analysis, three sterile 798 mL whirl-pak® sample bags (Nasco®) were opened beneath the air-water interface at a depth of about 0.25 meters. All samples were kept in the dark on ice until they were processed at the University of Missouri.

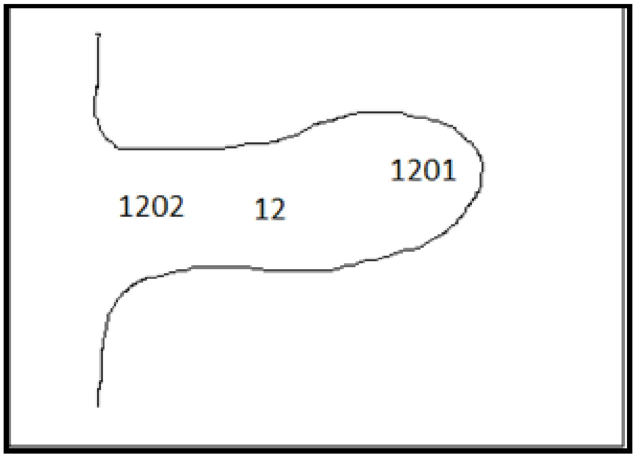

Figure 4. Sampling stations in an idealized cove. Stations 1201 and 1202 were used in supplementary cove sampling to check for longitudinal variation.

Limnological Data

Workups of all nutrient samples were performed at the University of Missouri Limnology Lab less than 24 hours after collection. Variables measured include chlorophyll (Chl), total and dissolved nitrogen (TN, DN), total and dissolved phosphorus (TP, DP), chloride (Cl), total suspended solids (TSS), volatile suspended solids (VSS), non-volatile suspended solids (NVSS), whole water turbidity, filtrate turbidity, and pH.

Sample water was filtered through two Pall® Life Sciences Type A/E glass fiber filters (1.0 µm particle retention) for Chl analysis, and two pre-ashed and tared Whatman® grade 934-AH glass microfiber filters (1.5 µm particle retention) to calculate concentrations of TSS, VSS, and NVSS. Both Chl and suspended solid filters were stored frozen in desiccant in the dark until further processing. Whole water was used to measure TN, TP, whole water turbidity, and pH. The 934-AH filtrate was used to measure DN, DP, and filtrate turbidity. Membrane filtered (0.45 µm mesh, Millipore HAWP mixed cellulose ester membrane) water was used to measure Cl.

Chlorophyll filters were submerged in ethanol and heated in a water bath to extract Chl products. Chlorophyll values were determined by processing the eluate through a fluorometer (Sartory and Grobbelarr 1986). Suspended solid filters were dried at 105˚C and weighed to determine TSS, then ashed at 550˚C to determine volatile and non-volatile suspended solids (APHA 1995). Total and dissolved nitrogen were analyzed by potassium persulfate digestion, and determined by calculating the second derivative of absorbance (Crumpton et al. 1992). Total and dissolved phosphorus were digested with ammonium peroxydisulfate, and determined colorimetrically (EPA method 365.3). Turbidity was measured on a HACH 2100N turbidimeter. Conductivity and pH were measured on a Mettler Toledo MC226 conductivity meter and AR25 accumet® meter, respectively. Chloride was analyzed using flow injection colorimetry (Lachat QuickChem 8000, QuickChem Method 10-117-07-1-B).

Fecal Coliform and E. coli Data

Filtering equipment was sterilized in an autoclave or by soaking in 10% bleach solution for at least 30 minutes (funnels only), then triple rinsing with de-ionized water before processing samples. All bacteria samples were prepared for incubation less than 12 hours after collection time. Fecal coliform (FC) was processed per APHA method 9222 D., and *E. coli* (EC) was processed per EPA method 1603. Media for incubation and growth were m-FC liquid media with rosolic acid for FC and modified m-Tec agar for EC. Three different volumes were filtered simultaneously (Figure 5) through 0.45 µm sterile mixed cellulose ester filters (47 mm diameter, Fisher Scientific) for each site for both FC and EC. Filters were then placed on aseptic Petri dishes (47 mm diameter, Millipore®) for incubation. Filter blanks were incubated each day to ensure sterility. Filtering blanks of 1,000 mL sterile deionized water were included at the beginning and end of each filtering day on each filtering station to assure equipment sterility and as a cross-contamination check. After incubation, bacterial colonies on each plate were counted by the same lab technician.

Figure 5. Filtering station for fecal coliform, *E. coli*, and *B. thetaiotaomicron*.

***Bacteroides thetaiotaomicron* Data**

Filtering equipment was sterilized per FC and EC methods above. Whole water from each cove was filtered through three 0.45 µm sterile mixed cellulose ester filters (47 mm diameter, Fisher Scientific) using low vacuum force until clogging the filter. Filtering blanks of 1,000 mL sterile deionized water were included at the beginning and end of each filtering day on each filtering station. Filtration stations were the same used in FC and EC processing. Filters were placed sample-side up in tight lidded aseptic Petri dishes (47 mm diameter, Millipore®) and frozen at -20˚C for subsequent DNA extractions.

For each sample, genetic material was extracted from 2 of 3 filters using the UltraClean™ soil DNA isolation kit. The third filter was stored in the dark at -20˚C as backup for extraction reruns. Extraction blanks were processed without filters using the UltraClean™ soil DNA isolation kit, and were intermittently included with sample extractions. Total DNA was measured by 260/280 absorbency on a GeneQuant pro spectrophotometer, and diluted with DNase-free water to 5 ng/µL DNA, which was the upper limit of detection (1-5 ng/µL) recommended by Carson et al. (2005). Dilution blanks using DNase-free water were included after every 50 samples to check for cross-contamination of samples and DNase-free water. DNA was stored at -80˚C until polymerase chain reaction (PCR) processing.

PCR was performed to determine presence or absence of *B. thetaiotaomicron* in samples. PCR reaction mixture included 20 µL of master mix and 5 µL sample DNA. *Bacteroides thetaiotaomicron* (BT) positive control reactions included 20 µL of master mix and 1 µL BT DNA (ATCC 29148) at a concentration of 0.05 pg/µL. Master mix was composed of 12.5 µL Jumpstart™RedTaq®ReadyMix™, 0.1 µL B.thetaF primer (5'-3' sequence: AACAGGTGGAAGCTGCGGA, Teng et al. 2004), 0.1 µL B.thetaR primer (5'-3' sequence: AGCCTCCAACCGCATCAA), and 7.3 µL DNase-free water. PCR was performed with an initial denaturing step at 94˚C for 2 min, and 35 cycles at 94˚C for 1 min, 60˚C for 30 s, and 72˚C for 1 min, with a final elongation step at 72˚C for 10 min. PCR products were injected into a gel (2.5 g Metaqphore Agarose in 110 mL 0.5X TBE)[3] that was submerged in 0.5X TBE. *B. thetaiotaomicron* positive controls were placed at the first and last well of each gel. Electrophoresis was performed at 120 volts for 60 minutes on a Bio-Rad PowerPac 1000. PCR products were stained with ethidium bromide and viewed on a Syngene Gene Genius Bioimaging system using ultraviolet light. Samples where BT was detected were rerun to confirm detections were positive.

Watershed, Anthropogenic Activity and Climatic Data

Cove units for this study include water in the cove and land area in the surrounding watershed. Watershed measurements used in analyses include total watershed area (TW), land area (LA), water area (WA), shoreline perimeter, shoreline density (shoreline perimeter/WA, Osgood 2005), shoreline complexity (shoreline perimeter/TW), and distance from Bagnell Dam. Percent urban cover, number of housing units (HU), and development value (DV, Mitzelfelt 1985) were used in cross-site analysis to assess impacts of anthropogenic activity on water quality metrics. Using methods of Mitzelfelt (1985), a housing unit was defined as a single family unit in a single family dwelling, a single family unit in a multiple family dwelling (apartment of hotel room), and any commercial buildings other than hotels (Figure 6). Development value was calculated using Mitzelfelt's equation (page 3). Daily road use data in the Lake Ozark region was recorded on Highway 54 (traffic volume=number of vehicles entering and leaving the region) and was used to monitor anthropogenic activity throughout the recreation season. Locations of facilities with EPA discharge permits, lagoons, and Camden County permitted septic systems were collected as inventory of the study region. Climatic data included daily precipitation and wind speed at Kaiser Memorial Airport in Lake Ozark, and discharge and lake level at Bagnell Dam from May-August 2007 and 2008.

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[3] Tris base-boric acid-EDTA

Figure 6. Single family housing unit (A), single family housing units in a multiple family dwelling (B), and commercial business as a single housing unit (C).

Watershed measurements (TW, LA, WA, shoreline perimeter, percent urban) and locations of EPA permitted discharges were provided by the University of Missouri Geographic Resources Center. Distance from Bagnell Dam or the Osage-Grand Glaize Arm confluence was estimated using the University of Missouri Center for Applied Research and Environmental Systems web site. Housing units were counted visually from the water, by land, by aerial assessments (using a combination of digital maps), and by phone for private neighborhoods and hotels. Locations of permitted septic systems were provided by Camden County Waste Water. Road usage data was obtained through the Missouri Department of Transportation at site 066-000555 on U.S. 54, 2 km East of Highway V in Miller County. Precipitation and wind speed from Kaiser Memorial Airport were obtained through the Utah State University Climate Center web site. Discharge at Bagnell Dam and lake level were obtained through United States Geological Survey and Ameren-Union Electric Company.

Statistical Analysis

Temporal Analysis

Long-term TP data provided by the University of Missouri Limnology Lab from Dr. John R. Jones were collected in July and August 1980-2008 (four samples per season) from main channel stations in Lake of the Ozarks (Perkins and Jones 2000). Data from stations 2.4 and 2.7 on the Osage Arm and Station 3 on the Grand Glaize Arm encompassed the current study area (Figure 3). For each arm, annual TP was calculated by averaging across samples and stations (Osage Arm stations 2.4 and 2.7) per sampling season. Seasonal discharge for the historic study period was calculated by averaging daily discharge during July and August[4] 1980-2008. Discharge was used as an independent variable, and seasonal TP as a response variable in regression analysis to describe the continuous effect of discharge (inflow) on reservoir nutrients (after Jones and Novak 1981).

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[4] Averages calculated with discharge from other months were also used in this analysis. Months showing the strongest correlation with total phosphorus (July-August) were presented in the results.

Bacterial data were not collected during the long-term study; therefore, daily geometric means (FC and EC) across coves and total daily BT detections (number of sites with detections) from May-August 2007 were used to examine temporal variation across the season. Temporal trends in daily bacteria data were compared with mean daily discharge and wind speed, and daily traffic volume to detect possible anthropogenic influences. Two-tailed t-tests were used to determine significant differences in pre- and post-weekend FC and EC concentrations for the 2007 weekend and 2008 holiday weekends when anthropogenic activity in the watershed increased. Fecal coliform and EC concentrations from individual samples from both the May-August 2007 and 2008 holiday data sets were evaluated with Environmental Protection Agency (EPA) standards used in Missouri (Missouri Department of Natural Resources 2007). The standards specify in waters used for whole body contact recreation, FC may not exceed a seasonal geometric mean of 200 CFU/100 mL, and EC may not exceed a seasonal geometric mean of 126 CFU/100 mL. These same samples were also evaluated with a Missouri discharge effluent standard. Discharge effluent entering a losing stream[5] may not exceed 1,000 CFU/100 mL for FC at any time. Missouri does not have an equivalent EC discharge effluent standard, but for comparison in this analysis, an effective discharge effluent standard of 630 CFU/100 mL will be applied for single samples[6]. For losing streams[3], EC may not exceed 126 CFU/100 mL at any time.

Cross-Site Analysis for Nutrients and Bacteria

For the May-August 2007 data, seasonal arithmetic means for each site were calculated for all limnological measurements (n=7 sampling days per site). Geometric means were calculated for FC and EC for consistency with EPA standards and total number of detections per site throughout the season were calculated for BT. ANOVA (p=0.05) was used to test for significant differences between the Osage and

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[5] Lake of the Ozarks is not a losing stream. Bacterial transport through porous soils in this region, however, may potentially reach drinking wells, which necessitates the use of more conservative standards.

[6] The effective EC discharge effluent standard of 630 CFU/100 mL=5*126 CFU/100 mL (the EC seasonal standard). This calculation was based on FC seasonal and discharge standards, where the FC discharge standard of 1,000 CFU/100 mL is 5 times the seasonal standard of 200 CFU/100 mL.

Grand Glaize Arms for limnological (Jones and Kaiser 1988) and bacterial values. ANOVA was also used to determine significant differences between mean nutrient and bacteria values in coves and main channel sampling sites within each reservoir arm. Nutrients and fecal bacteria measurements in individual main channel sites were compared with measurements in adjacent coves.

Following the methods of Mitzelfelt (1985), sites were binned into 5 development classes determined by the development value index (main channel, undeveloped coves, low developed coves, intermediate developed coves, and highly developed coves). Undeveloped coves (UD) had development values of 0-0.0001, low developed (LD) of >0.0001-0.1, intermediate developed (ID) of >0.1-0.2, and high developed (HD) of >0.2. Duncan’s t-test (p=0.05) was used with bin data to determine if anthropogenic development influenced nutrients, FC, or EC concentrations. A similar method was used for a cross-cove analysis for BT. Because data for BT (the dependent variable) was binary (presence/absence) and ordinal (number of detections per cove), measurements for independent variables (watershed metrics, anthropogenic development indices, and all limnological metrics) for coves were binned according to the number of detections per cove during the 2007 season (i.e., 0 detections, 1 detection, 2 detections, and so forth). A Duncan’s t-test (p=0.05) was used to determine significant differences between BT bins for each respective independent variable.

Linear regression was used for analysis of cross-cove patterns. Watershed metrics and anthropogenic development indices were used as independent variables to explain cross-cove variation in TN, TP, Chl, FC, and EC. To avoid development class categories set in the 1980s (Mitzelfelt 1985), development values for coves were also used as a continuous variable rather than a categorical variable. The validity of the development value index was also tested by using linear regression to determine autocorrelation among variables used in the estimate. All limnological measurements were used as independent variables in regression with FC and EC measurements from coves. Variables were log- or ln-transformed as appropriate. Fecal coliform and EC means were ln+1 transformed for regression and t-test analysis. Regression and correlation analysis were performed using statistical software packages in R (R Development Core Team 2008).

RESULTS

Hydrology

Summers 2007 and 2008 were seasons of record discharge in Lake of the Ozarks (Figure 7). Mean July-August discharge at Bagnell Dam in 2007 was 33,345 cfs, the largest discharge recorded since the completion of Truman Dam. For 2008 discharge was the third largest, 23,708 cfs. Mean July-August discharge in both seasons was about 8 times the discharge in low to moderate flow years. Within both seasons, May-June was characterized by numerous flood pulses (Figures 8 and 9). Flood pulses were more intense in 2007 than in 2008, carrying larger volumes of water into the basin. The largest rain event in 2007 carried more than 59 cm (23 inches) of rain to the local study reach. For comparison, the largest rain event in 2008 carried 5 cm (2 inches) of rain. Pool level in 2007 gradually increased starting in March and continuing throughout the study period (Figure 10). Pool level was highest in late July (660 ft), which was about 5 ft greater than its lowest level in early March. In 2008, pool level was similar to levels in 2007 (Figure 11), but did not steadily increase. Pool level was maintained around 660 ft, however, levels gradually decreased from April throughout study period.

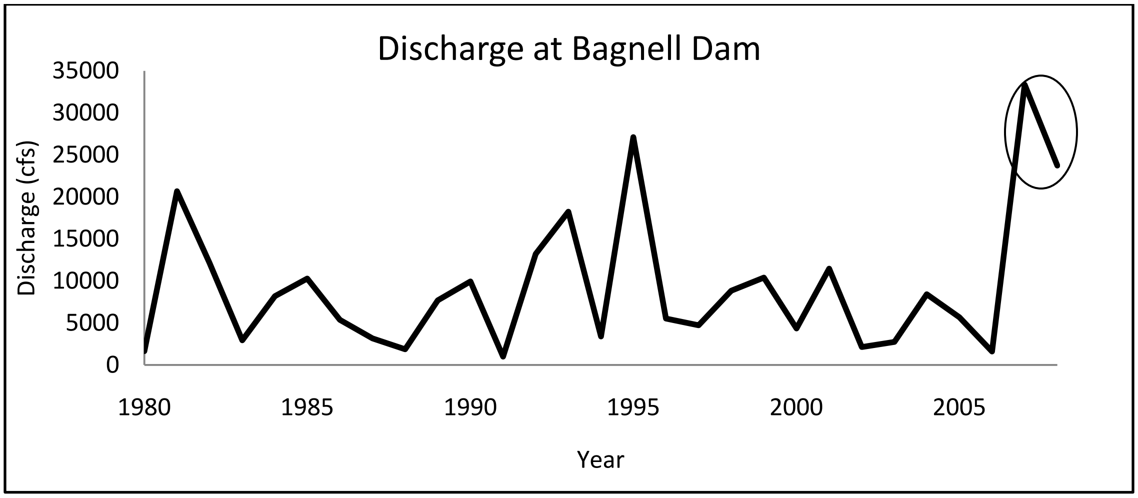

Figure 7. Mean July-August discharge at Bagnell Dam over a 28 year period, from 1980-2008. Years 2007 and 2008, the study years, are circled.

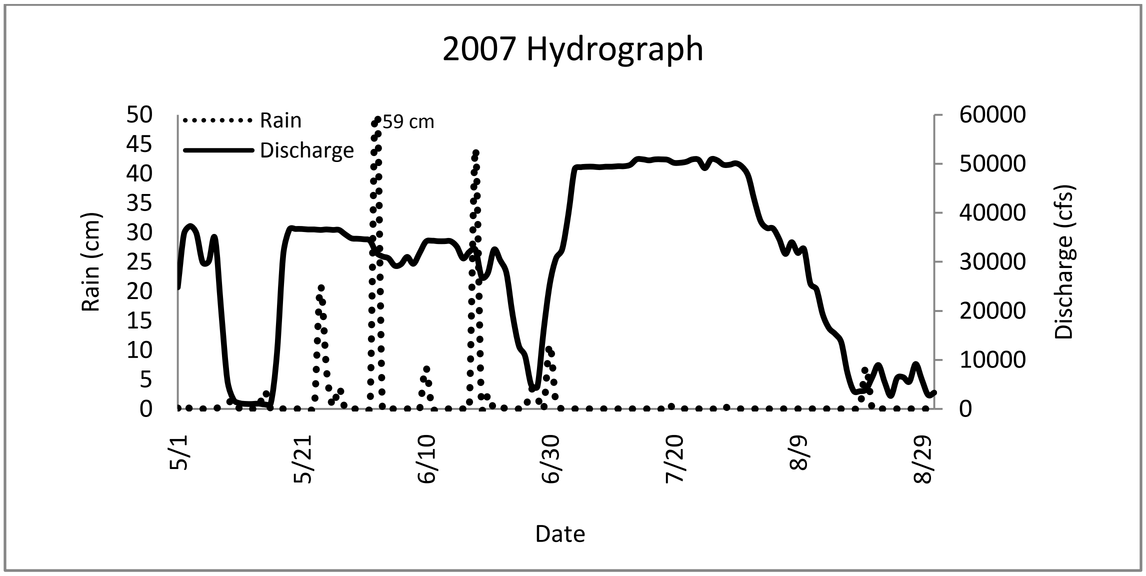

Figure 8. Hydrograph showing discharge and rain in Lake of the Ozarks during May-August 2007.

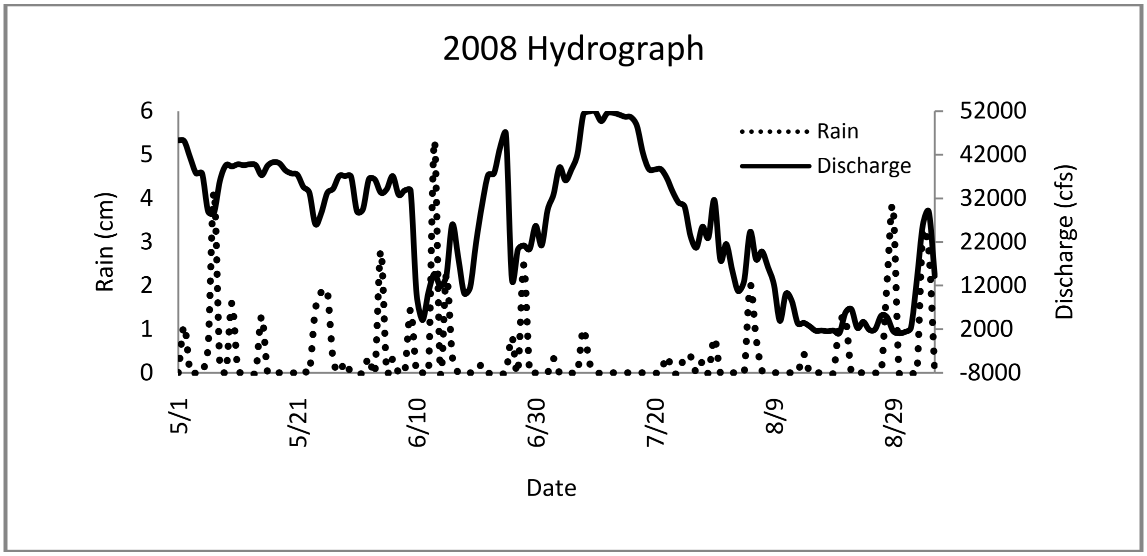

Figure 9. Hydrograph showing discharge and rain in Lake of the Ozarks during May-August 2008.

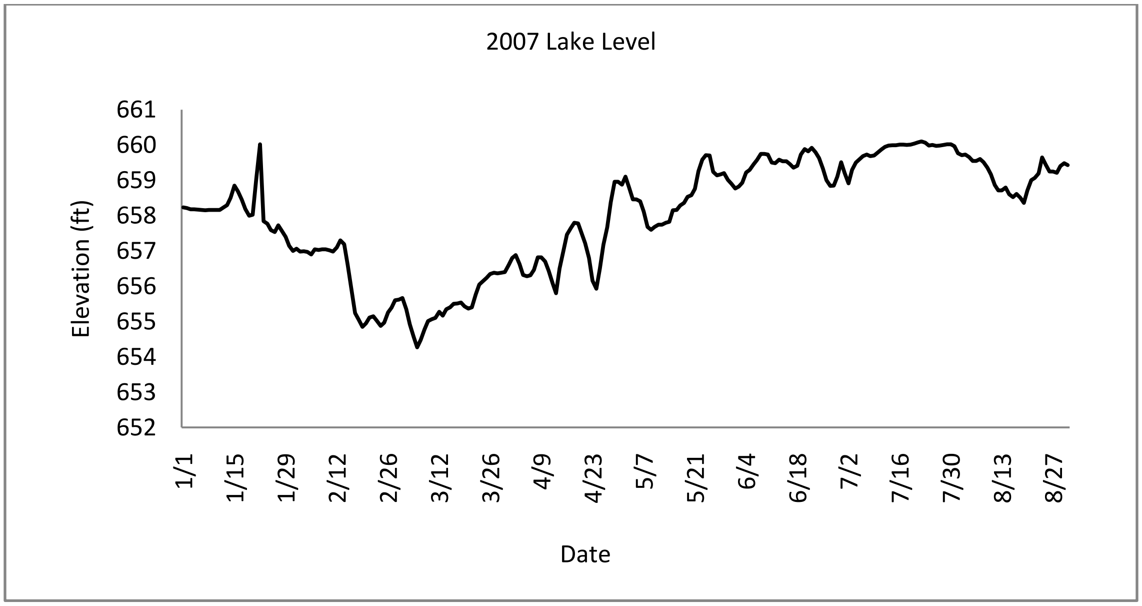

Figure 10. Lake level in Lake of the Ozarks during January-September 2007. Data were recorded at 12 AM daily.

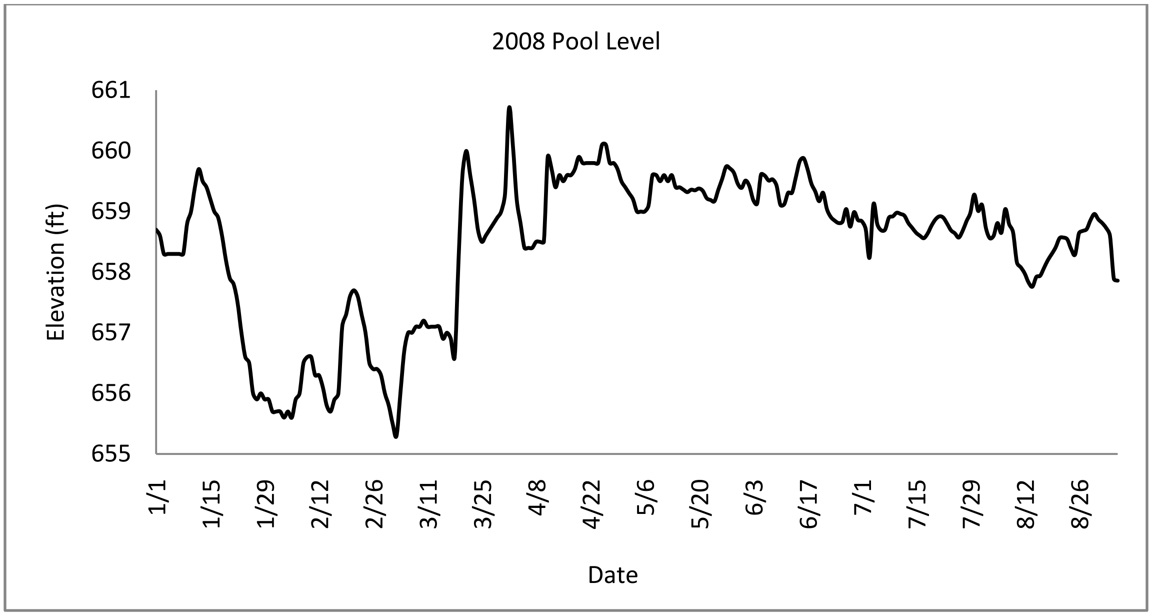

Figure 11. Lake level in Lake of the Ozarks from January-September 2008. Data were recorded at 12 AM daily.

Nutrients

Long-Term Temporal Variation and Spatial Variation

Long-term data from Lake of the Ozarks, collected during July and August 1980-2008, showed limnological characteristics fluctuated in response to inflow from the watershed and discharge from Bagnell Dam. Over the 28 year period, mean July-August discharge ranged from 990 cfs in 1991 to 33,345 cfs in 2007. Seasonal mean total phosphorus concentrations (TP) in the Osage Arm (sites 101/2.4 and 103/2.7, Figure 3) ranged from 15 µg/L in 1991 to 75 µg/L in 2007. Seasonal mean TP concentrations in the Grand Glaize Arm (Site 102/3, Figure 3) were 17 µg/L in 1991 and 45 µg/L in 2007. There was a strong positive correlation between $\log_{10}$TP and $\log_{10}$ discharge (Osage Arm, r=0.90 and Grand Glaize Arm, r=0.83, Figure 12) in these main channel sites on the Osage and Grand Glaize Arms during 1980-2008. During these 28 years, Lake of the Ozarks alternated, depending on inflow and discharge, almost equally between mesotrophic (52%) or eutrophic (48%) based on TP (Figure 12, Table 2).

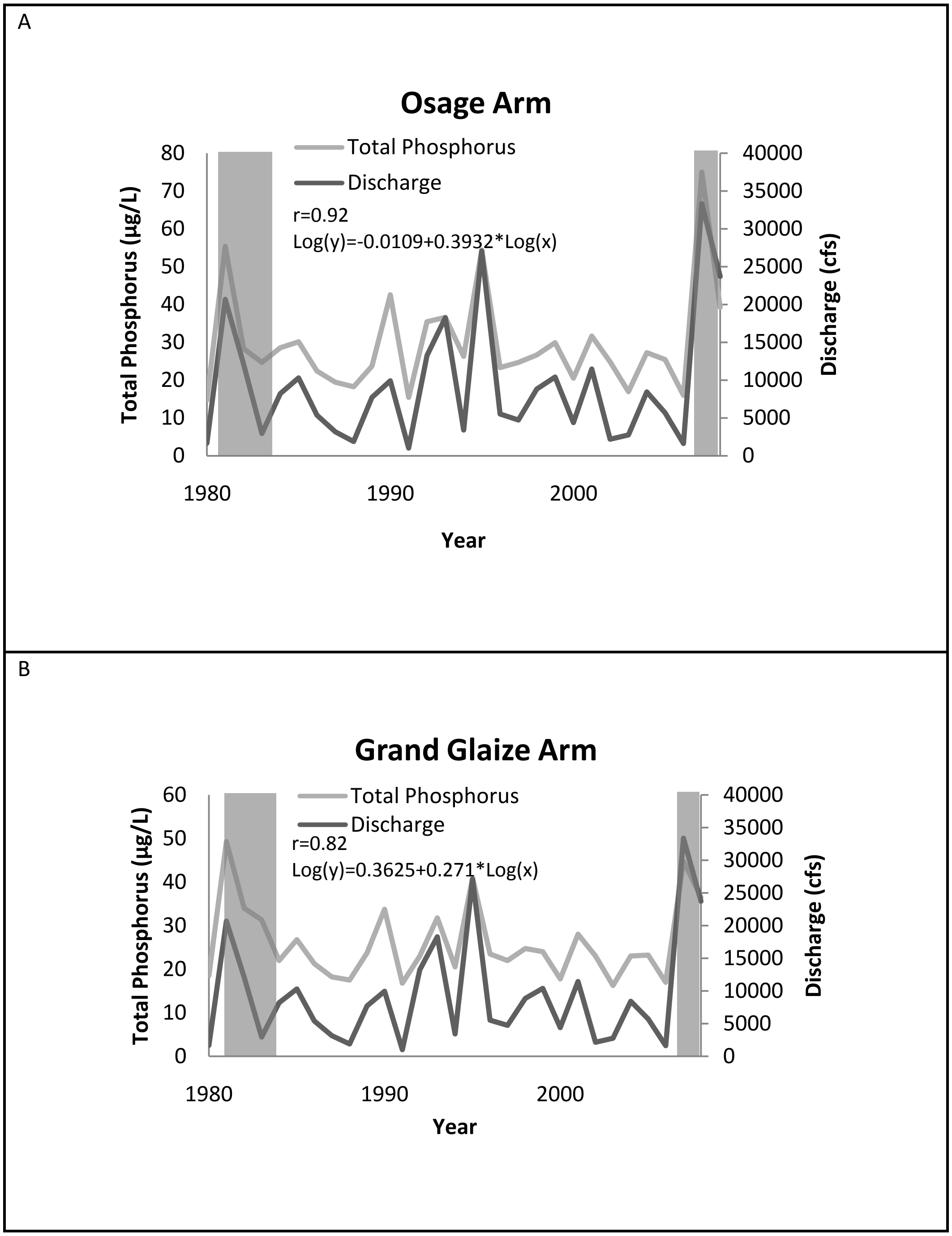

Figure 12. Total phosphorus ($\log_{10}$) is correlated with discharge from Bagnell Dam ($\log_{10}$), as shown here with 1980-2007 July-August means for main channel sampling sites in the Osage Arm (A) and Grand Glaize Arm (B). Mean total phosphorus data was collected at Osage Arm sites 2.4 and 2.7 (n=8 for most annual means) and Grand Glaize Arm Site 3 (n=4 for most annual means). Highlighted regions are years of collection for Mitzelfelt (1985) who sampled from 1981-1984 and the current 2007-2008 project. All data used in this illustration were collected in an ongoing University of Missouri project (J.R. Jones, unpublished data).

Table 2. Trophic state limits for Missouri reservoirs proposed by Jones et al. 2008a.

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi depth (m)
Oligotrophic	< 10	< 350	< 3	≥ 2.6
Mesotrophic	≥ 10 - 25	≥ 350 - 550	≥ 3 - 9	≥ 1.3 - < 2.6
Eutrophic	≥ 25 - 100	≥ 550 - 1200	≥ 9 - 40	≥ 0.45 - < 1.3
Hypereutrophic	≥ 100	≥ 1200	≥ 40	< 0.45

During the May-August 2007 study, values of TP (40-86 µg/L), total nitrogen (TN, 604-887 µg/L), chlorophyll (Chl, 18-43 µg/L), and Secchi depth (0.8-1.1 m) in coves and main channel sites in both the Osage Arm and Grand Glaize Arm study reaches were within the eutrophic range for Missouri reservoirs (Tables 2 and 3). Inflow from Grand Glaize Creek results in limnological characteristics on the Grand Glaize Arm that differ from the main stem or Osage Arm of the reservoir (Jones and Novak 1981). This previously described condition was evident in the May-August 2007 data: main channel TP averaged 71% larger on the Osage Arm (Site 101=75 µg/L, Site 103=79 µg/L) than on the Grand Glaize Arm (Site 102=45 µg/L), and TN (Site 101=826 µg/L, Site 103=806 µg/L) averaged 35% larger (Site 102=604 µg/L). These differences were evident among coves as well. Coves on the Osage Arm had significantly larger TP (by 58%) and TN (by 23%) values than coves on the Grand Glaize Arm (ANOVA, p=0.05). Among coves, measures of mineral turbidity (whole water turbidity, filtrate turbidity, and NVSS) were also significantly larger (by 14%, 167%, and 33%, respectively) in the Osage Arm. Measures of salinity (conductivity and Cl concentrations) were significantly lower (by 4% and 8%, respectively) in the Osage Arm coves than in Grand Glaize Arm coves. Measures of organic seston (VSS), algal biomass (Chl), or measures strongly affected by organic activity (DO and pH), were significantly lower (8-37%) in coves on the Osage Arm than on the Grand Glaize Arm.

Table 3. May-August, 2007 Osage and Grand Glaize Arm Limnological Measurements: Dam=distance from Bagnell Dam (Osage Arm) or distance from confluence (Grand Glaize Arm) in kilometers; DC=development class: MC=main channel, UD=undeveloped, LD=low development, ID=intermediate development, and HD=high developed; and site means: total phosphorus in µg/L (TP), total nitrogen in µg/L (TN), chlorophyll in µg/L (Chl), Secchi depth in meters, non-volatile suspended solids in mg/L (NVSS), volatile suspended solids in mg/L (VSS), dissolved oxygen in mg/L (DO), conductivity in µS/cm, pH, and chloride in mg/L. Sites are listed from up-reservoir to down-reservoir in both arms. n=7 for most means.

Reservoir Arm	Site	Dam	DC	T P	T N	Chl	Secchi	NVSS	VSS	DO	Conductivity	pH	Chloride
Osage	103	43.2	MC	79	806	22.4	0.8	3.3	3.2	6.8	243	8	5.8
	31	43.2	UD	81	826	21.8	0.9	4.3	2.1	5.2	241	7.56	5.6
	26	42.9	ID	80	830	22.4	0.9	3.9	2.2	5.6	241	7.56	5.7
	25	42.4	HD	86	883	28.3	0.8	4.6	2.8	5.6	242	7.59	5.8
	24	42	HD	83	880	27	0.9	4.2	2.5	5.7	227	7.63	5.7
	23	42	HD	85	849	29.4	0.9	4.4	2.9	6	241	7.63	5.7
	22	41.6	HD	81	841	24.6	0.9	4.3	2.5	5.8	241	7.65	5.6
	21	40.6	HD	81	829	24.3	0.9	4	2.1	5.8	241	7.65	5.7
	20	39.9	LD	84	884	25.4	0.9	3.6	2.6	6.5	228	7.77	5.9
	19	37	HD	82	846	25.5	1	3.8	2.5	5.7	238	7.75	5.7
	18	36.7	ID	77	830	23.3	0.9	3.7	2.4	6	239	7.75	5.6
	17	36.4	HD	79	834	24.1	1	3.7	2.4	5.9	241	7.77	5.6
	16	35.7	ID	79	859	24.7	0.9	3.8	2.8	6.2	242	7.72	5.6
	15	33.8	LD	69	887	24.7	1	3	3	7	248	7.9	5.9
	14	33.8	LD	74	861	26.5	1.1	3.2	2.7	6.6	242	7.76	5.7
	13	32.7	HD	74	831	20.8	1	3.4	2.3	6.6	238	7.72	5.6
	12	32.7	HD	80	854	24.5	1	3.5	2.6	6.9	240	7.75	5.6
	11	31.7	LD	62	821	22.4	1.1	3.4	3.2	7.7	243	7.97	5.7
	10	30.6	LD	62	766	25.2	1	2.8	2.9	6.7	248	7.88	5.9
	9	30.6	HD	66	816	20.1	1	3.2	2.6	6.3	240	7.72	5.8
	8	29.6	LD	69	807	22.3	1	3.8	3.2	8.3	242	8.03	5.7
	101	29.3	MC	75	826	24.4	1	4.6	2.2	7	241	8	5.6
	7	29	HD	70	801	21.3	0.9	3	3.1	8.4	241	8.03	5.6
	6	28.7	ID	70	821	22.4	1	3.2	3.1	7.5	241	8.02	5.6
	5	28.2	HD	72	817	22.4	1	3.1	3.5	8.1	241	8.1	5.7
	30	27	HD	72	834	22.4	1	3.6	3.2	7.3	242	7.87	5.7
	4	27	ID	61	736	17.9	1.1	2.7	2.7	8	242	8.15	5.8
	3	24.1	LD	66	790	19.1	1	3.2	2.6	7	243	7.88	5.7
	2	23.7	LD	65	774	19.9	1.1	3.2	2.9	7	243	7.9	5.7
	1	22.5	LD	62	729	18.8	1.1	3.3	3.1	7	241	8.08	5.7
Grand Glaize	36	8.4	UD	40	623	24.5	1	2.6	4.2	8.8	255	8.63	6.4
	34	7.7	LD	40	629	25.7	1	2.4	4.3	8.8	257	8.66	6.4
	35	7.4	UD	51	716	34.3	0.9	3.3	5	9.7	252	8.72	6.4
	33	3.6	UD	59	763	43.3	0.9	2.9	5.3	8.9	247	8.57	6.2
	32	2.7	LD	45	635	24.2	1.1	2.6	3.8	8.1	246	8.4	5.8
	29	2.7	LD	49	689	30.1	1	2.8	3.9	8.3	249	8.41	6.1
	28	2.7	LD	47	649	28.7	1.1	2.3	3.6	7.9	250	8.26	6.3
	102	2	MC	45	604	24.5	1.1	2.6	3.5	8	249	8.4	6.2

Differences in water quality measurements between the two arms likely reflect the larger flow volume, nutrient content, and suspended solid load of the Osage River in contrast to Grand Glaize Creek. Because of these differences in hydrology, nutrients, and suspended solids between the Osage and Grand Glaize Arms, limnological data from the two areas were analyzed separately. The remainder of the nutrient results will deal with May-August 2007 data, except where noted.

Osage Arm

Seasonal mean water quality variables measured in main channel sites and coves on the Osage Arm ranged from 61-86 µg/L for TP, 729-887 µg/L for TN, 18-29 µg/L for Chl, 2.7-5 mg/L for NVSS, 2.1-3 mg/L for VSS, 5.2-8 mg/L for DO, 227-248 µS/cm for conductivity, 7.56-8.15 for pH, and 5.6-6 mg/L for Cl (Table 3). On average, limnological measurements between main channel sites and coves (TP, TN, Chl, NVSS, VSS, DO, conductivity, pH, and Cl) were not statistically different (ANOVA, $p=0.05$) and values in the two main channel sites were similar to values in the most adjacent coves. These findings differ from findings of Mitzelfelt (1985). In fact individually, many coves had larger values than the main channel sites for TP (50%), TN (71%), and Chl (46%).

The historical down-reservoir decline in nutrients between the two main channel sites on the Osage Arm (Jones and Novak 1981) was not evident in the May-August 2007 means. The two sampling sites, located 16 km apart in the lacustrian zone, were similar for TP (79 µg/L vs. 75 µg/L), TN (806 µg/L vs. 826 µg/L), and Chl (22 µg/L vs. 24 µg/L). The longitudinal decline, however, was apparent when a larger reach (60 km) in the Osage Arm was considered; between kilometer 60 (reservoir-mile 38) and Bagnell Dam TP declined by 50 µg/L and TN declined by 95 µg/L during July-August 2007 (Table 4, J. R. Jones, unpublished data). Surprisingly, a longitudinal gradient was apparent among coves within the Osage Arm study reach. In linear regression analysis, this gradient showed the location of a cove relative to Bagnell Dam was a key factor influencing nutrient and Chl concentrations. Distance of a cove from the dam was positively correlated with values of TP ($r=0.86$), TN ($r=0.69$), and Chl ($r=0.71$, $n=28$, cross-cove linear regression, Table 6). On average among coves along the study reach, TP declined from 84 µg/L to 62 µg/L at a rate of 1.1 µg/L/km, TN declined from 867 µg/L to 777 µg/L at a rate of 4.4 µg/L/km, and Chl declined from 26 µg/L to 20 µg/L at a rate of 0.3 µg/L/km approaching Bagnell Dam. Mineral turbidity (NVSS) was also larger in coves located up-reservoir in the study reach. On average, within the 21 km of the Osage Arm study reach, NVSS decreased by 31% (from 4.2 mg/L to 2.9 mg/L, Table 5) among coves. In contrast, the organic fraction of the seston (VSS) increased on average by 29%, from 2.4 mg/L to 3.1 mg/L among coves located within this distance. On average, water clarity (Secchi depth) increased from 0.9 m to 1.1 m over this distance. Among coves, measurements influenced by biotic metabolism (DO and pH) also increased: DO increased by 41%, from 5.6 mg/L to 7.9 mg/L and pH increased from 7.6 to 8.07. Longitudinal patterns among coves were not distinguishable for conductivity and Cl.

Table 4. July-August, 2007 main channel site averages (J. R. Jones, unpublished data). Osage Arm Sites (5, 2.7, 2.4 and 2) are arranged in order approaching the dam in an attempt to show a general decreasing longitudinal trend in productivity. Note the Grand Glaize Arm site (3) is less nutrient-rich and less turbid than both Osage Arm sites. Site 5 is located 61 km up-reservoir of Bagnell Dam (reservoir-mile 38). Site 2.7 is located 43 km up-reservoir of Bagnell Dam (reservoir-mile 27). Site 2.4 is located 29 km up-reservoir of Bagnell Dam (reservoir-mile 18). Site 2 is located at Bagnell Dam.

Reservoir Arm	Site	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi depth (m)
Osage	5	110	778	36	0.7
	2.7/103	87	735	27	0.9
	2.4/101	79	668	24	1.1
	2	60	683	26	1.3
Grand Glaize	3/102	45	585	27	1.2

Table 5. Average longitudinal changes for select limnological measurements among coves on the Osage Arm study reach (20 km). Changes were based on linear regression. Percent increase (+) or decrease (-), and mean site limnological measurements up-reservoir (furthest from dam) and down-reservoir (closest to dam).

Limnological Measurement	% Change	Up-reservoir Value	Down-reservoir Value
Total Phosphorus (µg/L)	-26%	84	62
Total Nitrogen (µg/L)	-10%	867	777
Chlorophyll (µg/L)	-23%	26	20
Secchi Depth (m)	22%	0.9	1.1
Non-Volatile Suspended Solids (mg/L)	-31%	4.2	2.9
Volatile Suspended Solids (mg/L)	29%	2.4	3.1
Dissolved Oxygen (mg/L)	41%	5.6	7.9
pH	6%	7.6	8.07

Table 6. Significant regressions for nutrients and chlorophyll among coves in the Osage Arm study reach, May-August 2007. TN:TP= ratio of total nitrogen to total phosphorus. Other independent variables used in this analysis that were not statistically significant: log$_{10}$ percent forest area, log$_{10}$ percent crop area, log$_{10}$ percent pasture/grass/barren area, housing units, log$_{10}$ percent urban area, development value, housing density (housing units/land area), housing units/shoreline distance, shoreline density, and shoreline complexity. *p* critical=0.05, except where noted. Means for coves (28) used data from 7 sampling days (May-August 2007).

Response	**Model**	**r**	**F (df)**	**p**	**AIC**
Total Phosphorus	~Distance from Bagnell Dam	0.86	75 (1,26)	< 0.0001	162
	~Log$_{10}$Water Area	-0.67	22	< 0.0001	183
	~Log$_{10}$Shoreline Perimeter	-0.56	12	0.002	189
	~Log$_{10}$Total Watershed Area	-0.55	11	0.002	190
	~Log$_{10}$Land Area	-0.52	9	0.005	191
	~Distance from Bagnell Dam + log$_{10}$Land Area	0.92	67 (2,25)	< 0.0001	150
	~Distance from Bagnell Dam + log$_{10}$Shoreline Perimeter	0.92	73	< 0.0001	148
Total Nitrogen	~Distance from Bagnell Dam	0.69	24 (1,26)	< 0.0001	274
Chlorophyll	~Distance from Bagnell Dam	0.71	26 (1,26)	< 0.0001	123

Among coves on the Osage Arm, TP was correlated with several watershed metrics (all log-transformed). Cove shoreline perimeter (r=-0.56), TW (r=-0.55), and LA (r=-0.52) were all negatively correlated with TP. Cove WA was negatively correlated with TP (r=-0.67), but was also correlated with distance of a cove from the dam (r=-0.55). Land area and shoreline perimeter contributed slightly to a multivariate TP model using distance from Bagnell Dam. In this analysis, distance from the dam accounted for 74% of the variation in TP, and cove LA and shoreline perimeter accounted for over a third of the remaining variation (Table 6). Correlations between both TN and Chl and cove watershed metrics were not significant.

Influences of anthropogenic development on nutrients and Chl in coves on the Osage Arm were minor in 2007. Following the methods of Mitzelfelt (1985), binning main channel sites and coves by development class showed TP means increased with development class from low developed coves to high developed coves (Figure 13). There were no statistical differences, however, among/between development classes for the three water quality measures (Duncan's t-test, p=0.05). A scatter plot suggested that $\log_{10}$DV (HU/LA/WA) among cove watersheds had a positive exponential relationship with nutrients and Chl on the Osage Arm (Figure 14). Further evaluation of the development value using linear regression showed collinear variables in the index. Originally, the development value index was designed to measure anthropogenic influence (HU) while incorporating a dilution factor (LA/WA) for individual cove watersheds (Mitzelfelt 1985). In 2007, $\log_{10}$WA among coves was negatively correlated with distance from Bagnell Dam (r=-0.60)--cove WA increased with proximity to the dam. This pattern suggested the dilution factor, WA, strongly reflected basin morphology. When WA was removed from the development value calculations, the index was not correlated with TP, TN, or Chl. Because shoreline perimeter, like LA, was not significantly correlated with distance from Bagnell Dam, it was substituted as a dilution factor in the index (ie. HU/shoreline perimeter), but cross-cove correlations with nutrients and Chl were not significant. Cove HU were also used in this analysis, but were not correlated with nutrients. Because nutrients and Chl were not correlated with development indices or cove HU, the positive association between DV and nutrients reflected the longitudinal gradient (i.e. reservoir sedimentary processes, Thornton 1990) previously described in this reservoir, not anthropogenic activity or density. For confirmation, multivariate regression analysis using metrics from the original DV (HU, LA, and WA) showed HU was insignificant and did not contribute to multivariate nutrient models[7]. This conclusion was further supported in the same cross-cove analysis substituting 1980s TP and Chl data collected by Mitzelfelt (1985). Among 27 coves on the Osage Arm in the 1980s, correlations between TP and Chl and DV, HU/LA, HU/shoreline perimeter, and HU were not significant (cove means, Appendix 6). Overall in 2007, anthropogenic development indices, including percent urban area, were not significantly correlated with TP, TN, or Chl, which suggested anthropogenic influences were absent or undetectable among coves in 2007.

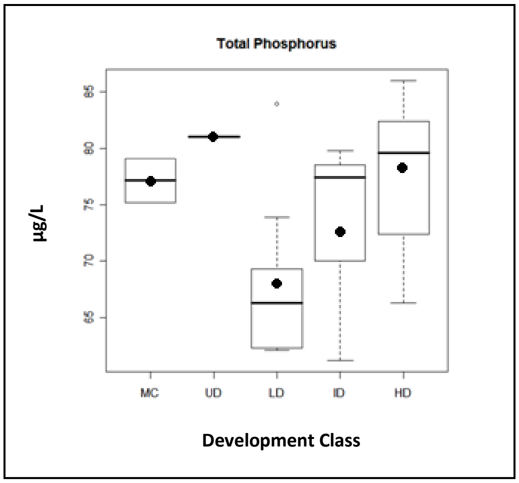

Figure 13. Osage Arm relationships between total phosphorus (µg/L) and development class (MC=main channel, UD=undeveloped, LD=low development, ID=intermediate development, HD=high development). Box plots represent minimum, maximum, upper and lower quartiles, and median values. The open circle in the box plot for LD is an outlier and all closed circles are means.

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[7] Independent variables used in regressions: Distance from Bagnell Dam, $\log_{10}$ total watershed area (ha), $\log_{10}$ land area (ha), $\log_{10}$ water area (ha), $\log_{10}$ shoreline perimeter (m), shoreline density, shoreline complexity, housing units, $\log_{10}$ percent urban area, $\log_{10}$ percent forest area, $\log_{10}$ percent crop area, $\log_{10}$ percent pasture/grass/barren area, development value, housing units/land area, housing units/shoreline distance.

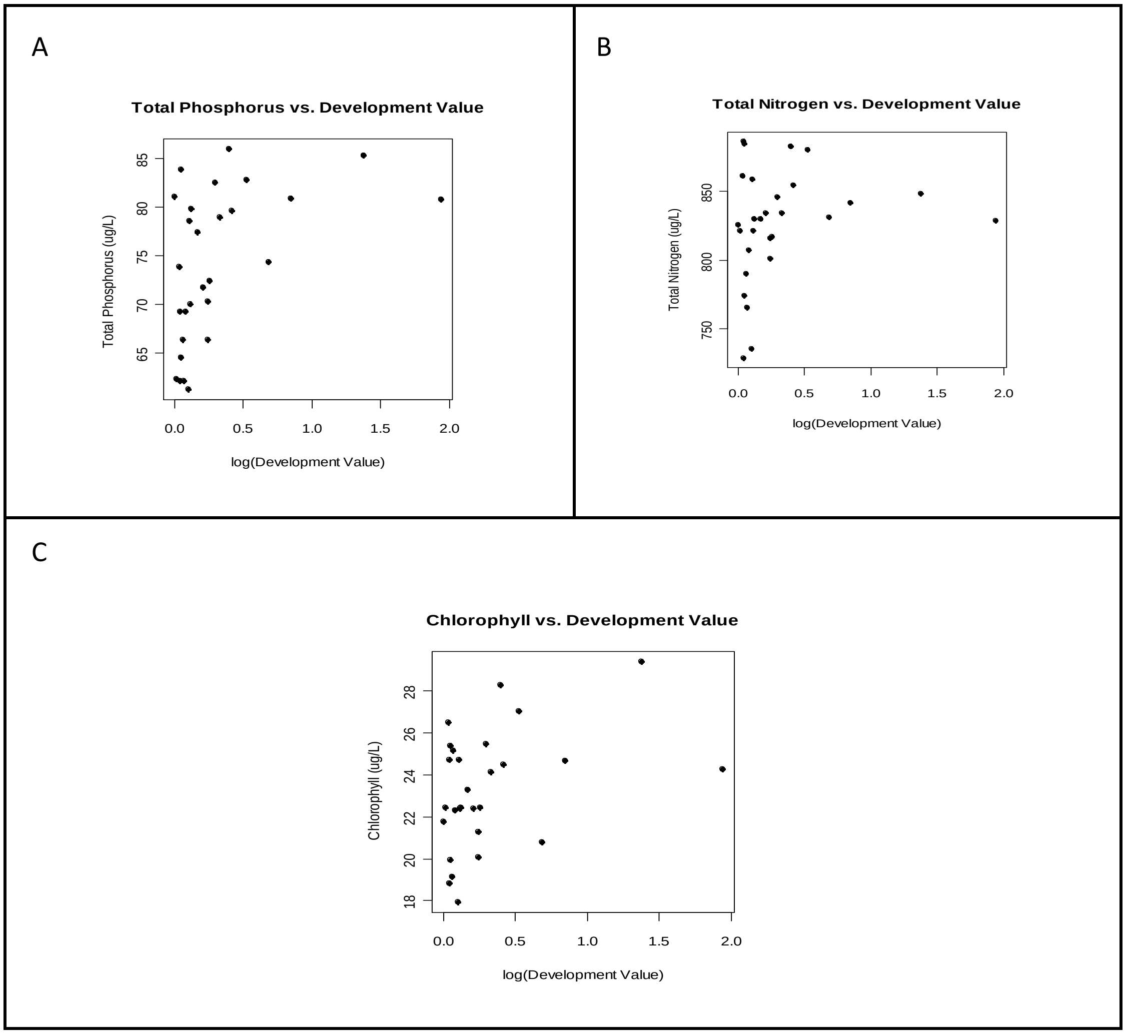

Figure 14. Scatter plots suggesting an exponential increase in total phosphorus (A), total nitrogen (B), and chlorophyll (C) with $\log_{10}$development value among 28 Osage Arm coves.

Grand Glaize Arm

On the Grand Glaize Arm (Figure 3), site averages ranged from 40-59 µg/L for TP, 604-763 µg/L for TN, 24-43 µg/L for Chl, 2.3-3.3 mg/L for NVSS, 3.5-5.3 mg/L for VSS, 7.9-9.7 mg/L for DO, 246-257 µS/cm for conductivity, 8.26-8.72 for pH, and 5.8-6.4 mg/L for Cl (Table 3). Seasonal means for water quality variables among coves and a single main channel site on the Grand Glaize Arm were similar to each other. Analysis of a longitudinal gradient in the main channel of the Grand Glaize Arm was not possible because only one main channel site was sampled. A gradient was not distinct among coves on the Grand Glaize Arm; although there was spatial variation in nutrients and Chl. Cove means for nutrients (TP, from 40-51 µg/L; TN, from 623-716 µg/L) and Chl (from 25-34 µg/L) declined from 6-10 km (mile markers 4-6) on the Grand Glaize Arm study reach. Cove 33, in the middle of the study reach, had the largest nutrient (TP=59 µg/L, TN=763 µg/L) and Chl (43 µg/L) means. Values of nutrients (TP=45-49 µg/L, TN=635-689 µg/L) and Chl (24-30 µg/L) were similar among the 3 coves downstream from this point (around kilometer 3 or mile marker 2). Results from descriptive and regression analyses, using watershed metrics, housing units, and percent urban area were not statistically significant on the Grand Glaize Arm likely because only 7 coves clustered near the lower end of the study reach (3-8 km) were sampled.

Fecal Indicators

In 2007, fecal coliform (FC) was detected in 84% of samples, *E. coli* (EC) in 94% of samples, and *B. thetaiotaomicron* (BT) in 14% of samples (n=311) collected from 3 main channel sites (2 Osage and 1 Grand Glaize) and 35 coves (28 Osage and 7 Grand Glaize). Bacterial counts ranged from 0-4,880 CFU/100 mL (median=13.3 CFU/100 mL) for FC and 0-547 CFU/100 mL (median=5.2 CFU/100 mL) for EC (Appendix 3). Seasonal means (geometric) for all sites ranged from 1-58 CFU/100 mL (CFU from here on) for FC and 1-39 CFU for EC (Table 7). Over the season, site detections for BT ranged from 0-5 counts, or a detection frequency[8] of 0%-71% (Table 7).

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[8] Site detection frequency=(Number detects in site/Number sampling days)*100

Table 7. Seasonal means and frequencies for Osage and Grand Glaize Arm bacteria, from May-August 2007: geometric means for fecal coliform (FC) in CFU/100 ml; *E. coli* (EC) in CFU/100 ml; *B. thetaiotaomicron* (BT, total counts per site); percent positive *B. thetaiotaomicron* detections (% BT=(No. detections/No. sampling days)*100); and their respective seasonal means calculated with August 20 data collected during a precipitation event (P). Sites are listed up-reservoir to down-reservoir in both arms according to their distance in kilometers from Bagnell Dam on the Osage or distance from the Osage-Grand Glaize Arm confluence on the

Reservoir Arm	Site	Dam	FC	EC	BT count	% BT	FC-P	EC-P	BT-P	% BT-P
Osage	103	43	2	1.8	1	17	3.2	1.8	1	14
	31	43	8.1	3.8	0	0	12.2	4.2	0	0
	26	43	5.8	4.6	1	17	9.7	4.3	1	14
	25	42	26	17.1	2	33	42.1	20.1	2	29
	24	42	17.1	12	2	33	17.1	14.6	2	29
	23	42	23.3	20.2	1	17	41.6	22.8	2	29
	22	42	7.6	3	0	0	12.3	3.1	0	0
	21	41	13.8	3.7	1	17	17.7	4.5	1	14
	20	40	42.8	12.9	1	17	54.4	15.9	1	14
	19	37	22	7.6	2	33	38.1	8.2	2	29
	18	37	21.7	15.4	1	17	35.8	16.1	1	0
	17	36	14.6	10.2	1	17	26.2	10.7	1	0
	16	36	28.2	33.3	2	33	58.8	38.9	2	29
	15	34	18.6	11.9	1	0	18.6	13	2	29
	14	34	9	5.6	1	17	9	6.8	1	14
	13	33	10	6.4	0	0	14	8.7	0	0
	12	33	7.1	6.1	1	17	10.7	7	1	14
	11	32	8.5	1.5	0	0	12.8	1.5	0	0
	10	31	24.5	12.1	0	0	40.8	12.8	0	14
	9	31	11.3	3.9	1	17	25.7	7	1	14
	8	30	6.7	2	0	0	6.7	2.9	0	0
	101	29	5.4	1.8	1	17	8.5	1.9	1	14
	7	29	12.5	2.1	1	17	23.9	3	1	14
	6	29	4.2	2.3	0	0	4.2	3	1	14
	5	28	9	5.1	1	17	9	6.4	1	14
	30	27	20	7.4	2	33	43.6	7.4	3	43
	4	27	14.8	3	1	17	25.6	3.7	1	14
	3	24	15.6	4.3	1	17	26.7	3.9	2	29
	2	24	12.3	4.8	1	17	21.8	4.7	1	14
	1	23	6.2	1.4	4	67	6.2	1.8	5	71
Grand Glaize	36	8	0.7	2	2	33	1.3	2.5	2	29
	34	8	5.2	2.5	0	0	5.7	2.8	0	0
	35	7	0.7	0.9	0	0	1.1	1.1	0	0
	33	4	1.2	1.9	3	50	0.9	1.9	3	43
	32	3	0.8	1.6	0	0	2.9	1.9	0	0
	29	3	1.3	1.1	1	17	1.7	1.3	1	14
	28	3	1.1	1.3	1	17	1.5	1.5	1	14
	102	2	1.1	0.7	1	17	0.8	0.8	1	14

Exceeding Standards

Site geometric means for both FC (1-58 CFU) and EC (1-39 CFU) during May-August 2007 (n=38 sites) did not exceed EPA standards for waters used for whole body contact recreation (200 CFU and 126 CFU, respectively). Ten coves in both the Osage and Grand Glaize Arms, however, exceeded discharge effluent standards for FC (1,000 CFU) and/or losing stream standards for EC (126 CFU) on some sampling dates during the season (8 samples for FC and 7 samples for EC, Table 8). These samples represented < 3% of the samples collected in 2007 from all sites. Individual EC samples did not exceed the effective discharge effluent standard of 630 CFU during the 2007 season. *B. thetaiotaomicron* was not included in this assessment because no standards have been established.

Short-Term Temporal Variation and Spatial Variation

Fecal coliform and *E. coli* varied temporally as a function of hydrology and climatic conditions. Discharge, precipitation, and wind speed contributed to this variation. Elevated discharge and/or rain events were associated with increases in FC and EC concentrations throughout the main channel sites and coves (Figure 15). Runoff from local precipitation events may have been a predominating factor producing short-term variation in FC and EC concentrations in main channel sites and coves. A thunderstorm beginning 8 hours before collections on 20 August, 2007 and ending at the 4th hour of collections that day delivered 7.1 cm (2.9 inches) precipitation to the Lake Ozark region. This storm event significantly elevated seasonal site averages for FC by as much as 263% and for EC by as much as 219% relative to averages with August 20 data omitted (Table 7, paired t-test, p=0.05). The August 20 event yielded FC concentrations that exceeded the EPA discharge effluent standard of 1,000 CFU: 6 of the 8 samples that exceeded this standard occurred on August 20. *B. thetaiotaomicron* seemed unaffected by the precipitation event (Figure 16). The number of BT detections on August 20 (6 detections) was typical of most sampling days (range 3-6 detections), except May 29 when there were 13 detections (Table 9). Site averages (FC and EC) and detection frequencies (BT) for the remainder of the 2007 bacterial analysis excluded 20 August sampling date due to the increases in FC and EC bacteria during the rain event.

August 20, however, was included in the temporal analysis.

Table 8. Samples exceeding losing stream (*E. coli*=126 CFU) and discharge effluent (*E. coli*=630 CFU and fecal coliform=1,000 CFU) standards from May through August in 2007 and 2008. --- indicates a sample in compliance with standards. For *B. thetaiotaomicron,* + indicates a detection and – indicates absence or no detection. *B. thetaiotaomicron* was not analyzed in 2008 (NA).

Date	**Cove**	**Fecal coliform (CFU)**	***E. coli* (CFU)**	***B. thetaiotaomicron***
29-May-07	16	---	200	+
	20	---	133.3	+
11-Jun-07	23	---	380	+
9-Jul-07	21 (mouth)	1086.7	---	-
	26 (back)	---	300	-
	26 (mouth)	---	300	-
	26	---	546.7	-
23-Jul-07	16	1070	240	-
6-Aug-07	30	---	133.3	-
20-Aug-07	7	1146.7	---	-
	9	1560	221.7	-
	16	4880	---	-
	19	1040	---	-
	23	1350	---	+
	30	2140	---	+
27-May-08	16	---	136.7	NA
	23	1220	753.3	NA
	24	---	331	NA
3-Jul-08	9	---	170	NA

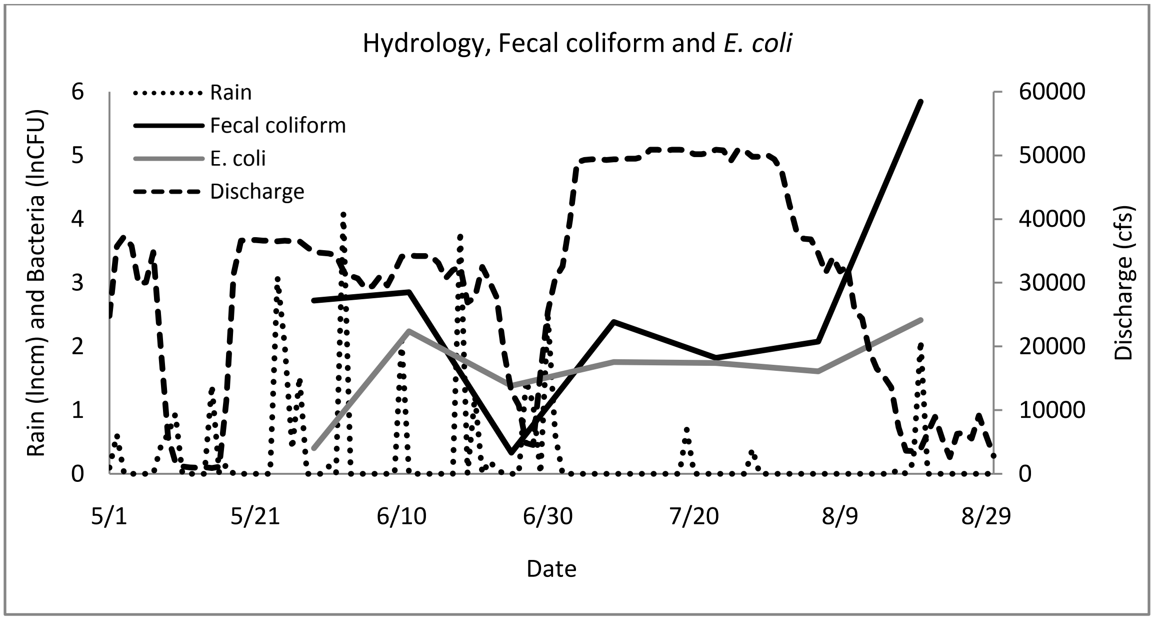

Figure 15. Fecal coliform and *E. coli*, and their relationship with discharge and precipitation. Discharge and bacteria data are daily means for all May-August 2007 sites (n=38). Rain data are total precipitation in cm per day. Both bacterial and rain data are ln+1-transformed.

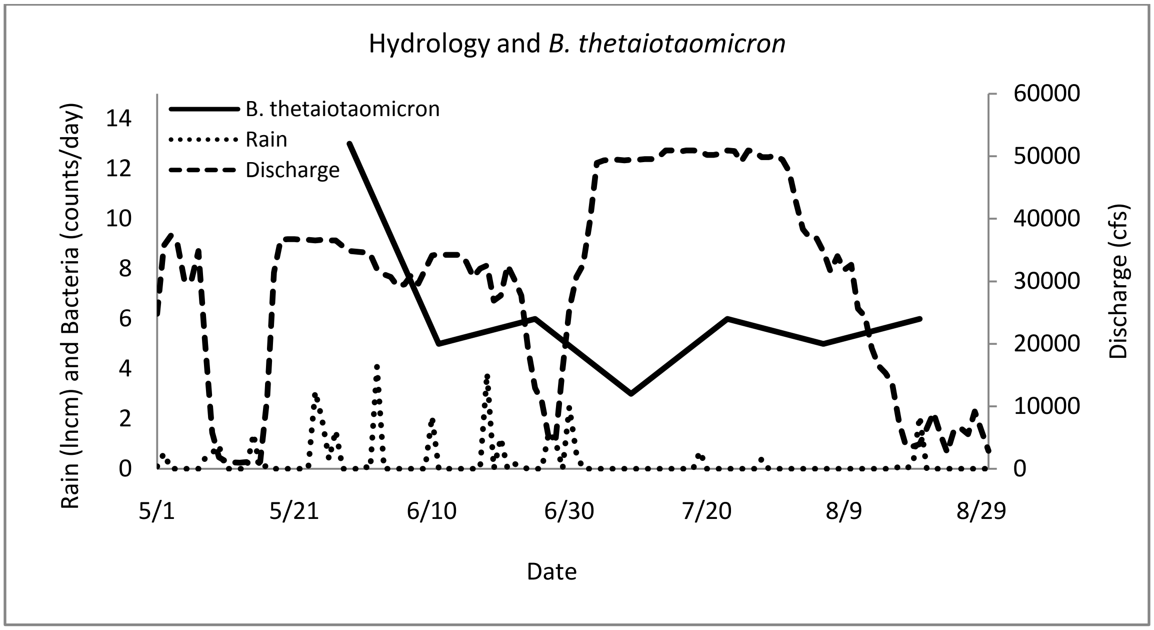

Figure 16. *B. thetaiotaomicron* and its relationship with discharge and precipitation. *B. thetaiotaomicron* values are total number of detections per day for the reservoir (i.e. Number of positives per day for all 38 sites). Discharge data are daily means, and rain data are total precipitation in cm per day (ln+1-transformed).

Table 9. Mean daily wind speed, discharge from Bagnell Dam, traffic volume at Bagnell Dam from the previous Friday (No. cars/day), fecal coliform, and *E. coli*, and daily *B. thetaiotaomicron* counts in Lake of the Ozarks May-August 2007. For most days, n=38 for fecal coliform and *E. coli* averages.

Date	Wind Speed (km/hr)	Discharge (cfs)	Traffic (vehicles/day)	Fecal coliform (CFU/100 mL)	*E. coli* (CFU/100 mL)	*B. thetaiotaomicron* (count/day)
29-May	3.22	34800	20842	15.2	0.5	13
11-Jun	9.66	34300	15645	17.4	8.4	5
25-Jun	3.22	12900	16382	1.4	3	6
9-Jul	8.05	49400	15964	10.9	4.8	3
23-Jul	4.83	50900	17921	6.2	4.7	6
6-Aug	6.44	34600	17599	8	4	5
20-Aug	19.32	3960	16126	345.4	10.2	6

Local wind speed also contributed to short-term variation in bacteria. Increased mean wind speed on 20 August corresponded with the rain event that day and the concurrent increase in FC and EC (Table 9). Wind speed is associated with sediment suspension via turbulence or currents, which explained the positive correlation between daily mean wind speed and daily mean FC (r=0.83) and EC (r=0.93) over the 2007 season (temporal regression analysis, n=7, Figure 17, Table 9). Alternatively, wind speed was negatively correlated with BT when 20 August was omitted (r=0.74, p=0.1), but the correlation was weak, partly because of low sampling frequency (n=6 sampling days) and the binary (presence/absence) nature of the data (Figure 18).

Rain also confounded assessments of fecal indicators over holiday weekends in 2008 (Figure 19). The region received 3.4 cm of rain before the post-Memorial Day trip, which likely contributed to increases in FC (by 1.2-180 times) and EC (by 1.7-331 times) relative to pre-weekend collections. Rain (0.33 cm) before the pre-Independence Day collection likely elevated FC and EC concentrations, which contributed to a misleading decrease in FC (by 31%=mean) and EC (by 70%=mean) after the weekend (Appendix 3). The 2008 holiday analysis excluded Memorial and Independence Day weekends (unless otherwise noted).

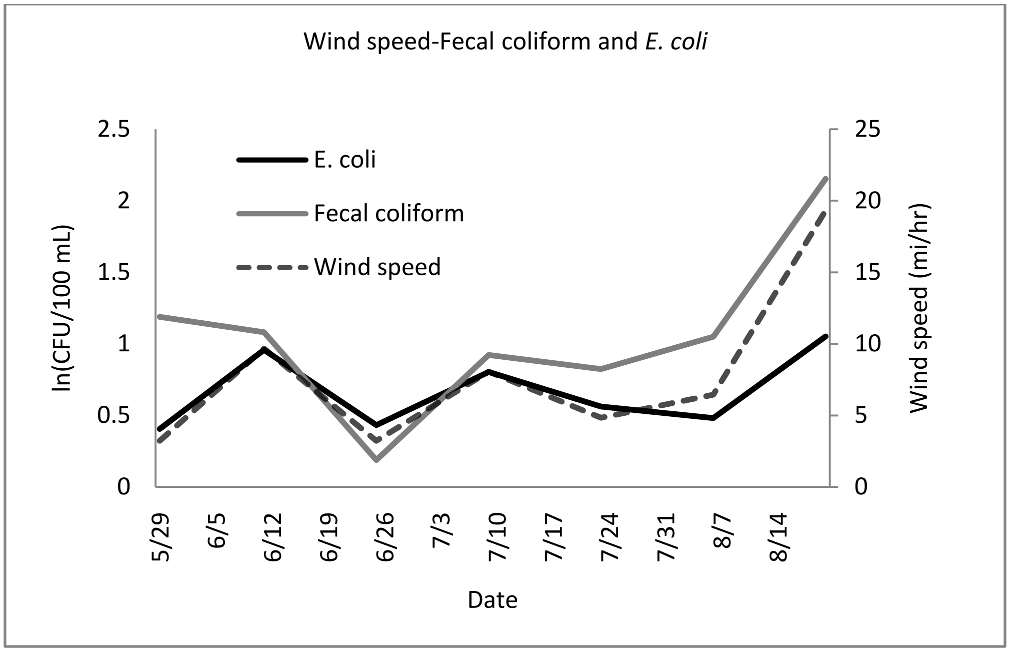

Figure 17. Fecal coliform and *E. coli*, and their relationship with wind speed. Fecal coliform, *E. coli*, and wind speed data are daily means for all May-August 2007 sites (n=38).

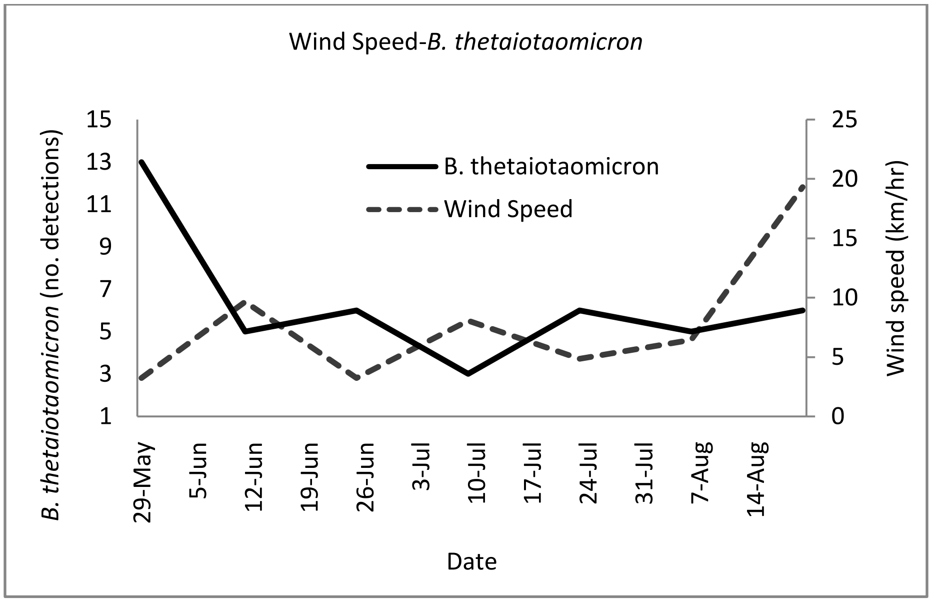

Figure 18. *B. thetaiotaomicron* and its relationship with wind speed. *B. thetaiotaomicron* values represent number of sites per day where the bacteria were detected (n=38 sites). Wind speed data are daily means.

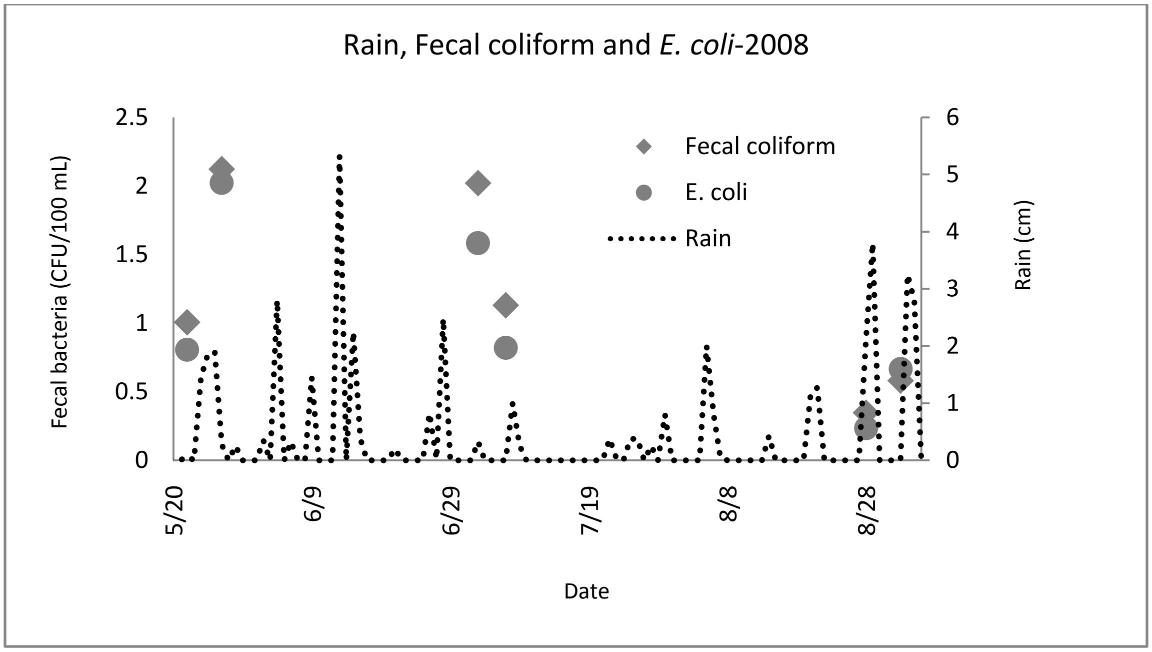

Figure 19. Potential effects of rain on fecal coliform and *E. coli* during 2008 holiday sampling on the Osage Arm.

After removing 20 August data, individual FC values ranged from 0-1,087 CFU (median=10 CFU), instead of 0-4,880 CFU, and seasonal means for sites were 1-43 CFU, instead of 1-58 CFU. The range and median for individual EC values were unchanged (0-547 CFU, median=5 CFU) by excluding this day, and seasonal means for sites were 1-33 CFU, instead of 1-39 CFU (Table 7). The number of FC samples exceeding the EPA discharge effluent standard decreased from 8 to 2. The number of EC samples exceeding the EPA losing stream standard decreased from 7 to 6. The range in BT detection for sites decreased from 0-5 detections to 0-4 detections. Frequency of BT detection, however, was unchanged: across sites the range was 0-17%. Change in the frequency of detection in individual sites changed because of a decreased number of sampling days used in the calculation[9]. For sites with BT detection on 20 August, frequencies decreased, and frequencies increased for sites lacking BT detection on 20 August (Table 7).

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[9] Site detection frequency=(Number detects in site/Number sampling days)*100

Similar to limnological measurements in the study reach, bacterial measurements of FC and EC differed between the Osage and Grand Glaize Arms. Main channel sites on the Osage Arm had seasonal averages 2-5 times larger for FC and 3 times larger for EC than on the Grand Glaize Arm. On average, FC in Osage Arm coves was 8 times that in Grand Glaize Arm coves, and EC in Osage Arm coves was 4 times that in Grand Glaize Arm coves. These differences in FC and EC between the two arms were statistically significant (ANOVA, p=0.05). In contrast to limnological, FC, and EC findings, BT was equally detected in the main channel of the Osage Arm (2 sites) and the main channel of the Grand Glaize Arm (1 site, detected frequency=17%), and on average, was equally detected among coves on the two arms (mean detected frequency=17%, Table 7). Patterns in FC and EC concentrations between the Osage and Grand Glaize Arms were similar to patterns in limnological measurements (page 25). These patterns likely reflected a smaller load of allochthonous material in the Grand Glaize Arm watershed. For this reason, all bacterial data (including BT) were further analyzed separately for the Osage and Grand Glaize Arms, except where noted.

Osage Arm

On the Osage Arm, site means ranged from 2-43 CFU for FC and 1-33 CFU for EC. Site frequencies for BT ranged from 0-67% (Table 7). Fecal coliform and *E. coli* in coves (4-43 CFU and 1-33 CFU, respectively) were on average, 4 times larger than in the two main channel sites (2-5 CFU and 2 CFU, respectively). Fecal coliform and *E. coli* values in main channel sites, however, were similar to values in adjacent coves. Frequency of detection for *B. thetaiotaomicron* in coves (17%, ranging from 0-67%) and main channel sites (17%) did not differ. In fact, frequencies greater than 17% occurred exclusively in coves.

The geometric means in the 2 main channel sites were similar to each other for FC (Site 103=2 CFU, Site 101=5 CFU) and did not differ for EC (2 CFU) and BT (17%). Surprisingly, location along the Osage Arm was a key factor influencing FC and EC means among coves. Similar to nutrients and Chl, both

FC and EC declined from up- to down-reservoir in the study reach. Regression analysis using the 28 coves showed mean FC values were not significantly correlated with distance from Bagnell Dam. Three outlier coves, however, had surprisingly low FC concentrations considering their up-reservoir location. When these sites were removed from this analysis, FC was positively correlated with distance from Bagnell Dam (r=0.54, Table 10). For EC, a positive correlation with distance from Bagnell Dam was significant among all 28 coves (r=0.46, Table 10). Both FC and EC declined by about 1.1 CFU per kilometer proceeding towards Bagnell Dam. For BT, spatial and longitudinal gradients were not apparent in the data.

Table 10. Fecal coliform and *E. coli* regressions across Osage Arm coves (n=28) in 2007. Other independent variables used in this analysis that were not statistically significant: $\log_{10}$land area, $\log_{10}$shoreline distance, $\log_{10}$ percent forest area, $\log_{10}$ percent crop area, $\log_{10}$ percent pasture/grass/barren area, housing units, $\log_{10}$ percent urban area, development value, housing density (housing units/land area), housing units/shoreline distance, shoreline density, and shoreline complexity. n=6 for most individual cove statistics. *p*-critical = 0.05, except where noted. * Model does not include data from coves 22, 26, or 31.

Response	**Predictor**	**r**	**F (df)**	**p**	**AIC**
$\log_e$Fecal coliform	Distance from Bagnell Dam*	0.54	9.27 (1,23)	< 0.01	37.6
	Secchi Depth	-0.32	2.96 (1,26)	0.097 (p crit=0.1)	49.2
	$\log_{10}$Chlorophyll	0.43	5.98	0.02	46.4
	$\log_e$*E. coli*	0.77	38.29	< 0.01	26.9
$\log_e$*E. coli*	Distance from Bagnell Dam	0.46	7.07	0.01	66.5
	Secchi Depth	-0.48	7.82	0.01	65.9
	$\log_{10}$Chlorophyll	0.67	21.01	< 0.01	56.7
	Total Phosphorus	0.54	10.71	< 0.01	63.6
	Total Nitrogen	0.54	10.92	< 0.01	63.5
	Dissolved Nitrogen	0.33	3.18	0.086 (p=0.1)	70
	pH	-0.53	9.93	< 0.01	64.2
	$\log_{10}$Dissolved Oxygen	-0.47	7.27	0.01	66.4
	Temperature	-0.55	11.15	< 0.01	63.3

In contrast to TP patterns, neither FC nor EC means were correlated with cove watershed metrics. Regression analysis was not possible using binary BT data, so measurements of watershed metrics were binned or averaged according to the number of detections per cove during the 2007 season (i.e. 0 detections, 1 detection, 2 detections, and 4 detections). Differences between bins were assessed using a Duncan's t-test (p=0.05). Bins were not significantly different; however, trends among bins were consistent for all watershed metrics. On average, BT frequency decreased among coves with increasing watershed metrics. For LA, coves with 0 detections averaged 123 ha, coves with 1 detection averaged 72 ha, and coves with 2 detections averaged 56 ha. For WA, coves with 0 detections averaged 17 ha, coves with 1 detection averaged 11 ha, and coves with 2 detections averaged 6 ha. For shoreline perimeter, coves with 0 detections averaged 5,609 m, coves with 1 detection averaged 4,105 m, and coves with 2 detections averaged 3,528 m (Table 11, Figure 20).

Table 11. *B. thetaiotaomicron* and mean cove limnological, watershed, and bacterial measurements. All measurements are averaged in bins respective of the number of *B. thetaiotaomicron* detections throughout the 2007 season. Bins, 0 (n=8), 1 (n=14), 2 (n=5), and 4 (n=1)

	Number of *B. thetaiotaomicron* detections (Bin)			
	0	**1**	**2**	**4**
Measurement	**(n=8)**	**(n=14)**	**(n=5)**	**(n=1)**
Distance from Bagnell Dam (km)	34	33.4	36.8	22.5
Water Area (ha)	17.4	10.7	6.1	18.5
Land Area (ha)	122.7	71.9	56	66.4
Total Watershed Area (ha)	140.1	82.6	62.1	84.9
Shoreline Perimeter (m)	5609	4105	3528	4181
Percent Urban Area	37	38.7	22.9	22.8
Number of Housing Units	244.3	155.8	101.2	50
E. coli (CFU/100 mL)	5.4	7.3	15.5	1.4
Fecal coliform (CFU/100 mL)	11	15.3	22.7	6.2
Chlorophyll (µg/L)	23.8	23.6	26.7	19.6
Dissolved Oxygen (mg/L)	7.4	7.2	6.5	7.5
Chloride ion (µg/L)	6	6	6	6.1
Total Phosphorus (µg/L)	71	74.6	81.4	61.1
Total Nitrogen (µg/L)	829	826.1	869.7	718.3
Secchi Depth (m)	0.95	0.92	0.86	1
Dissolved Phosphorus (µg/L)	38.6	42.6	46.5	35.2
Dissolved Nitrogen (µg/L)	544.8	569.3	596	511.7
Temperature (˚C)	7.4	7.4	6.9	8.2
pH	7.9	7.9	7.7	8.2

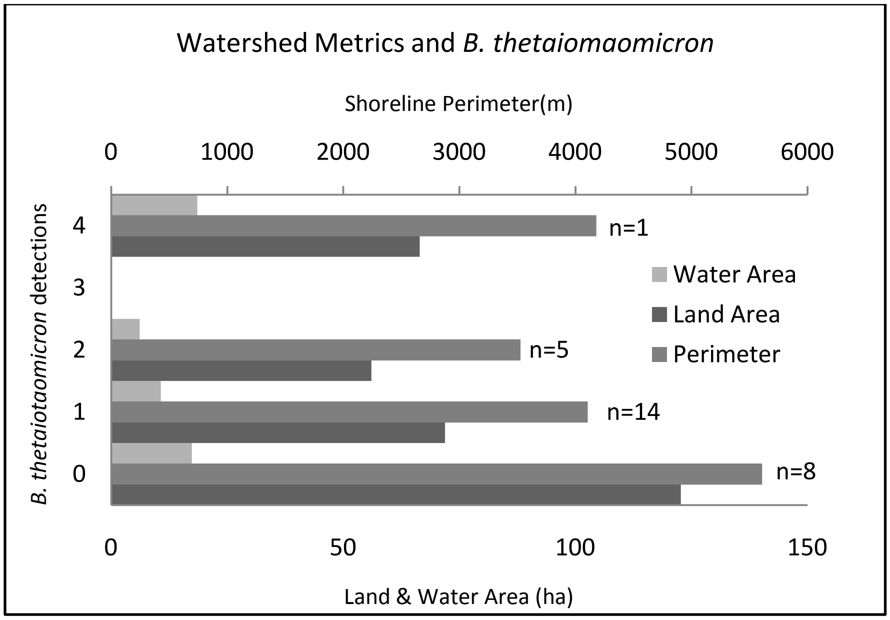

Figure 20. *B. thetaiotaomicron* relationship with land area, water area, and shoreline perimeter among cove watersheds on the Osage Arm study reach. Watershed metrics were binned and averaged according to the number of *B. thetaiotaomicron* detections in the individual cove over the 2007 season.

Grand Glaize Arm

On the Grand Glaize Arm, site means for FC (1-5 CFU, mean=1.6 CFU) and EC (1-2.5 CFU, mean=1.6 CFU) were low and similar among coves and main channel sites (Table 7). Frequency of BT detections ranged from 0-50% among sites. On average, values of FC (2 CFU) and EC (2 CFU) in coves, and detection frequencies for BT (16.7%) were nearly identical to main channel site FC (1 CFU), EC (1 CFU), and BT (17%). Analysis of a longitudinal gradient for fecal bacteria in the main channel of the Grand Glaize Arm was not possible because there was only one main channel site. A gradient was also not evident among the 7 coves on Grand Glaize Arm. There were, however, spatial patterns in FC and EC cove means: Cove 34, at the upper reach of the arm, had the largest mean FC (5.2 CFU) and EC (2.5 CFU), and Cove 33 (mid-reach) had the largest BT detection frequency (50%). Interestingly, Cove 33 also had the largest mean TP, TN, and Chl concentrations on the Grand Glaize Arm (page 33). The large frequency for BT detection and the presence of a septic lagoon in this watershed suggested nutrient and Chl enrichment were of anthropogenic origin. Descriptive and regression analyses using cove watershed metrics were not statistically significant on the Grand Glaize Arm because only 7 coves were sampled and they were clustered near the lower end of the study reach (3-8 km). For BT, there were too few detections on the Grand Glaize Arm to perform the bin analysis.

Anthropogenic Influences on Fecal Indicators among Coves

Most results in this section incorporate FC and EC data from 2007 and 2008 from both Osage and Grand Glaize Arms. Main channel sites are mostly excluded from this section because they lacked localized equivalents to a cove watershed.

In 2007 among the Osage Arm coves, mean FC and EC were not correlated with percent urban area, HU, or Cl concentrations[10] (cross-cove analysis, n=28). Surprisingly, in the bin analysis, BT detection in coves decreased with increasing HU: on average, coves with 2 detections had 101 HU, coves with 1 detection had 156 HU, and coves with 0 detections had 244 HU (Table 11, Figure 21). Differences between bins, however, were not statistically significant in the Duncan's t-test. The same decreasing pattern did not exist with percent urban data, which suggested the BT and HU pattern may have reflected more effective waste water treatment in populated coves or heavier dependence on septic systems in less populated coves. The pattern may have also reflected the negative relationship between BT and $\log_{10}$LA (Figure 20), because HU was positively correlated with $\log_{10}$LA (r=0.52) in the Osage Arm cross-cove analysis.

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[10] Chloride ions can indicate human waste in water (Ownbey and Kee 1967, Morrice et al. 2008).

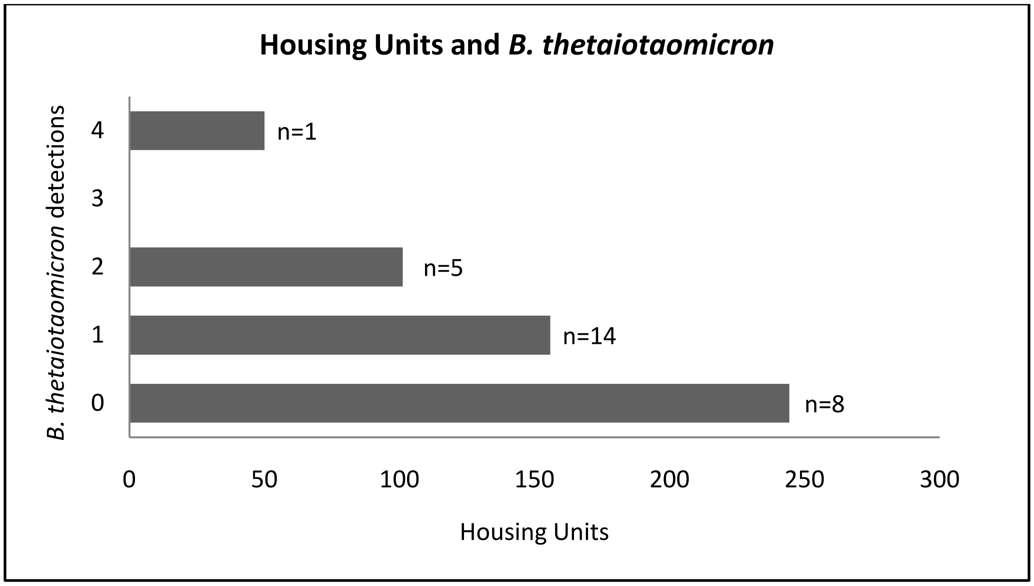

Figure 21. *B. thetaiotaomicron* relationship with housing units among coves on the Osage Arm study reach. Housing units were binned and averaged according to the number of *B. thetaiotaomicron* detections in a cove over the 2007 season.

Relationships between fecal bacteria and anthropogenic activity[11] were confounding. Mean daily FC and EC concentrations in coves across the study region were negatively related to traffic volume entering the Lake Ozark region during 2007 (temporal analysis, n=7, Table 9, Figures 22 and 23). Alternatively, BT counts were positively correlated with traffic volume recorded on the Friday prior to sampling (r=0.62, temporal analysis, Table 9, Figure 24). This correlation was weak and not significant when May 29 was omitted from the analysis.

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[11] Anthropogenic activity was measured by variation in traffic volume throughout the 2007 season and changes in bacteria over a 2007 weekend and 2008 holiday weekends.

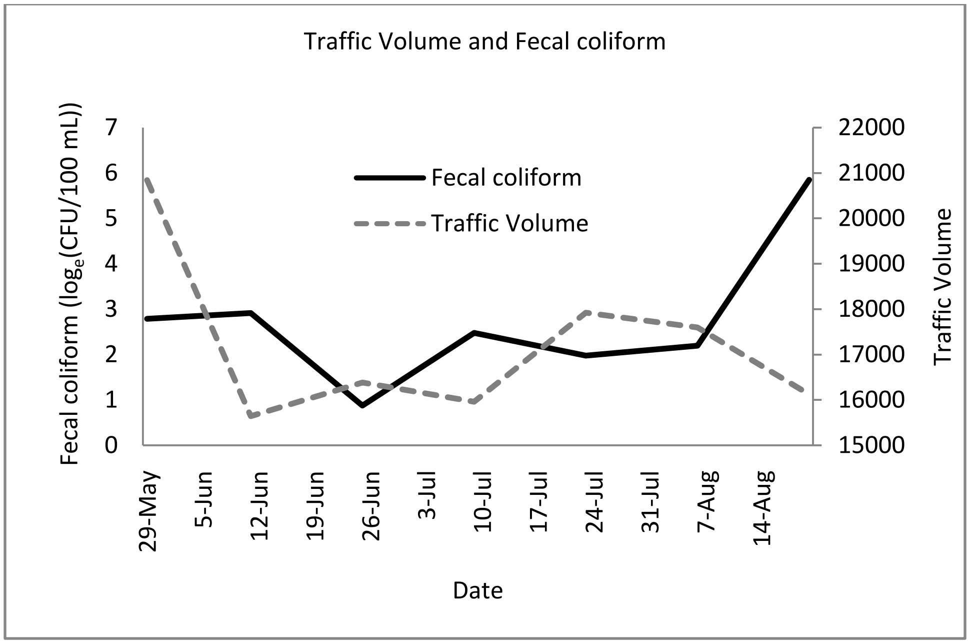

Figure 22. Relationship between daily traffic volume and mean daily fecal coliform for all coves and main channel sites in the study reach from May-August 2007.

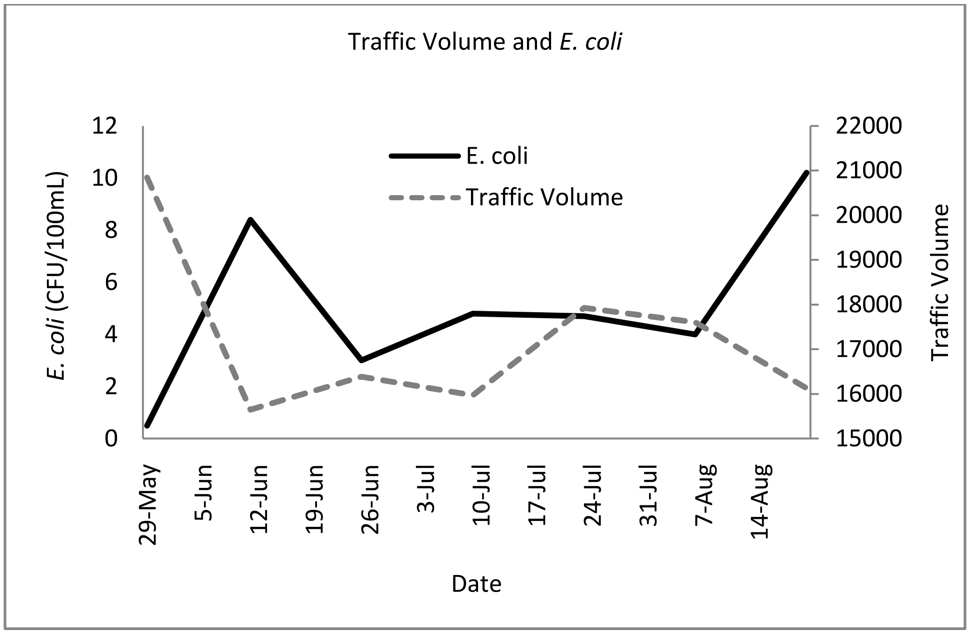

Figure 23. Relationship between daily traffic volume and mean daily *E. coli* for all coves and main channel sites in the study reach from May-August 2007.

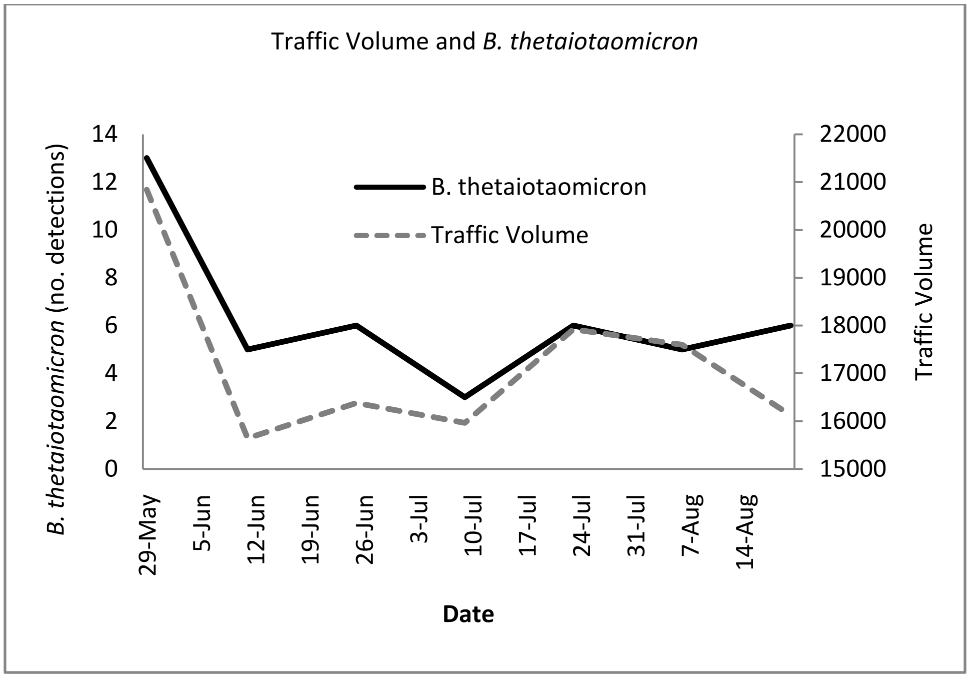

Figure 24. Relationship between daily traffic volume and number of *B. thetaiotaomicron* detects per day for coves and main channel sites in the study reach from May-August 2007.

Traffic volumes indicated activity peaked in the Lake Ozark region on weekends and holidays. Both FC and EC increased in 11 coves (9 Osage and 2 Grand Glaize) over the weekend of August 3, 2007 weekend (Table 12, Figure 25). Fecal coliform before and after this weekend ranged from 7-983 CFU (median=85 CFU) and 0-307 CFU (median=41 CFU), respectively. Over the 2007 weekend, FC increased in 45% of these coves as much as 25.7 times. On average, however, increases in FC were not significant over the weekend (paired t-test, p=0.1). *E. coli* before and after this same weekend ranged from 0-5 CFU (median=4 CFU) and 1-33 CFU (median=4 CFU), respectively. *E. coli* increased in 64% of the coves, including party cove, over the 2007 weekend as much as 10 times. On average, the increase for EC over the weekend was significant (paired t-test, p=0.1). For BT, daily frequency of detection was the same before and after the weekend (2 detections). In 13 Osage Arm coves over Labor Day weekend 2008 (Table 12), FC ranged from 0-9 CFU (median=0 CFU) pre-weekend and 0-14 CFU (median=3 CFU) post-weekend. Fecal coliform increased in 31% of the coves as much as 9.3 times. On average, however, the increase in FC was not significant (paired t-test, p=0.1). *E. coli* before and after Labor Day weekend ranged from 0-3 CFU (median=2 CFU) and 0-19 CFU (median=2 CFU), respectively. *E. coli* increased in 69% of the coves sampled by as much as 12.7 times. On average increases for EC were significant (p=0.1, Figure 25).

Table 12. Fecal indicators in coves before and after the August 3, 2007 weekend and Labor Day weekend in 2008. Main channel sampling sites 101 and 103 were also sampled over Labor Day weekend. Detection of *B. thetaiotaomicron* is denoted with "+." INT=microbial growth interference on plate. *B. thetaiotaomicron* were not sampled in 2008.

		Fecal coliform (CFU)		*E. coli* (CFU)		Multiplication Factor		*B. thetaiotaomicron*	
Weekend	Site	*pre*	*post*	*pre*	*post*	*Fecal coliform*	*E. coli*	*pre*	*post*
August Weekend 2007	10	74	66.7	3.6	3.6	0.9	1	+	-
	14	8.4	14.7	0.5	0.5	1.8	1	-	-
	15	7.8	200	1.6	4	25.7	2.5	+	-
	16	160	0	2.7	6.5	0	2.4	-	-
	18	420	10	5.3	33.3	0.02	6.3	-	-
	20	186.7	306.7	3.6	5.2	1.6	1.4	-	-
	23	983.3	10	4.4	3.8	0.01	0.9	-	-
	24	17.5	106.7	5	4.4	6.1	0.9	-	+
	25	6.7	145	4.8	28.4	21.7	5.9	-	-
	33	95	3.3	0.4	4	0.03	10	-	+
	party cove	INT	INT	1.3	2	INT	1.5	-	-
Labor Day 2008	103	0	0.5	0	0	0.5	1	---	---
	26	0	0	0	1.7	1	1.7	---	---
	25	0	9.3	2.1	8.8	9.3	4.2	---	---
	24	6.7	4.3	0	2.4	0.7	2.4	---	---
	23	9.2	13.9	3	0.8	1.5	0.3	---	---
	20	8	6.7	2.5	2.4	0.8	1	---	---
	19	0	INT	2.9	3.2	INT	1.1	---	---
	16	0	0	1	12.7	1	12.7	---	---
	15	0	0	3.3	19	1	5.7	---	---
	14	0	0.7	3	0	0.7	0	---	---
	9	1.7	0	2.7	7.5	0	2.8	---	---
	30	0	5.7	0	1.2	5.7	1.2	---	---
	4	4	0	1	6.8	0	6.8	---	---
	7	3.7	5.5	2.2	0	8.3	0	---	---
	101	0	6.7	2	3.2	6.7	1.6	---	---

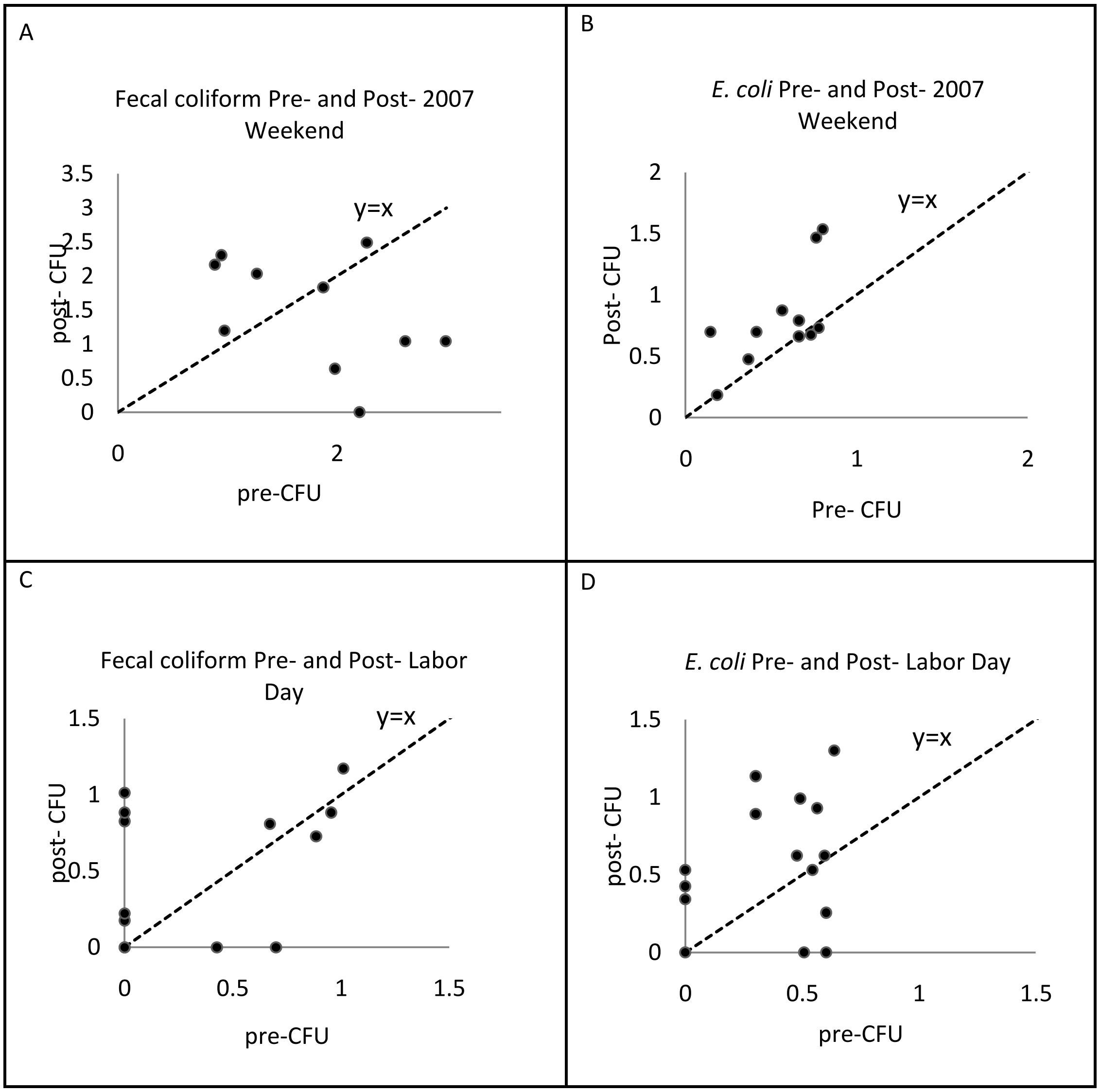

Figure 25. Fecal coliform and *E. coli* before and after an August 2007 weekend in eleven coves on the Osage Arm (A and B) and Labor Day Weekend (C and D) in 13 coves and 2 main channel sites on the Osage Arm. Points falling above the line represent coves or sites that increased over the weekend, while points falling below the line represent coves or sites that decreased over the weekend. Points falling close to or on the line represent coves or sites that showed little to no change in concentrations over the weekend. Values are ln+1-transformed.

Locations of permits were also examined in conjunction with samples from 2007 and 2008, including those collected within 48 hours of and during precipitation events. Presence of septic permits and discharge outfalls did not explain or match samples exceeding standards[12] or BT detections[13]. Twenty-seven coves exceeded standards and/or tested positive for BT over the 2007 and 2008 seasons. Overall, more than half of these coves (15 coves) did not have permits. Non-permitted discharges may be a factor, but most likely subsurface lateral flows from septic tanks in adjacent coves or non-permitted septic systems are influencing fecal indicators in these coves. Correctly identifying the exact sources of bacterial pollutants in these 15 coves was beyond the scope of this project. Because of this, permits were not an effective correlate of anthropogenic fecal pollution among Lake of the Ozarks coves for this study.

Specificity of Fecal Indicators

The detection of BT in a sample is indicative of anthropogenic fecal pollution (Carson et al. 2005), while the detection of FC and EC bacteria in a sample is not conclusive of anthropogenic fecal pollution even when surpassing standards[14]. Samples detecting FC or EC concurrently with BT strongly indicate anthropogenic fecal contamination, while samples detecting FC or EC in absence of BT indicate other sources of contamination. In 2007, FC (262 detections) and BT (46 detections) were detected concurrently in 36 of 311 samples (12%). *E. coli* (291 detections) and BT were detected concurrently in 41 samples (13%). Therefore, 226 FC positive samples (73%) and 250 EC positive samples (80%) may have represented non-human sources of bacterial contamination or naturalized FC and EC bacteria of anthropogenic origin.

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[12] FC and EC colonies were detected in all remaining coves that did not exceed standards; however, the presence of FC bacteria and EC does not always indicate the presence of human fecal pollution because these bacteria have been found as naturalized inhabitants of soil and sediment environments (Appendix 1). FC and EC standards indicate a possible presence of human fecal pollution and a potential threat of infection or illness from enteric pathogenic bacteria. This is why only coves with exceeding values were used in this part of the analysis.

[13] The detection of BT at 1-5 ng/μL total DNA level is indicative of human fecal pollution (Carson et al. 2005), but does not indicate a potential for pathogenic infection like the conventional FC and EC standards.

[14] When standards are exceeded, there is a possibility that human fecal pollution is present; although other sources may be contributors.

Threats of possible anthropogenic fecal contamination, based on EPA standards in 2007, were often false alarms. Eight samples exceeded the FC discharge effluent standard (1,000 CFU), but BT was absent in 6. Seven samples exceeded EC stream standards (126 CFU), but BT was absent in 4. These results suggested most of the exceeding samples (6 for FC and 4 for EC) represented non-human sources of contamination. Some of these samples (4 for FC and 1 for EC) were collected during the August 20 rain event. Sources for the remaining samples (2 for FC and 3 for EC) were unknown. Data from 2007 also showed that FC and EC bacteria are often absent or undetectable when anthropogenic fecal pollution is present: FC colonies were not detected in 10 BT positive samples, and EC colonies were not detected in 5 BT positive samples. Four of the 10 BT positive samples where FC was not detected were unreadable due to excessive growth of non-FC microbes[15] or inorganic interference.

Other Correlations among Osage Arm Coves

In the cross-cove analysis on the Osage Arm, mean FC and EC were positively correlated (r=0.77, n=28 coves, Table 10). For every EC colony per 100 mL, there were 2 to 3 FC colonies. Fecal coliform and *E. coli* were negatively correlated with Secchi depth (cross-cove analysis, r=-0.32, p crit=0.1 and r=-0.48, respectively) -- as water clarity increased among coves, FC and EC decreased. Secchi depth was also negatively correlated with wind speed (temporal analysis, r=-0.74, n=7 sampling days), and distance from Bagnell Dam (cross-cove analysis, r=-0.80). Both FC and EC were also positively correlated with $\log_{10}$Chl (cross-cove analysis, r=0.43 and r=0.67, respectively). *E. coli* was positively correlated with nutrients (TP, r=0.54; TN, r=0.54; and dissolved nitrogen, r=0.33) and negatively correlated with pH (r=-0.53), temperature (r=-0.55) and $\log_{10}$DO (r=-0.47).

For BT, an analysis using the bins showed a positive relationship between BT and the conventional fecal indicator bacteria (FC and EC). On average, FC and EC increased as BT counts in coves increased, except for the 4-count bin which represented only one cove (Figure 26). Mean FC more than

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[15] Overgrowths of non-FC microbes were visible as converging pink colonies, or vertical dendritic fungal stalks. Further culturing or molecular identification was not performed to confirm taxa of non-FC microbes.

doubled from 11 CFU in coves with 0 detections to 23 CFU in coves with 2 detections. Mean EC more than tripled from 5 CFU in coves with 0 detections to 16 CFU in coves with 2 detections (Table 11). Among individual samples where BT was detected, FC was larger (by 27%) and EC was larger (by 50%) than samples where BT was absent. Mean FC and EC were also larger (by 51% and 67%, respectively) in sites where BT was detected than in sites where BT was absent. *B. thetaiotaomicron* also shared general patterns with conventional fecal indicators (FC and EC). The bin analysis suggested BT was negatively related to Secchi depth (Figure 27). On average, coves with greater BT detection generally had low Secchi depth: the range was from a mean of 0.95 m in the 0 bin to a mean of 0.86 m in the 2 bin (Table 11). Coves with greater BT detection also had larger mean nutrient values (TP= 70-81 µg/L, dissolved phosphorus= 39-46 µg/L, DN= 545-596 µg/L, Table 11, Figures 28 and 29). All variables correlated with FC and EC, and related with BT were also correlated with distance from Bagnell Dam. Additionally, bins were not statistically different for BT. Trends in the bin analysis, however, provide motives for future quantitative work.

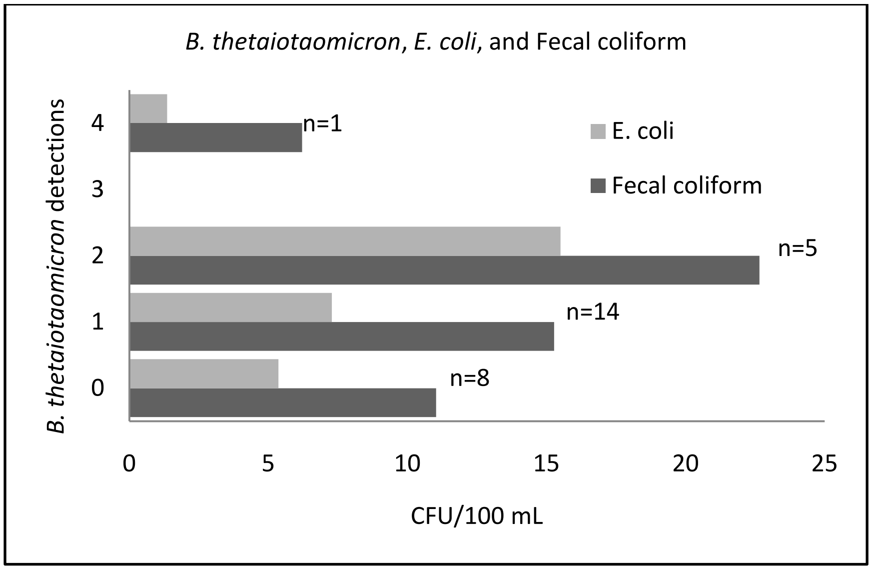


Figure 26. *B. thetaiotaomicron* relationship with fecal coliform and *E. coli,* which were binned and averaged according to the number of *B. thetaiotaomicron* detections in a cove over the 2007 season.

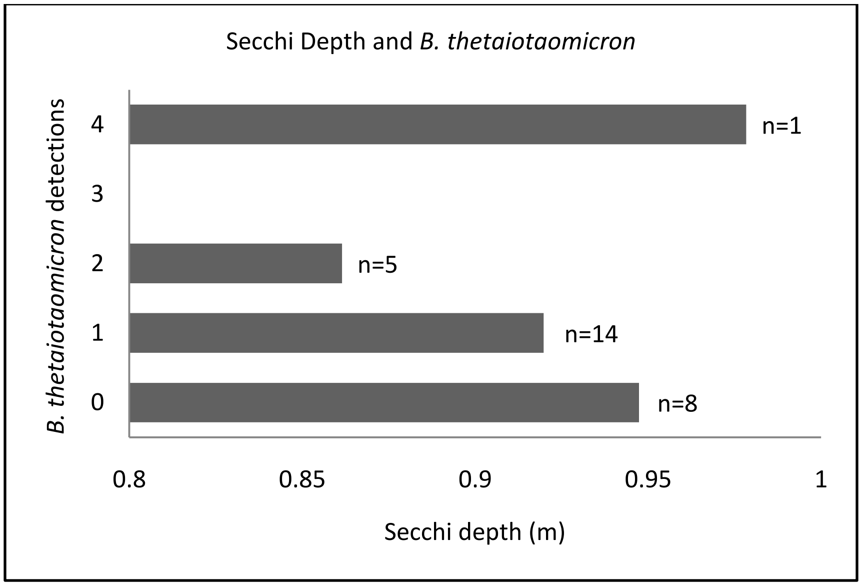
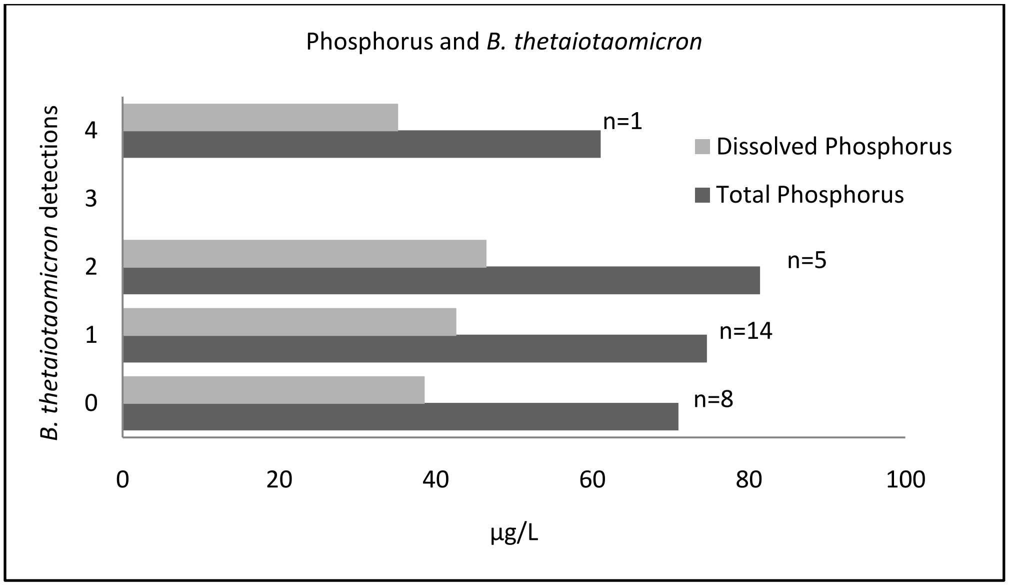


Figure 27. *B. thetaiotaomicron* relationship with Secchi depth, which was binned and averaged according to the number of *B. thetaiotaomicron* detections in a cove over the 2007 season.



Figures 28. *B. thetaiotaomicron* relationship with total and dissolved phosphorus, which were binned and averaged according to the number of *B. thetaiotaomicron* detections in a cove over the 2007 season.

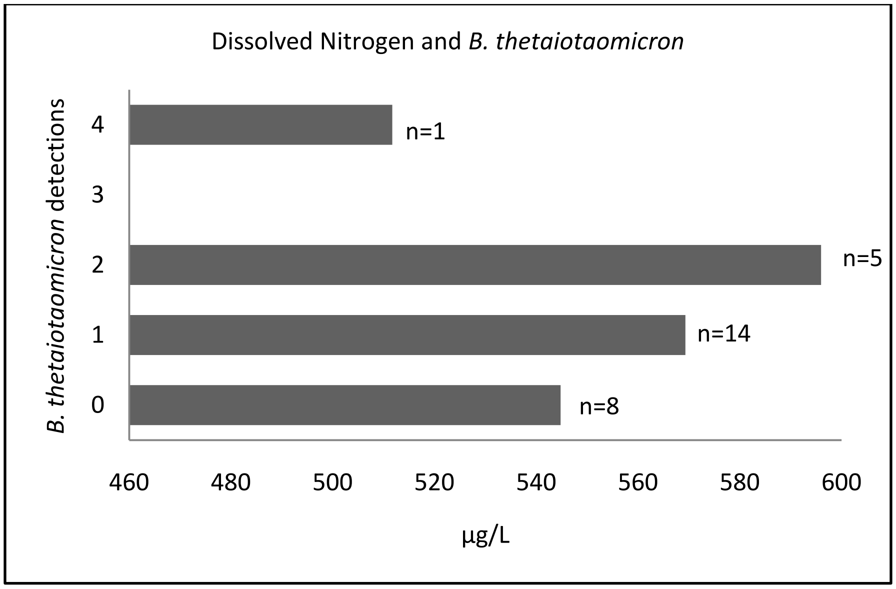


Figure 29. *B. thetaiotaomicron* relationship with dissolved nitrogen, which was binned and averaged according to the number of *B. thetaiotaomicron* detections in a cove over the 2007 season.

DISCUSSION

A major objective of this project was to assess change in water quality in the study reach since the 1980s. Main channel sites and coves were mesotrophic in the 1980s throughout the study reach (Mitzelfelt 1985, Appendix 6). The relationship between land use and reservoir trophic state is well documented. Jones et al. (2004) reported trophic state increased with percentage crop land in the watersheds among reservoirs and lakes in Missouri. In this same study, residual analysis suggested lakes and reservoirs in urban watersheds were more eutrophic compared to lakes and reservoirs in watersheds with cropland and forested land. In a similar study assessing water quality in streams in the Ozark Plateau of Missouri, Smart et al. (1985) found that urban development accounted for more variation in nutrients and Chl than pasture and forest. Loeb et al. (1984) found that littoral algae increased with urban development in the watershed of Lake Tahoe. Loeb et al. (1984) suggested this increased production was attributable to septic waste in the watershed. Similarly, Edmondson (1961) attributed eutrophication in Lake Washington to septic waste. In a series of 6 streams in North Carolina, housing density in watersheds was positively correlated with TP and TN (Carle et al. 2005).

In Lake of the Ozarks, Mitzelfelt (1985) similarly found a positive relationship between housing units in the watershed and trophic state among coves throughout the study reach. Thus, an average 40% increase in housing units among coves was predicted to translate into an increase in trophic state in 2007. Season 2007, however, was an unordinary year for Lake of the Ozarks. The hydrograph was characterized by large flood pulses (Figure 8). Discharge, a surrogate for inflow, was the greatest recorded since the completion of Truman Dam in 1979 (Figure 8) and pool level increased steadily (Figure 10). Historically (1980-2008) in Lake of the Ozarks, discharge explains about 75% of the annual fluctuation between mesotrophic and eutrophic state classification in the study reach (Figure 12; Perkins and Jones 2000). Consequently, while trophic state metrics had on average nearly doubled in all cove and main channel sites in 2007 (Table 3, Appendix 6), the increases were likely the result of larger discharge rates and large flood pulses, not anthropogenic factors. Among coves, steady increases in pool level likely forced main channel water to backflow into coves. Backflow of main channel water into coves dilutes the site-specific linkages between water quality and watershed land uses in various coves (Ford 1990). Due to this strong influence of hydrology, assessing trophic state change over time in coves and main channel sites was not warranted in 2007.

Likewise, assessing anthropogenic change in trophic state among coves and main channel sites would require sampling seasons of equal or comparable discharge values (Knowlton and Jones 2006) or aggregation of data from seasons of varying discharge (Jones et al. 1998). Therefore, a lack of relationship between anthropogenic metrics and trophic state in the study coves did not indicate of a lack of anthropogenic influence in the study reach. In years of moderate to low inflow, drawdown or discharge may be the primary factor controlling advection currents in riverine reservoirs (Ford 1990). Coves and embayments are generally semi-isolated from the main water mass (Jones and Kelso 2008), especially in impoundments like Lake of the Ozarks that have rapid flushing rates and high hydrologic turnover (Van Winkle et al. 1981). Comparisons with findings from years of reduced inflow support this theory. For example, relative to 2007, Mitzelfelt (1985) found on average, coves were more nutrient rich and productive than main channel sites in this study reach. Longitudinal gradients among coves on the Osage Arm during the 1980s were unrecognizable for TP and TN and weak for Chl (r=0.15, n=27, Appendix 6). By contrast, in 2007 concentrations of nutrients and Chl in coves were not distinct from concentrations in the main channel likely due to dilution from main channel water. Main channel sites and coves were similar in nutrient and Chl values (Table 3). Likewise, nutrients and Chl among coves on the Osage Arm exhibited strong declining gradients that are typically characteristic of the main water mass in Lake of the Ozarks (Jones and Novak 1981). Nutrients and Chl among coves in the Osage Arm study reach decreased by about 10-25% from up- to down-reservoir (Tables 5 and 6).

In the study reach in the 1980s, Mitzelfelt (1985) found FC concentrations among coves increased with watershed development. Mitzelfelt (1985) also found FC concentrations increased with traffic volume (number cars/day) in the Lake Ozark region and on weekends and holidays. Other research has shown FC and/or EC concentrations increased with housing density (Young and Thackston 1999), urban density (Carle et al. 2005), impervious surface (Young and Thackston 1999), and road density (Hoyer et al. 2006). In a New Jersey watershed, Selvakumar and Borst (2006) sampled storm water runoff and found FC and EC were more concentrated in high-density residential areas than in low-density residential and landscaped commercial areas. These researchers concluded that fecal indicators were of domestic animal and wildlife origin because outfalls were not crossed with sanitary wastewater connections. In a study of five water bodies, Mallin et al. (2000) found the percentage of impervious surfaces (i.e. roofs, roads, driveways, sidewalks, parking lots) accounted for 95% of the variation in FC. They also found percentage impervious surface was most correlated (positively) with the abundance of FC over a set of other land use factors (watershed population and percentage developed land). Therefore, in 2007 values of FC among main channel sites and coves were predicted to increase due to anthropogenic loading from an expanding urban area. In 2007, however, mean FC in coves and main channel sites were similar to 1980s values (Table7, Appendix 6). Furthermore, correlations between anthropogenic metrics and FC were not significant in 2007 or 2008. Correlations between anthropogenic metrics and EC were also not significant in 2007 or 2008.

Results of the present study suggested anthropogenic influence on FC and EC among coves were masked by hydrologic and climatic factors in 2007 and 2008. Peaks in FC and EC among all sites occurred during a local rain event (7.1 cm or 2.9 inches) on 20 August (Figure 15). This rain event was highly influential. In some coves, seasonal mean FC and EC increased more than 200% when data collected on 20 August were included in calculations (Table 9). Antecedent rain events produced elevated levels in 2008 holiday sampling as well (Figure 19, Appendix 3). This response to rain events has been described by several researchers (Barbaro et al. 1969, Goyal et al. 1977, Crowther et al. 2003, Whitman and Nevers 2003, Jeng et al. 2005). During summer in Wyth Lake Beach in Iowa, Meyer et al. (2006) found that a large rain event (13.5 cm or 5.3 inches) significantly increased average weekly EC concentrations from

130-370 CFU. In Mississippi Lake, a shallow eutrophic lake in Canada, Hendry and Toth (1982) showed FC increased ten-fold following a rain event (1.9 cm or 0.73 inches). Lipp et al. (2001) found a positive relationship between FC and 7-day antecedent rainfall (r=0.26) in a Florida estuary that drains 2 freshwater rivers.

Fecal coliforms and *E. coli* are natural inhabitants and/or replicate in soils and sediments (Gagliardi and Karns 2000, Solo-Gabriele et al. 2000, Whitman and Nevers 2003, Ishii et al. 2006). Thus, in 2007 and 2008, bacteria originating from soil runoff and resuspended sediments likely diluted anthropogenic influence as represented by FC and EC. In 2007, spatial patterns in FC and EC among sites in the study reach suggested cove water was diluted with main channel water from increases in pool level and backflow into coves. For instance, values of FC and EC were similar in main channel sites and adjacent coves (Table 7). Additionally, FC and EC among coves showed a longitudinal gradient on the Osage Arm study reach (Table 10). Fecal coliform and *E. coli* declined by about 40 and 20 CFU, respectively, from up- to down-reservoir among coves on the Osage Arm study reach. This longitudinal gradient also indicated reservoir sedimentary processes (Thornton 1990) were factors that masked anthropogenic influence for FC and EC among coves on the Osage Arm study reach.

During the 1980s, years of less inflow relative to 2007 and 2008, resuspension of sediments and soil erosion from rain was likely reduced, and coves were probably somewhat isolated from the main channel. Less inflow is probably why 1980s FC levels in the study area were associated with development among coves, and why FC levels in main channel sites were distinct from FC levels in adjacent coves (Mitzelfelt 1985). Mitzelfelt (1985) found FC was less abundant in main channel sites than adjacent coves. Furthermore, a decreasing pattern for FC was unrecognizable among coves in the Osage Arm study reach (n=9 coves, Appendix 6).

Because EC and many bacteria in the FC group naturally reside in soils and sediments, disturbance to the soils and sediments has the potential to elevate FC and EC concentrations in ambient waters. Besides storm events, disturbances may include boat disturbance, bioturbation, recreational disturbance, or wave and tidal action. Wind may also indirectly disturb sediments by producing advection currents. Wind and reservoir currents commonly move in the same direction, with current speed lagging behind wind speed (Garvey et al. 1998). During 2007, wind speed was a dominant factor influencing FC and EC on a daily basis across all sites in the study reach. Wind speed explained 67% and 86% of the variation in FC and EC, respectively, in the temporal analysis (Figure 17). This finding was surprising considering the use of these bacteria as fecal indicators.

Wind speed likely influenced FC in the 1980s and may have contributed to the variance in the FC-development value relationship reported by Mitzelfelt (1985). Other researchers have also reported relationships between wind and fecal indicators. Garvey et al. (1998) reported wind speed as a major factor indirectly influencing the magnitude of FC bacteria in Quabbin Reservoir, an oligotrophic drinking water reservoir in Boston, Massachusetts. On 63rd Street Beach in Chicago, Illinois, Whitman and Nevers (2003) found positive correlations between EC concentrations in beach sand and the speed and direction of wind.

Discharge also creates advection currents in reservoirs (Ford 1990), which potentially influence FC and EC levels via sediment disturbance. In 2007 the relationship between discharge and fecal indicators (FC and EC) was not significant (Figure 15). Discharge, however, is subject to management for power generation and shows great variation within a season depending on the demand for hydro-electric energy and the need for flood control. By aggregating data from multiple seasons for the duration of 1 year, Lipp et al. (2001) found a significant positive relationship between FC and mean daily discharge (r=0.395), and FC and streamflow (r=0.475) in Charlotte Harbor estuary, Florida. Aggregating summer data from multiple seasons of various flow regimes could possibly show this relationship (Jones et al. 1998).

While anthropogenic influence was not apparent in individual coves because main channel hydrology dominated cove characteristics, Cove 33 mid-reach in the Grand Glaize Arm study area was the exception. Cove 33 was undeveloped and located in a state park. This watershed, however, contains a discharge lagoon that treats septic waste from park visitors (Figure 3, Appendix 5). In 2007, this cove had the largest nutrient, Chl, and EC means of any cove on the Grand Glaize Arm study reach. The largest BT frequency also occurred in Cove 33, which confirmed there was anthropogenic loading of nutrients and EC (Table 7).

Unlike FC and EC, *Bacteroides* species do not survive or replicate in environments outside the host. In a mesocosm experiment, Fiksdal et al. (1985) demonstrated that fecal streptococci and EC initially increased in numbers while *B. fragilis* remained at the same initial concentration. The same experiment showed that cell die-off was greater for *B. fragilis* than for fecal streptococci and EC. River monitoring also showed *B. fragilis* had a greater die-off rate than EC (Allsop and Stickler 1985). Thus, relationships between environmental factors and FC and EC were predicted, while a lack of relationship between BT and non-anthropogenic environmental factors was predicted for 2007.

As previously mentioned, factors associated with resuspension of sediments, soil erosion, and sedimentation strongly influenced FC and EC in 2007 and 2008. Fecal coliform and *E. coli* values varied temporally as a function of local climatic events (rain, Figure 15 and wind, Figure 17) and spatially as a function of hydrology (longitudinal gradient, Table 10). Climatic and hydrologic factors in these years of high inflow were more influential on FC and EC values than anthropogenic factors. These findings for FC and EC suggested soil and sediment may have been larger contributors of these conventional fecal indicators than humans among coves during summers 2007 and 2008.

In 2007 findings for BT did not match FC and EC findings, which indicated factors other than hydrology (Figure 16) and wind (Figure 18) influenced BT in the study reach. The lack of association between BT and hydrologic and climatic variables suggests soils and sediments were not a source of BT

(Bower et al. 2005). For BT among coves, the absence of pattern along the Osage Arm study reach was also in contrast to FC and EC findings. This absence of pattern suggested BT was not influenced by sedimentary processes in the main channel. It also suggested the most influential factors for BT originated from cove watersheds, not from soil erosion and sediment resuspension from up-reservoir. Spatial gradients however can occur. Allsop and Stickler (1985) showed *B. fragilis* concentrations decreased down-river from sources of pollution. It is likely that this also occurs in Lake of the Ozarks for BT. In this study gradients may have been disrupted by changing water levels. Another possibility is that qualitative data are not well suited for analyses of gradients. Overall results supported findings that *Bacteroides* species do not survive and replicate in sediment and soil.

What was most compelling in the BT analysis was the positive relationship between BT and traffic volume, a measure of anthropogenic activity, despite background wind and rain that accounted for a large portion of the variation in FC and EC in the temporal analysis (Figures 16-18). The relationship suggests residents and visitors entering the study area on Friday potentially contributed to total BT detections the following Monday. This finding indicates that BT was more specific to human fecal pollution than the conventional fecal indicators, FC and EC.

Conclusions

This short-term study showed flood pulses, soil runoff, sediment resuspension and dilution masked potential anthropogenic influences among coves for nutrients, Chl, and conventional fecal indicators. Long-term continuous monitoring during seasons with low and moderate inflow and discharge is needed to accurately assess anthropogenic changes in water quality among coves and main channel sites within the study reach.

The correlation between conventional fecal indicators and wind speed was surprising considering their wide-spread use as fecal indicators and indicates a high degree of internal loading of FC and EC in this region of Lake of the Ozarks. An emerging hypothesis from this finding is that measurements of fetch in Lake of the Ozarks may predict coves that are prone to larger FC and EC concentrations in surface waters. The relationship suggests that wind speed may be a valuable predictor of day to day FC and EC concentrations in surface waters of lakes and reservoirs, especially those with large fetch.

What was most compelling was the positive relationship between BT and traffic volume despite record discharge rates, high inflow, possible dilution from increased pool level, and wind speed. This finding demonstrated through environmental monitoring that BT was a more human-specific indicator than conventional fecal indicators. In fact, this may be the first documentation of a relationship between BT and an easily measured surrogate for anthropogenic activity in environmental sampling.

Other research has focused on detection of BT in environments where humans knowingly contribute to contamination in order to test the specificity of the indicator (Carson et al. 2005, Hong et al. 2008, and Shanks et al. 2008). Reports of semi-quantification (Shanks et al. 2008) and quantification (Hong et al. 2008) of BT in environmental samples have recently emerged in the literature. Yampara-Iquise et al. (2008) sampled several streams, rivers, and creeks throughout Missouri. Using quantitative PCR, these researchers found markers for BT were greatest in highly populated regions with known sewage problems. Markers were very low or undetected in low populated regions. The future direction of research is moving towards using quantitative methods and further exploring the relationship between BT and anthropogenic metrics in watersheds.

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Appendix 1

BACTERIAL FECAL INDICATOR LITERATURE REVIEW

Purpose of Review

This review encompasses various aspects of fecal indicator bacteria research in aqueous environments. My goal is to give an overarching review which will first define and give a brief history on fecal coliforms and *E. coli* and explore literature covering the ecology of these organisms once introduced into the environment. Lastly, *B. thetaiotaomicron,* a new emerging fecal indicator, will be briefly discussed.

Taxonomy and Diagnostics

Bacteria of the family Enterobacteriaceae, more commonly called enteric bacteria, naturally inhabit the intestinal flora of most animals, and are commonly found in soil, on plants, and on decaying vegetation. Enteric bacteria found in the intestinal flora are opportunists, causing infection only when introduced to another location on or in the body.

Diagnostically, enteric bacteria are aerobic or facultative anaerobic Gram-negative bacilli (coliform/rod-shaped) or coccobacilli (non-coliforms/sphere to rod-shaped) ranging from 1 to 3 µm in length. Coliforms ferment lactose and produce acid and gas within 48 hours of incubation at 35°C in a lactose broth; non-coliforms lack this ability. The fecal coliform group generally contains *Escherichia*, *Enterobacter*, *Klebsiella*, and *Bacillus* genera, although some bacteria of this group are also found in soil and on plants (Bauman et al. 2004).

Escherichia coli is the most well known and commonly studied species of the coliform and fecal coliform groups. *E. coli* has a bacillus form and ranges from 1-2 µm in length with a diameter of 0.1-0.5

µm. Minimum and maximum growth temperatures are 7°C and 41°C, respectively, and optimal pH is generally 6-7 (Atlas and Bartha 1997). *E. coli* naturally resides in the lower intestine of mammals, but is sometimes found in avian feces (Hussong et al. 1979). Doubling time for *E. coli* in the intestine is two days (Savageau 1983). The life cycle of *E. coli* in its host is highly variable, with a single cell persisting anywhere from 26 hours to 66 years (Winfield and Groisman 2003) prior to excretion.

Like many enteric bacteria, most strains of *E. coli* inhabiting the intestines are opportunistic, causing infection only when introduced to another location on the body; although, certain strains produce toxins, such as the O157:H7 strain. This strain, as well as other Shiga-toxin producing strains persists commensally in the intestines of ruminant mammals (deer, cattle, etc.), but can cause a number of illnesses in humans: septicemia, urinary tract infections, neonatal meningitis, peritonitis, mastitis, pneumonia, and gastroenteritis (Bauman et al. 2004). Gastroenteritis receives the most attention, due to the strain's mode of transmission and toxigenic properties. Many reported cases of *E. coli* associated gastroenteritis can be traced to the O157:H7 strain which is most commonly associated with non-pasteurized dairy products, juices, and meats; but can also be traced to fecal contamination in streams used to irrigate crops, as in the 2006 North American spinach outbreak.

Indicator Organisms and the Coliform Index

Fecal coliforms and *E. coli* are used in water quality testing, and their presence in certain concentrations indicates a possibility of recent fecal contamination. This section narrates the development and use of indicator organisms and the coliform index.

In 1855, John Snow from London speculated that devastating outbreaks of cholera were linked to drinking water. He hypothesized that feces of cholera-infected victims were contaminating the drinking water supply and being consumed by and infecting healthy victims. The incidence of cholera immediately decreased when Snow removed the handle from the main drinking water pump. With this simple act, Snow had unknowingly taken the first major step in the field of wastewater management (Gleeson and Gray 1997). The next major breakthrough was the identification of *Bacterium coli commune* in infant feces by a German pediatrician named Theodore Escherich in 1885. As research continued, *Bacterium coli commune,* later renamed *Escherichia coli* after its discoverer, was repeatedly found in all human feces, not only infant feces. The two disciplines (wastewater management and human medicine) were eventually linked in 1892 by a scientist named Schardinger, who suggested that the presence of *B. coli* in water indicated the potential of fecal contamination and therefore the possible presence of pathogenic enteric bacteria (Dufour 2003). Thus, *E. coli* was conceptually used as the first indicator organism.

Over time, many other coliform bacteria were discovered in human feces and the indicator was expanded to include all organisms fermenting lactose and producing hydrogen gas. A simple test tube confirmation with lactose based substrate was widely used to test for the presence of fecal contaminates. This test was eventually termed the “total coliform” method. This method would be widely accepted for use until the 1940s, when researchers insisted that coliforms were present in many environments such as water, soil, and paper mill waste effluents (Gleeson and Gray 1997). In order to continue the use of coliforms as fecal indicators, the test had to be more specific. To specifically target fecal coliforms, researchers began incubating at 44°C as opposed to 35°C. Incubating at this higher temperature would eliminate coliforms naturally inhabiting external environments, and target only coliforms of the intestinal tract. The two main bacteria that grow using this method are *E. coli* and *Klebsiella pneumonia* (Dufour 2003). A problem arising from using this method was that *Klebsiella* is commonly found in industrial waste and soils and is not an exclusive fecal coliform, yielding a vast overestimation of the quantity or concentration of “fecal contaminants” in the water. In the 1970s a membrane filtration method and a multiple tube fermentation method were developed to specifically target *E. coli*, which is always found in human, domestic, and wild animal waste (McLellan and Jensen 2003, Hoyer et al. 2006).

Today, most states in the United States have not adopted *E. coli* into there state water quality standards for whole body contact recreation (Environmental Protection Agency 2003). These states continue to use fecal coliform, and a few continue to use total coliform. One major reason for continued use of fecal and total coliform methods is partly the slow process of certification of new methods by the Environmental Protection Agency (EPA). Before 1989, despite updated techniques, the multiple tube fermentation technique and a membrane filtration test for detection of total coliform bacteria in water were the only EPA certified techniques for water quality testing of pathogens. In 1991, the EPA eliminated the requirement for enumeration of total coliform bacteria in water samples, which allowed states to adopt the fecal coliform and *E. coli* membrane filtration technique into their state water quality standards. In 2000, the Beaches Environmental Assessment and Coastal Health Act (BEACH) was passed, initiating a resurgence of research. The BEACH act targeted all US recreational beaches, including beaches in the Great Lake's watersheds. The act encouraged formation of new methods for predicting indicator levels above EPA standards. Research sparked by this act also documented new accounts of *E. coli* survival and resistance in the external aquatic environment, which resurfaced a historic debate over which organism or group of organisms serves best as a fecal indicator (Wolf 1972, Gleeson and Gray 1997, Shibata et al. 2004).

Since the passing of the BEACH Act, studies have shown that fecal indicators not only indicate the possible presence of fecal pathogens, but are positively correlated with the occurrence of swimming-associated illness in great lakes beach sites (Wade et al. 2006, 2008), and that the incidence of swimming-associated illness is higher in children (Wade et al. 2006). Some researchers have focused efforts on finding a human-specific fecal indicator (Carson et al. 2001, Field et al. 2003, Teng et al. 2004, Carson et al. 2005, and Vogel et al. 2007) while others focused on more efficient methods for announcing beach closures (Dick and Field 2004, Haugland et al. 2005, Bower et al. 2005, Wade et al. 2006, Hong et al. 2008, and Shanks et al. 2008).

Sources of Fecal Coliform and E. coli

As sanitary science was first blossoming, the recognized source of fecal pollution was human waste effluent from point sources. Over time, waste water treatment facilities grew more common in cities and towns. Urban areas are now minor contributors to human fecal pollution; yet rural areas lacking municipal sewage operations remain major contributors. Reasons for this are neglect of maintenance on septic systems and improper placement of septic systems. In recreational waters, human fecal pollution from swimmers is considered inconsequential and does not significantly contribute to increases in fecal coliforms or *E. coli* concentrations (Whitman and Nevers 2003).

Researchers eventually recognized that fecal pollution not only originated from human waste, but also from animal wastes. Now it is commonly accepted that all mammalian feces contain fecal coliforms and *E. coli*. Other than human fecal material, livestock fecal material is a major source of concern in rural areas. This particular source of pollution may enter a water body through stormwater runoff (Geldreich 1996), groundwater percolation (Gagliardi and Karns 2000), or directly through the use of water bodies for watering livestock. In a year long study surveying four sites with differing land use in a subestuary of the Chesapeake Bay, Carney et al. (1975) found that total and fecal coliform and streptococci showed the highest frequency of occurrence in the site that received pasture land runoff. New technologies in bacteria source tracking have also identified wildlife and other domestic mammals as sources of fecal contamination (Carson et al. 2001).

Total coliforms, fecal coliforms, and *E. coli* concentrations have been associated with avian abundance (Hussong et al. 1979, Whitman and Nevers 2003, Hoyer et al. 2006, Meyer et al. 2006). Hussong et al. (1979) estimated per capita, Canada geese and whistling swans released 10^7 and 10^9 fecal coliforms per day, respectively. Ricca and Cooney (1998) examined droppings from pigeons, geese, and herring gulls finding on average, 10^9 thermotolerant coliforms (fecal coliforms) per gram of feces. As with mammalian waste, avian fecal contaminants may enter a water body via runoff water, groundwater percolation, or direct contamination from feeding and nesting waterfowl.

Efforts have also focused on sediments and soils as sources of fecal pollution outside and within the water body. There is evidence indicating soils and sediments serve as a reservoir or protective niche for fecal coliforms, *E. coli*, and fecal pathogens. Additionally, soils and sediments may also serve as a substrate for replication, and subsequently a source of fecal pollution. The persistence of these organisms in soil provides a long term source of pollution after initial contamination. Gagliardi and Karns (2000) demonstrated if soil conditions are ideal, viable *E. coli* O157:H7 can percolate below top layers of soil for over two months after initial contamination. In cases such as this, the viable organisms could possibly contaminate ground water sources. Several studies find that *E. coli* and/or fecal coliform concentrations are higher in sediments or on the surface of sediments than in the water overlying them (Obiri-Danso and Jones 1999, Davis et al. 2005). Whitman and Nevers (2003) found that temperate beach sand could function as a reservoir for *E. coli*. Studies also document the replication of fecal coliforms and *E. coli* in sediments and soils in tropical regions (Gagliardi and Karns 2000, Solo-Gabriele et al. 2000), as well as temperate regions (Whitman and Nevers 2003).

Factors Influencing Concentrations in the Surrounding Watershed and Movement of Contaminants into the Water Body

Much like abiotic elements, the movement of fecal contaminants into a water body is largely determined by the slope of the land, porosity and absorptive potential of the soils, underlying bedrock conditions, type of land cover, and frequency and amount of precipitation.

Soil may serve as a reservoir for fecal organisms, and depending on the condition of the soil, may also serve as a slow-release of organisms (Gagliardi and Karns 2000). In a Lake Michigan beach area, Whitman and Nevers (2003) found beach sand to be a reservoir for gull feces, and therefore a source of fecal contamination for this recreational area. They also speculated that *E. coli* were able to remain viable due to the relative stability of the sand environment.

In addition to the ability of fecal coliform and *E. coli* to survive in soils, recent studies demonstrate an ability to replicate in this environment. Replication is the main element which distinguishes the fate of bacteria in soil from the fate of chemicals in soil. In Ft. Lauderdale, Florida, *E. coli* is not only able to survive, but is also capable of multiplying in bank soils, essentially naturalizing as part of the soil flora (Solo-Gabriele et al. 2000). Replication has also recently been observed in soils of temperate regions. Gagliardi and Karns (2000) in Maryland showed that *E. coli* was able to replicate in clay loams and saturated soils. *E. coli* has also shown to over-winter in a Lake Superior watershed and become part of the natural soil flora (Ishii et al. 2006).

Type of material covering the soil also has a large impact. Density and type of vegetative cover has been shown to affect the rate and amount of contaminants and pollutants moving into a given body of water. Generally, density of vegetation is negatively related to the amount of contaminants/pollutants entering a water body (Smart et al. 1985, Jones et al. 2004). Percent impervious surface in a watershed can also be a factor influencing ecological health of a water body (Klein 1979, May et al. 1997). Increases in the amount of impervious surface in the watershed have been associated with elevated fecal coliform and *E. coli* counts, especially following rain events. Hoyer et al. (2006) studied 99 lakes finding a positive relationship between *E. coli* counts and road density in the surrounding watershed. In a study of five water bodies, Mallin et al. (2000) found that the percentage of impervious surfaces (i.e. roofs, roads, driveways, sidewalks, parking lots) was most correlated (positively) with the abundance of fecal coliform over a set of other land use factors.

Frequency, duration, and amount of precipitation are overriding determinants of the concentration and movement of non-point source fecal pollution into a water body. Fecal coliform and *E. coli* significantly increase after rain events (Jeng et al. 2005, Meyer et al. 2006, Lipp et al. 2001, Hendry and Toth 1982). Increased frequency, duration, and amount of precipitation may also facilitate the movement of fecal contaminants in the leachate field of a septic system (Geldreich 1972).

Factors Potentially Influencing Concentrations within the Water Body

As mentioned previously, doubling time for *E. coli* in the lower intestine of mammals (its natural habitat) is two days and its life cycle in a host can range anywhere from 26 hours to 66 years. In fact, historically *E. coli* has been thought to perish in the external environment. *E. coli* and other fecal coliform bacteria have been shown to decrease rapidly in freshwater microcosms and in lab experiments using whole water (Hood and Ness 1982, Lim and Flint 1989, Davis et al. 2005). *E. coli* has a half-life of 1 day in water (Faust et al. 1975), 1.5 days in sediments (Gerba and McLeod 1976), and 3 days in soils (Temple et al. 1980). Factors contributing to these organisms' short term survival and mortality include environmental elements such as sediment conditions, wind and wave activity, temperature, pH, ultra-violet radiation, nutrient availability, and competition and predation by autochthonous microbes. Precisely how some of these elements of the aquatic system facilitate or hinder the survival of fecal coliforms and *E. coli* in this habitat is uncertain due to inconsistencies in research results. Demonstrating the organisms' abilities or lack of abilities to survive and/or replicate in this environment validates their historic use or misuse as fecal indicators.

Sediments

After entering a water body, fecal coliforms and *E. coli* were commonly considered dead or non-viable once reaching the sediments. Now most research presents sedimentation as an opportunity for survival in this environment (Goyal et al. 1977, Cavari and Bergstein 1986, Bergstein Ben-Dan et al. 1997). Like the soils in the surrounding watershed, sediments in the water body are often found to be a reservoir for these organisms. In many studies, fecal coliform and *E. coli* concentrations in sediments tend to be much higher than the water overlying them (Goyal et al. 1977, Burton et al. 1987, Doyle et al. 1992, Irvine and Pettibone 1993, Obiri-Danso and Jones 1999, Davis 2005), and several studies show sand sediments serving as a reservoir (Ghinsberg et al. 1994, Oshiro and Fujioka 1995, Whitman and Nevers 2003). There is even evidence of suspended sediments facilitating the prolonged survival of these organisms prior to reaching bottom sediments. Roper and Marshall (1978) found a mode in which certain clay particles facilitated the survival of *E. coli* and other coliforms in saline water by physically inhibiting *E. coli* and coliform predators.

Studies concerning these organisms' association with differing particle sizes had conflicting findings. Whitman and Nevers (2003) found that total coliforms and *E. coli* were most correlated with particles ranging from 3.2-4.5 µm in diameter, while Jeng et al. (2005) found they were correlated to a wide variety of particles ranging from 0.45-30 µm. Jeng attributed attachment to such a wide range of particle sizes to the organisms' rod-shape. The lack of association with particles less than 3.2 µm in Whitman and Nevers study might be explained by the lack of clays on this Lake Michigan beach site. Despite these conflicting findings, there is much evidence showing the association of fecal bacteria and particles. In an across-systems study, Hoyer et al. (2006) found Secchi depth to be negatively correlated with *E. coli* counts. Mahler et al. (2000) found 50% of fecal coliform bacteria were associated with suspended particles. Hipsey et al. (2006) found 80% of fecal bacteria were associated with suspended particles. Type of sediment available for adsorption is the determining factor for degree of sedimentation for these organisms. For example, clays are naturally more electrostatic than silts or sands and also provide more surface area for attachment.

Once incorporated into the sediments, viable organisms may at any time be resuspended into the water column. In a Lake Michigan beach study, Whitman and Nevers (2003) showed a continuous flux in *E. coli* concentrations between sediments and water. This suggested that bottom sediments prolonged and allowed the survival and replication of *E. coli*; and that bottom sediments essentially functioned as a source of fecal contamination, rather than a sink for the organisms. Resuspension may be attributed to any event or action which disturbs bottom sediments, such as storm events (Whitman and Nevers 2003, Wynne et al. 2004), wave and tidal action (Whitman and Nevers 2003, Jeng et al. 2005), boat disturbance, bioturbation, or recreational disturbance (Brookes et al. 2004, Wynne et al. 2004).

Sunlight

Sunlight is a major factor influencing the survival of fecal coliforms and *E. coli* in aqueous environments. Yet, while most research supports this general statement, some debate remains over which property of sunlight has the most significant role in fecal coliform and *E. coli* mortality. Some studies attribute temperature as the most significant factor controlling fecal coliform and *E. coli* survival (Mancini 1978), while other studies show that light or ultra-violet radiation as the most significant influential factor (Garvey et al. 1998). Many researchers also acknowledge the complexity of the system, finding that interactions with autochthonous members of this environment must also be a factor (McCambridge and McMeekin 1981, Flint 1987, González et al. 1990, Menon et al. 2003, Brookes et al. 2004).

Correlations between fecal coliforms, *E. coli*, and temperature in water are widely recognized. Like other organisms, fecal coliforms and *E. coli* have optimal temperatures for survival and growth. Temperatures under or over these optimal temperatures eventually suffice in death. The minimum and maximum growth temperatures for *E. coli* in its natural host environment are 7°C and 41°C, respectively (Atlas and Bartha 1997). Experiments have generally found as temperatures decrease, survival time for fecal coliform increases, until the ultimate fatal low temperature is reached. Likewise, as temperatures are elevated, fecal coliform mortality increases rapidly (Faust et al. 1975, Menon et al. 2003). In a laboratory experiment, Darakas (2002) examined the effect of temperature on *E. coli* mortality using *E. coli* isolated from water samples. He incubated *E. coli* in saline solutions at 4°C, 10°C 20°C, 30°C, and 37°C. At 4°C, *E. coli* concentrations were maintained for 4.4 days; at 10°C, concentrations were maintained for 13.6 days; at 20°C concentrations were maintained for 7 days; at 30°C for 2.9 days; and at 37°C for 0.5

days. Darakas (2002) concluded the optimal temperature for *E. coli* survival in water was 10°C. At 30°C, survival rapidly declines, and at 37°C, mortality was expedited further.

Many studies proceeded by examining the impact of sunlight radiation, as opposed to heat produced by sunlight. The majority of these studies show that visible light has some kind of negative effect on concentrations of fecal coliforms and/or *E. coli* in fresh water (Gameson and Saxon 1967, Jagger 1975, Grigsby and Calkins 1979, Fujioka et al. 1981, Kapuscinski and Mitchell 1981, McCambridge and McMeekin 1981, Barcina et al. 1986, Pommepuy et al. 1992, Sinton et al. 2002). Barcina et al. (1989) found that although visible light had a negative effect on *E. coli* cells in fresh water, cell lysis did not occur. These finding were supported by multiple studies showing the inhibition of metabolic processes (Kapuscinski and Mitchell 1981, Fujioka and Narikawa 1982, Sinton et al. 2002), including inhibition of growth (Pommepuy et al. 1992) and decreased nutrient uptake (Barcina et al. 1989) when exposed to light.

While some researchers have interpreted these results as decreases in survival or cell dye-off (Garvey et al. 1998), most research suggests that these conclusions are misinterpretations which can be attributed to the methodology used to quantify fecal bacteria. Many studies have used some kind of incubation method to quantify or enumerate organisms through colony counts. These methods utilize bacteria that are able to replicate or grow. Fecal coliforms are most susceptible to UV-B light (wavelengths < 318 nm) (Davies-Colley et al. 1997, Sinton et al. 2002), and the resulting damages are not fatal and often repairable (Sinton et al. 2002). Many researchers argue that fecal coliforms, *E. coli*, and other indicator organisms may enter a state of dormancy (Barcina et al. 1989) or a state in which organisms are still metabolically viable, but not culturable (VBNC), hence undetectable by incubation methods, yet still surviving. Cells in these two states would yield underestimates of fecal pollution in the water being tested.

Nutrients

Nutrients are the least emphasized of all interacting elements influencing the fate of fecal coliforms and *E. coli* in the external environment. The lack of research available may signify that nutrients are the least significant factors influencing the survival of these organisms, or that this particular aspect of fecal bacterial ecology has yet to be thoroughly examined. Nutrients are recognized as playing a role in the survival of these organisms after release into the environment (Korhonen and Martikainen 1991). Many studies show that when deprived of nutrients and/or stressed, indicator or enteric bacteria are unable to compete with autochthonous bacteria and are forced into a state of dormancy (Carlucci and Pramer 1960, Lim and Flint 1989, Smith et al. 1994). Nutrient loading has also been shown to stimulate growth and increase survival time of fecal bacteria (Sheheta and Marr 1971, Evison 1988). Many observations of the association of fecal bacteria with sediment or soils and the ability to sometimes replicate within these environments are commonly attributed to nutrient availability as well as protective benefits from particles (Standridge et al. 1979, Hardina and Fujioka 1991, Davies et al. 1995, Gagliardi and Karns 2000, Darakas 2002).

Carbon is the most emphasized nutrient in environmental fecal bacteria literature. This is most likely because of the association of dissolved organic carbon (DOC) with particulate matter (Lind et al. 1997), where the bulk of fecal bacteria are found. Fecal bacteria may utilize carbon compounds found in microhabitats of organic or inorganic particles that have accumulated organic compounds. Tate (1978) found *E. coli* populations were three times higher in organic based soils than in sandy soils. Dissolved organic carbon excreted by algae or decaying macrophytes has also been cited as a source of carbon for fecal bacteria. Whitman et al. (2003) found *E. coli* and enterococci multiplying in *Cladaphora* in nearshore waters of a Lake Michigan beach, and attributed this to carbon excretion as well as a protective habitat from predators. In a study surveying 99 lakes in Florida, Hoyer et al. (2006) found a positive correlation between chlorophyll and *E. coli*. This correlation is likely due to the utilization of carbon on algal cells by *E. coli*. There is also evidence weighing against this theory. Brettar and Höfle (1992) concluded that increased particle production by algal cells provided structure for survival, rather than organic matter for *E. coli*. Laboratory experiments show *E. coli* utilizing carbon. Lim and Flint (1989) added glucose, glycerol, and lactose to pre- filtered and autoclaved water containing an *E. coli* population, and found a five-fold increase in *E. coli* numbers within three days of additions. However, the same additions of carbon substrates to non-filtered, non-autoclaved water yielded no increase in populations, signifying the importance of predation and competition within natural waters.

There is far less literature covering the effects of phosphorus and nitrogen on fecal coliforms and *E. coli*. Hoyer et al. (2006) found a positive correlation between total nitrogen and *E. coli* and total coliforms. Lim and Flint (1989) also found that nitrogen additions to laboratory chambers increased the survival time of *E. coli* in sterilized and unsterilized water, signifying that predation and/or competition does not play as important a role as carbon in the uptake of nitrogen by *E. coli*. Lim and Flint (1989) found phosphorus additions had no effect on *E. coli* survival time in filtered or unfiltered water, while Hoyer et al. (2006) found a positive correlation between total phosphorus and *E. coli* among a group of lakes.

Predation and Competition

Predation has the most effect on mortality of fecal bacteria outside of their natural host. This is widely recognized by sewage treatment workers and scientists studying fecal pollution (Enzinger and Cooper 1976, McCambridge and McMeekin 1980, 1981, Barcina et al. 1986, Chao and Feng 1990, Korhonen and Martikainen 1991, Mezrioui et al. 1995, Simek et al. 2001). Predacious protozoa, bacteriophages (Carlucci and Pramer 1960), predacious bacteria (Mitchell 1971, Roper and Marshall 1977), and general autochthonous bacteria have been documented as potential predators and competitors. The latter group of organisms has been a source of controversy.

A common theory in the literature is that fecal bacteria perish more rapidly than autochthonous bacteria due to an inability to compete for nutrients in aqueous environments (Mitchell 1971, Gerba and Schalberger 1973) or an inability to resist bacterial predation (Mitchell 1971). Alternatively, Enzinger and

Cooper (1976) found that when removing protozoa (mostly microflagellates and microciliates) from estuarine samples, the presence of autochthonous bacteria did not affect fecal bacteria mortality; but when including protozoa, mortality increased rapidly. This was preliminary evidence that mortality of *E. coli* was not dependent on autochthonous bacterial predation, competition, or antagonism (Enzinger and Cooper 1976). Other studies show that although autochthonous bacteria have some kind of detrimental effect on fecal bacteria, this effect is eliminated in the presence of protozoan predators that graze on fecal bacteria and autochthonous bacteria (McCambridge and McMeekin 1980). Menon et al. (2003) supports this finding with results from a study examining natural water from a marine and freshwater habitat. The results of this study show mortality rates for fecal bacteria and autochthonous bacteria are in the same magnitude in both environments and suggest the same factors limit both types of bacteria, signifying that fecal bacteria are not the “poor competitors” once thought to be (Menon et al. 2003). However, this same study acknowledges that protozoan predators have an affinity for larger fecal coliform cells as opposed to smaller autochthonous bacteria cells. Perhaps this explains Mitchell (1971) finding a proportionality between number of natural bacteria and decline in *E. coli* cells, and concluding *E. coli* was unable to compete with natural microflora.

The presence of protozoan predators is the overriding and determining factor influencing the fate of fecal bacteria in water, soil, and sediments. Suspended fecal bacteria are filtered by ciliates and flagellates, and settled and soil-bound bacteria are phagocytized by amoeba (Mitchell 1971). Macrozooplankton grazing or filtering of fecal bacteria is probably present, but not significant given there preference for larger sized particles (Wetzel 2001). Microciliates, microflagellates, and heterotrophic nanoflagellates (HNF) feed on 0.2-5 µm sized particles and prefer larger particles. Fecal coliforms and *E. coli* range from 1-3 µm in length and are larger than most autochthonous bacteria (Menon et al. 2003). Some studies document the presence of microciliates and flagellates as the determining factor of *E. coli* mortality (Curds and Fey 1969, Curds 1973, Enzinger and Cooper 1976, Wcislo and Chrost 2000). Menon et al. (2003) found protozooplankton grazing was the culprit for 54%-99% of *E. coli* mortality in a freshwater system. This protozooplankton community was composed of HNFs and microplanktonic ciliates. Based on the sequence of grazers in a lake microcosm experiment, Bretter and Höfle (1992) concluded that flagellates had the strongest impact on reduction of *E. coli* cells.

Still many insist that the fate of fecal bacteria in the external environment is controlled by other parameters or that it is dependent on a combination of factors. In estuarine waters, McCambridge and McMeekin (1981) monitored the decline in fecal bacteria numbers after exposing fecal bacteria to solar radiation and natural predators independently and in combination. Results showed that the greatest declines in fecal bacteria numbers occurred in the presence of solar radiation and natural predators combined. Garvey et al. (1998) found that light intensity was the most influential factor causing coliform die-off in a freshwater lake rather than predation, temperature, and source of coliforms. Numerous observations of increasing fecal coliform and *E. coli* mortality with increasing temperatures have also been explained by increased ciliate and HNF grazing pressure on autochthonous and allochthonous fecal bacteria (Menon et al. 2003). There are also instances when increased water temperatures have expedited the grazing rates of protozoa (Caron et al. 1986, Sherr et al. 1988).

Temporal and Spatial Patterns

Distribution of fecal coliform and *E. coli* in lentic systems seems to be associated with sediments and their disturbance. Horizontally, surface waters of the shallower areas and littoral zone have the highest concentrations of organisms (Whitman and Nevers 2003, Hoyer et al. 2006). Vertically, most studies show concentrations to be highest in sediments or in the water directly above the sediments (Goyal et al. 1977, Burton et al. 1987, Doyle et al. 1992, Irvine and Pettibone 1993, Obiri-Danso and Jones 1999, Davis et al. 2005). Davis et al. (2005) found very little variation in surface waters horizontally, and strong variation vertically, with concentrations ten times higher in water above the thermocline than in surface waters.

Across and within many geographic locations, temporal trends tend to be related to storm events that introduce new organisms into the water body or resuspend viable organisms residing in sediments (Geldreich 1972, Geldreich et al. 1980, Hendry and Toth 1982, Kay and McDonald 1983). This perhaps explains conflicting findings in seasonality patterns in the literature. Fecal coliform and *E. coli* showed no temporal patterns in five creeks within a geographic region (Mallin et al. 2000). Lipp et al. 2001 found highest fecal coliform concentrations in August, and December through February. Most studies report higher concentrations for indicator organisms in winter months (Faust et al. 1975, Sayler et al. 1975, Goyal et al. 1977, Hoyer et al. 2006). This seasonal pattern is likely attributable to the organisms' ability to survive in reduced climates in addition to reduced predation due to lower temperatures.

Bacteroides thetaiotaomicron

Bacteria of the genus *Bacteroides* are gram-negative rod-shaped obligate anaerobes that grow optimally at a temperature of 37°C and a pH around 7.0. *Bacteroides* are naturally found in the guts of animals, including humans, and insects (Holdeman et al. 1984). In the human gut, *Bacteroides* are the most abundant microbes (Holdeman et al. 1976). *Bacteroides thetaiotaomicron* is a relatively human-specific microbe, ranging in size from 0.7-1.1 µm in width and 1.3-8.0 µm in length when grown in sterile glucose broth (Holdeman et al. 1984). This bacterium persists in symbiosis in the human gut (Comstock and Coyne 2003), and like other enteric bacteria, only causes infection when introduced to locations other than the intestinal tract. *B. thetaiotaomicron* has been documented as causing a cholesteatoma and later meningitis in a middle-aged individual (Feuillet et al. 2005).

Bacteroides species have long been acknowledged for their potential use as human fecal indicators (Geldreich 1972) because they are the predominant genera in human intestinal flora. *Bacteroides* species also do not replicate in water and have faster cell die-off than traditional fecal indicators. In a mesocosm experiment, Fiksdal et al. (1985) demonstrated that fecal streptococci and *E. coli* initially increased in numbers while *B. fragilis* remained at the same initial concentration; and cell die-off was greater in *B. fragilis* than in fecal streptococci and *E. coli*. *Bacteroides* species, however, are also commonly found in other animals (dogs, cattle, chickens, horse, and geese). Because of this, efforts in adapting *Bacteroides* species for use as a human fecal pollution indicator in water turned to bacteria source tracking methods. Bacteria source tracking originally involved geographic-specific archives or libraries of the target bacterium in its respective host, but recently has been focused on host-specific molecular markers within these target bacterium to avoid the need for a library. For example, *E. coli* extracted from water bodies has been traced molecularly to various animal origins (pig, cow, goose, and human) through bacteria source tracking (Carson et al. 2001).

Teng et al. (2004) discovered a *B. thetaiotaomicron* marker that was not present in other *Bacteroides* species. Carson et al. (2005) tested the specificity of this new marker to human feces. This study detected presence/absence of the bacteria in various animal fecal samples, domestic sewage samples, and water samples downstream from sewage discharges; and used serial dilutions of total DNA from samples to reflect relative abundance of the bacteria in feces of different animals. *B. thetaiotaomicron* was detected in all human excrement samples and water samples, but was also detected in a few samples of domestic dog feces (Carson et al. 2005). However, presence of this species in domestic dog feces may be due to sharing of microbes by owner and pet.

Carson et al. (2005) concluded that 1-5 ng of total DNA in a water sample would indicate human fecal pollution, especially with a strong PCR signal. Weaker PCR signals using 1-5 ng DNA may reflect domestic pets living in close association with humans. There was no attempt to quantify the bacteria in the 2005 study other than using serial dilutions of total DNA. The same lab In May 2008, however, used quantitative PCR to estimate concentrations of *B. thetaiotaomicron* in samples collected from creeks, rivers, springs, inflow from wastewater treatment plants, human fecal samples, and animal fecal samples. *B. thetaiotaomicron* was detected in all human fecal and sewage samples, most water bodies, and was never detected in fecal samples from animals (Yampara-Iquise et al. 2008). Hong et al. (2008) also published a study that same May that determined relative abundances of *B. thetaiotaomicron* in human and swine feces, and in municipal wastewater and swine wastewater using hierarchical oligonucleotide primer extension (HOPE). Results indicated a high detection rate of *B. thetaiotaomicron* in human fecal and wastewater samples (59%-98% of bacteria in sample); and no detections of *B. thetaiotaomicron* in swine fecal samples and swine wastewater samples.

Conclusion

E. coli and other fecal coliform bacteria may survive and multiply in many environments ranging from tropical to cool temperate regions. The most significant environmental factors influencing concentrations and transport of fecal coliform and *E. coli* bacteria entering a system seem to be land use practices, topography, and soil type and condition in the surrounding watershed; while the most significant factors influencing concentrations of these bacteria within a system seem to be the presence of ciliate and flagellate predators and the presence and concentration of particulate matter protecting the bacteria from these predators. Even when these conditions are unfavorable for fecal coliform and *E. coli* survival and replication, disturbance of the watershed and/or the sediments is the overriding factor facilitating contamination of the water body.

Preliminary research has recently begun for *B. thetaiotaomicron* in the aquatic environment. Although it has been established as a human-specific gut microbe, there is still much to learn about the fate of this bacterium in the environment. For instance, laboratory experiments have shown *B. thetaiotaomicron* can easily rebound after temporary exposure to oxygen. Pan and Imlay (2001) showed growth ceased upon exposing *B. thetaiotaomicron* to air, but upon returning to anaerobic conditions after 1 day of air exposure, cell growth resumed within 1 hour. The original colony actually retained >90% viability after 1 day of air exposure. Investigations of *B. thetaiotaomicron* survival after exposure to oxygen in aqueous and soil environments have not been reported in the literature. If survival is possible, however, *B. thetaiotaomicron* may replicate upon reaching anoxic lake sediments. Without this information, researchers may not be able to determine the timing of fecal contamination.

Appendix 2. 2007 Cove landscape characteristics: Dam=distance from Bagnell Dam on the Osage Arm or distance from Osage-Grand Glaize confluence on the Grand Glaize Arm (km), land area (ha), water area (ha), shoreline perimeter (m), percent forest/woodland, percent grass/pasture/barren, percent crop, percent

Reservoir Arm	Cove	Dam	Land Area	Water Area	Perimeter	Forest	Grass	Crop	Urban	Housing Units
Osage	1	23	66	19	4181	70	7	0	23	50
	2	24	76	12	4295	74	5	0	21	46
	3	24	53	10	3440	47	31	0	23	33
	4	27	164	12	6789	61	2	0	37	213
	5	28	55	9	4035	64	3	0	32	148
	6	29	97	18	5288	40	0	0	59	210
	7	29	55	13	3645	4	0	0	96	199
	8	30	72	16	4528	76	4	0	20	101
	9	31	98	12	5828	40	4	0	57	326
	10	31	314	27	11404	41	21	0.03	38	601
	11	32	103	27	5430	80	8	0	13	38
	12	33	42	12	3180	58	5	0	37	256
	13	33	29	9	3218	37	3	0	60	259
	14	34	178	35	7322	55	20	0	26	228
	15	34	288	35	8685	65	19	0.1	16	463
	16	36	99	16	5386	77	10	0.1	13	176
	17	36	29	7	2496	57	3	0	40	77
	18	37	44	8	3214	74	3	0	23	62
	19	37	22	4	2427	65	2	0	33	29
	20	40	65	11	3673	70	11	0.1	19	36
	21	41	17	2	1905	8	0	0	92	185
	22	42	39	5	3204	5	6	0	88	282
	23	42	37	3	2659	67	6	0	27	327
	24	42	41	3	2997	77	8	0	15	83
	25	42	97	4	4665	79	10	0	11	199
	26	43	95	4	4995	83	5	0	13	45
	30	27	22	4	2162	50	8	0	42	19
	31	43	40	2	3114	96	1	0	3	0
Grand Glaize	28	3	842	41	15823	82	6	0	13	514
	29	3	573	52	15701	96	2	0	2	24
	32	3	145	14	8150	99	1	0	0	17
	33	4	23	3	2191	99	0	0	1	0
	34	8	43	4	2739	91	4	0	5	3
	35	7	54	4	3065	100	0	0	0	0
	36	8	301	13	8306	92	8	0	0	0

Appendix 3. Raw data from surface samples. Coves labeled with “01” and “02” indicate sample collected at back and mouth of coves, respectively. F Notes= Field notes: A=ashes, S1-S5=little sun-full sun, WV1-5=no surface movement-extremely wavy, C1-5=clear sky-overcast, WD1-5=no air movement-very windy, AB=algal bloom, P1-2=light shower-full rain, SW=swimmers at beach, H=very hot ambient temperature, B=boat/jet ski/barge activity, AG=algal clumps on surface, FW=fledgling waterfowl, CR=strong currents. Z=max depth (m) at sampling location, Secchi depth (m), T=temperature (˚C), DO=dissolved oxygen (mg/L), cond=conductivity (µS/cm), w-turb=whole water turbidity (mg/L), f-turb=filtrate turbidity (mg/L), Chl=chlorophyll (µg/L), NVSS=non-volatile suspended solids (mg/L), VSS=volatile suspended solids (mg/L), TN=total nitrogen (µg/L), DN=dissolved nitrogen (µg/L), TP=total phosphorus (µg/L), DP=total phosphorus (mg/L), Cl=Chloride ions (µg/L), EC=*E. coli* (CFU/100 ml), FC=fecal coliform (CFU/100 ml): INT=microbial interference on plate, BT=*B. thetaiotaomicron* (presence/absence): 1 indicates detection in one duplicate, and 2 indicates detection in both duplicates., and total DNA (ng/L). PrM=processing mistake and MB=meter broken (no data). “---“ indicates no data collected.

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
5/29/2007	9	8:21	A	5.4	0.9	23	MB	255	7.1	9.1	4.4	19.9	2.9	1.8	940	790	61	42	7.9	0	95	1	3257.78
	10	8:34	A	9.2	0.8	24	MB	265	7.7	7.9	2.4	19	4.3	2.6	710	540	46	22	8.7	33.3	95		2340.00
	12	8:52		11.8	0.7	23	MB	249	7.7	12.1	6.6	10.3	2.6	1	940	940	72	65	7.2	20	24		2337.21
	13	9:00		12.8	0.7	22	MB	251	7.6	9.2	5	12.4	2.8	1.3	1020	930	80	63	7.5	6.7	0		2495.24
	14	9:11		14.9	0.7	23	MB	253	7.6	9.2	4.9	11.4	3.6	1.5	1050	860	77	52	7.7	100	10	2	2327.68
	15	9:22		10.2	0.7	24	MB	260	7.8	10.1	2.4	30.5	4.2	3.2	1060	640	77	32	8.2	20	114.3		4593.75
	16	9:46		8	0.7	24	MB	251	7.8	8.8	6.5	11.9	3.4	2.3	1010	910	81	57	7.3	200	180	1	5710.32
	17	9:33	S2,WV5	11	0.8	24	MB	250	7.8	11.1	6.4	10	2.6	1.6	1020	960	82	68	7.2	13.3	45	2	2750.00
	18	10:07		9.9	0.7	24	MB	249	7.8	11.3	7.6	8.3	2.7	1.5	820	940	79	67	7.2	6.7	20	2	3456.16
	19	10:15		8	0.9	24	MB	248	7.7	8.8	6.5	5.9	2.3	1.5	1050	930	80	68	7.1	13.3	20	2	5783.33
	20	10:28		9.9	0.7	25	MB	253	7.7	7.5	7.6	7.6	1.7	1.4	940	950	73	65	7.6	133.3	90.5	2	2539.62
	21	10:37		9.9	0.7	24	MB	247	7.7	7.7	8.2	10.6	2.7	1.5	950	940	78	70	7.1	0	23.8	1	1436.34
	22	10:47	WV5	10.8	0.7	24	MB	249	7.7	10.3	7.4	8.6	2.7	1.6	1030	940	74	67	7.2	0	13.3		2017.35
	23	11:00	WV5	8.7	0.8	24	MB	248	7.7	10.3	9.3	9.4	3.4	1.8	970	910	75	70	7.4	20	33.3		2049.65
	24	11:11	WV5	9.9	0.8	25	MB	247	7.8	6.5	7.3	6.5	1.8	1.4	960	930	77	69	7.1	20	80		1699.48
	25	11:30		8.2	0.7	24	MB	249	7.7	7.6	7.4	8.3	3.4	1.8	1010	970	77	68	7.5	20	47.6	1	2138.46
	26	11:42	C5	11.8	0.7	25	MB	247	7.7	9.4	8	11.3	3.6	1.9	990	950	79	66	7.4	0	50		4743.06
	31	11:51		9.1	0.8	24	MB	248	7.7	11.7	6.9	6.8	2.7	1.4	960	910	81	70	7.3	13.3	40		2072.22
	103	11:59		24.7	0.7	23	MB	246	7.7	8.2	7.6	7.7	3.5	1.3	930	830	75	62	7.2	0	0		2748.17

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	11	12:24		11.2	0.8	24	MB	255	7.9	7.6	5.3	17.3	5.3	4	970	850	62	43	7.6	0	18.8		1852.38
	8	13:55		9.2	0.8	24	MB	253	7.6	7.2	4.9	21.4	4.4	2.9	980	860	66	54	7.5	0	13.3		1877.59
	101	14:06	WD5,WV5	21.6	0.8	23	MB	249	7.3	8.4	7.8	7.9	3.3	1.5	880	940	69	65	7.6	13.3	20	1	1774.87
	30	14:13	WD1	10.7	0.9	24	MB	257	7.2	7.9	4.7	18.9	4.1	3.6	1040	840	70	51	7.8	6.7	45		2322.22
	3	14:23		10.2	0.9	24	MB	258	7.4	7.2	5.1	13.7	2.7	1.8	910	790	55	44	7.7	13.3	25		2295.24
	2	14:33		8.2	0.8	24	MB	258	7.4	6.4	3.5	14	3	2.1	820	730	51	35	7.7	13.3	33.3		2097.34
	1	14:43		17.4	0.7	25	MB	250	8.7	6.2	3.4	26.7	5.7	5.1	660	520	51	36	7.9	0	43.8	1	3320.00
	4	15:14		13.9	1	24	MB	255	8.1	6.4	4.6	18.5	3.8	3.1	830	690	53	42	7.9	6.7	35		3011.07
	5	15:27		13.8	0.9	24	MB	254	7.7	7.2	4.8	19.6	3.9	2.9	940	910	72	56	7.9	13.3	166.7	2	1945.45
	6	15:38		17	0.9	24	MB	254	7.5	6.7	5.8	10.6	2.9	1.9	990	860	62	54	7.6	0	45		3072.06
	7	15:46		17.5	0.9	25	MB	253	7.6	8	5.1	10.6	2.8	1.7	960	880	64	56	7.6	6.7	60		2525.58
	28	16:06	C2,WV1	11.9	1.2	25	MB	267	8.5	3.5	1.1	26.1	2.1	3.1	580	390	32	16	8.9	0	0	2	2915.26
	29	16:16		12.3	1.1	25	MB	263	8.5	4.2	2	21.4	2.9	2.6	710	460	33	17	8.5	0	6.7		2699.42
	102	16:24	WD5 , C5	28.1	1.1	25	MB	262	8.6	3	1	30.3	2.6	3.3	530	400	33	16	8.1	0	20		1960.00
	33	16:30		6.7	0.7	24	MB	259	8.9	6.3	1.1	116	4.4	10.1	1220	650	91	49	8.4	40	10		4213.33
	34	16:41		5.5	1.2	25	MB	260	8.8	3.5	0.6	27	2.5	3.6	440	280	30	14	7.2	6.7	6.7		2099.74
	36	16:46		7.3	1.1	25	MB	259	8.9	4.4	0.9	40.4	2.6	4.6	580	330	37	16	8.2	0	0		3152.00
	35	16:54	S2	7.2	0.8	25	MB	255	9.1	6.8	0.9	71.2	3.6	7.3	960	500	70	37	8.1	0	0		3378.95
6/11/2007	103	7:35	WV1,C5	14.5	1	24	6.8	280	7.7	6.3	1	31.2	5.3	2.5	940	730	79	34	8.2	1	2		3394.42
	31	7:44	WV1,C5	8.3	1	24	5.7	280	7.6	8.8	1.2	25.5	4.3	2.1	950	800	79	41	7.7	2	4.7		3415.38
	26	7:49	WV1,C5	11.5	1	24	6.1	279	7.7	5.5	1.3	27.3	3.5	2.5	1060	710	78	38	7.7	6.9	11.9	1	3802.47
	25	7:57	WV1,C5	7.1	0.9	24	5.8	280	7.7	8	1	34.2	4.8	2.9	1110	700	87	37	8.3	35	23.3		5447.76
	24	8:05	WV1,C5	6.8	0.9	24	6	279	7.7	8.1	1.3	29	4.3	2.1	960	760	76	35	8.1	100	193.3		5883.12
	23	8:42	WV1,C5	8.2	0.9	24	6.5	280	7.7	5.6	1.1	34.2	4.4	2.9	1000	710	82	35	8.2	380	103.3	1	4714.29

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	22	8:56	WV1,C5	10.9	1	24	5.8	280	7.7	5.6	1.3	24.6	3.7	2.2	1000	780	76	39	8	24	15.3		4842.64
	21	9:04	WV1,C5	9.8	1	24	5.6	280	7.7	5.4	1.1	24.3	4.7	2	1000	700	75	43	8	15	8.4		5070.59
	20	9:13	WV1,C5	5.9	0.9	24	6.5	279	7.7	6.6	1.1	30.4	4.4	2.4	1100	660	113	37	8.2	10	13.3		3795.45
	19	9:32	WV1,C5	8.3	1	24	6.1	279	7.7	5.5	1.3	29.2	4	2.4	980	690	79	40	7.6	6	51		3317.31
	18	9:42	WV1,C5	10.6	1	24	6.3	279	7.7	7	1.6	24.4	3.3	2	980	700	68	37	7.6	17	10		4250.00
	17	9:53	WV1,C3	12	1	24	6.4	280	7.7	7	1.3	29.5	4	2.2	1040	720	73	37	7.6	13	26.3		4628.57
	16	10:06	WV1,C3	8.4	0.9	25	7.7	278	7.9	4.9	1.2	43.2	4.2	3.8	1210	640	88	34	7.6	19	57.8		2662.34
	15	10:26	WV1,C3	9.9	0.9	25	7.7	275	8	5.9	1.3	10.9	5.2	3.2	1020	640	63	17	7.5	36.3	48.9		2494.62
	14	10:37	WV1,C3	15.5	1	25	7.2	278	7.9	6.3	1.3	33.2	3.9	2.7	1110	720	73	31	7.5	7	11.3		3518.52
	13	10:55	WV1,S2	12.7	0.9	25	7.4	279	7.9	6.6	1.3	28.9	3.7	2.7	1070	750	74	38	7.8	6	20		4904.46
	12	11:09	WV1,S2	11.4	0.9	25	7.4	280	7.9	8	0.9	31.3	4.4	2.6	1020	740	81	37	7.6	6.7	3.6		2619.05
	10	11:28	WV1,S2	9.7	0.9	25	7.9	277	8	6.1	1.2	21.8	3.6	2.1	830	740	59	26	7.5	30	15.8		2729.17
	9	11:42	WV1,S2	5.2	1.1	25	8.1	276	8	7.1	1.3	27.4	4.1	2.9	1000	720	65	28	7.6	17	113.3		2436.17
	11	11:53	WV3,S2	11	1.1	25	8.4	277	8	7.5	1	32.4	4.2	3	1110	700	70	31	7.8	6	5.6		3721.52
	8	12:58	WV3,WV5,S2,WD4	9	0.9	26	8.4	276	8.2	5.5	1.1	35.6	4.3	3.5	1030	690	76	33	8	6	14.4		3132.53
	101	13:10	WV3,WV5,S2,WD1	17.8	0.5	25	7.6	280	8	6.8	1.2	32.9	4.3	3	1010	760	75	37	7.7	1	3.3		3127.82
	30	13:20	C3,WV5	9.9	1	25	8.1	278	8	7.3	1.1	34.5	4.4	3.3	1030	730	78	40	7.7	4	65		2355.33
	3001	13:29	C3,WV5	1.8	1	26	8.1	279	8.1	6.3	1.2	23.9	3.8	2.8	950	760	70	37	7.7	31	22		1731.18
	3002	13:38	C3,WV5,WV4	12.1	1	25	7.7	279	7.9	4.9	1	29.3	4.5	3	1000	730	75	37	7.7	7	6.7		3038.25
	3	13:51	WV5	11.8	1.1	25	7.2	278	8	4.8	1.4	16.5	3.2	2.2	850	740	54	29	7.7	6	20	1	1520.00
	2	14:00	WV3	7.6	1	25	8.1	277	8.1	4.2	1.3	18.3	3.2	1.9	870	710	51	27	7.5	5	18.5		1734.69
	1	14:15	WV3	16.4	1	25	7.2	278	8	4.8	1.4	24.7	3.7	2.8	1020	720	62	29	7.5	8	15		3395.35
	201	14:27	WD1,AB	1.5	0.5	25	13.2	267	8.8	16.4	1.7	68.6	4.4	17.8	2270	1320	314	224	7.6	3	26.3		7384.62
	202	14:36	WV4	13.6	1.1	25	6.9	279	8.1	4.7	1.2	21	3.3	2.2	1040	760	59	33	7.6	5	6.7		4237.84

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	4	15:00	C2,WV3	14.84	1.1	25	8.6	275	8.3	4.2	0.9	26.3	3.6	2.8	890	620	56	22	8	14	48.3		6341.46
	401	15:10	C2,WD1	1.2	0.9	25	10.6	272	8.7	7.6	0.8	63.6	5.3	6.8	1180	660	88	37	7.6	48.2	51.5		4424.24
	402	15:24	C2,WD1	12.6	1	25	8	275	8.3	4.9	1.2	25.7	4.4	2.6	890	620	54	22	7.6	11	81.7		8550.56
	5	15:35	WV1,C5	12.2	1	25	8.6	277	8.3	5.5	1.1	26.5	3.1	3.2	940	670	67	37	7.6	12	0		5220.78
	6	15:44	WV1,C5	17.3	1.1	25	7.6	279	8	6.7	1.9	22.6	4	2	940	710	67	37	7.2	7	21.1		3457.14
	601	15:52	WV1,C5	5.6	1.5	26	7.7	279	8.1	6.3	1.4	22.4	3.2	2.2	940	680	65	37	7.4	40.5	50		3344.83
	602	15:59	C5,WV5	21.6	1.1	25	7.4	279	8	7.2	1	28.2	4	2.3	950	770	71	37	7.5	14	4.6		3230.00
	7	16:06	C5,WV1	16.3	1	25	8.6	278	8.1	7.3	0.7	31.6	3.6	3.6	1000	770	77	40	7.4	12	73.3	1	6000.00
	28	16:21	C5,WV1,P1	12.9	1	26	9.7	274	8.5	3.4	0.9	47.2	2.9	4.2	870	460	62	13	7.3	7	6.8		7180.56
	32	16:29	C5,WV1,P1	13	1.1	25	8.5	275	8.5	4	1.2	32.9	4.3	3.7	810	500	45	10	7.5	3	6		5468.93
	29	16:35	C5,WV1,P1	11.9	1	25	9.2	275	8.5	5.6	0.6	40.4	4.2	4	900	520	53	12	7.5	3	0		3556.82
	102	16:42	C5,WV1,P1	20	1	25	9.2	274	8.6	5	1	33.2	4.2	3.6	800	470	46	10	7.4	5	2.3		5093.33
	33	16:48		7.3	0.8	25	11.6	271	8.8	5.3	1.3	70.3	4.5	6.4	1010	470	68	16	7.5	3	3.8	1	5662.16
	34	16:59	SW,C5,WV1	6.7	1	26	10.1	277	8.9	6.1	1	60.3	2.3	6.7	910	500	74	15	7.3	7	13.3		5545.30
	36	17:06	C5,WV1	7.1	1.2	26	9.6	277	8.8	2.6	1.4	20.3	2.3	3.3	610	450	39	9	7.1	6	7.5		3476.92
	35	17:14	C5,WV1	6.6	1	26	12.4	273	8.9	4.5	0.7	45.2	3	4.8	890	450	57	11	7.6	6	5.3		3708.33
6/25/2007	103	7:29	S2,WV1,WD4	14.1	0.8	27	8.3	277	8.1	3.5	0.6	54.7	4.3	4.2	930	410	60	16	7.2	9.3	1.6		3638.89
	31	7:43	C3	12	1	27	8.6	280	8.2	3.6	0.3	42.5	3.8	3.5	790	330	52	16	7.3	3.5	0.6		4862.07
	26	7:51	C3	9.5	0.9	27	8.9	280	7.9	3.8	0.4	42.6	3.6	3.6	850	370	56	17	7.6	3.5	5		3086.96
	25	7:59	S2,WV3	5.5	0.6	28	8.7	282	8	4.3	0.5	56.8	3.9	4.2	810	480	59	17	7.4	6	3.6		6123.60
	24	8:21	S2,WV3	8.6	0.8	27	8.9	280	8.2	4.5	0.7	61.8	3.6	4.3	940	490	61	18	7.2	5	0	1	5486.73
	23	8:38	S2,WV3	9.1	0.9	27	8.8	282	8.2	4.9	0.3	65.1	3.6	4.4	670	420	64	18	7.4	15	17.1		5027.78
	22	9:01	S2,WV3	11	0.8	28	9.6	280	8.4	4.1	0.4	57.7	3.5	4.2	690	400	60	18	7.1	6	5.3		12147.06
	21	9:09	D	9.6	0.9	28	9.3	281	8.4	5.1	0.4	51.9	3.7	3.5	600	330	54	16	7.2	6	4.7		5876.71

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	20	9:23	D	5.7	1	28	10.1	279	8.5	4.8	0.5	47.4	3.6	3.9	820	380	53	16	7.5	13.5	2.8		14976.19
	19	9:37	S2,WV3	8.7	0.9	28	9.8	282	8.4	4.6	0.3	69.9	3.9	4.9	820	410	65	17	7.6	8.5	3.3		12638.55
	1901	9:42	WV3	4.9	0.8	28	9.2	283	8.4	4.8	0.3	44.9	4.3	3.6	620	450	52	15	7.3	5.6	5.6		6718.31
	1902	9:50	WV3	10.4	1.1	28	9.6	281	8.5	4.1	0.4	45.1	3.8	3.5	660	440	48	14	7.3	8	5.3		8642.86
	18	9:58	WV3	10.6	0.8	29	10.4	281	8.6	5.1	0.4	62	3.6	4.5	860	420	61	17	7.3	30.8	22.7		4584.27
	17	10:07	WV3	11.6	0.9	28	10	281	8.6	5.2	0.3	65.4	3.9	5	920	450	64	19	7.6	18	13		4871.79
	16	10:17	WV3	8.4	0.8	28	10.4	281	8.6	3.9	0.4	52.9	3.7	4.9	820	420	60	18	7.3	9	13.3		6231.40
	1601	10:27	WV3	1.6	0.8	28	8.5	285	8.7	4.8	0.2	28.8	3.5	3.7	640	350	48	13	8	24.3	155.6		3589.74
	1602	10:37	S3,WV4,WD1	13.4	0.9	29	10.8	278	8.8	5.1	0.3	52.4	3.3	4.9	830	390	58	15	7.3	4.5	2.2		6426.47
	14	10:59	S3,WV4,WD1	15.6	1.1	28	10.5	279	8.7	4.5	0.3	61.9	3.2	5.5	910	410	69	19	7.4	13.4	14		6142.86
	1501	11:25	C3	2.3	0.9	29	9.8	281	8.5	4.2	0.3	41.9	2.9	5.9	960	370	71	20	7.4	10.5	16.8		6495.24
	15	11:32	H	9.5	0.8	29	10.1	279	8.8	3.1	0.3	46.2	1.9	4.5	830	330	60	18	7.5	14	0		5142.86
	1502	11:37	H	11.6	0.9	29	9.9	279	8.6	4.1	0.3	39.2	2.2	4.3	730	310	53	14	7.5	6.5	8.9		3421.05
	1201	11:52	H	3.1	0.8	29	10.2	280	8.2	3.9	0.3	25.2	2.7	3.7	720	320	47	15	7.2	2	1.9		6816.90
	13	12:01	H	13.2	1	30	11.3	279	8.6	3.7	0.3	44.5	2.8	4.4	740	320	56	16	7.1	5.7	46.7		5605.44
	1202	12:30	H	17.7	0.9	29	11.3	279	8.6	4.6	0.3	69	3.4	6.3	850	340	72	22	7.1	8	12.5		5746.27
	12	12:41	C3	13	0.9	29	12.1	278	8.7	4.5	0.3	59	3.2	6	950	330	81	21	7.4	13.5	2.8	1	6016.00
	1101	12:45	C3	2	1.3	30	9	284	8.4	2.7	0.3	27.2	2	4.3	720	290	44	13	7.4	3.4	1.7		5675.32
	11	12:52	C3	12.2	1.2	30	10.2	280	8.5	2.4	0.4	24.3	1.8	3.6	650	290	37	13	7.5	1	3.1		7937.50
	1102	12:58	D	19.1	1	29	10.7	280	8.6	3.1	0.2	29.6	2.8	4	650	280	41	12	7.4	0.8	0		6071.43
	10	13:09	D	11.8	1.2	29	9.3	282	8.5	3.3	0.3	52.8	2.4	5.6	850	330	59	17	7.6	20	22		5235.77
	9	13:18	D	6.1	0.9	30	9.2	283	8.4	3.3	0.3	28.8	2.1	4.1	770	350	48	15	7.8	2.8	0		4616.67
	8	14:19	H	10	1.2	31	12.3	280	8.8	4.7	0.4	29.2	2.4	4.8	730	290	49	12	7.1	2.4	1.6		4213.48
	30	14:32	H	11	1	30	11.2	281	8.7	3.2	0.3	22.2	1.6	3.5	690	290	38	9	7.4	9	1.7		5703.70

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	3	14:42	H	10	1.2	31	10.4	282	8.6	4.5	0.3	28.6	1.6	4.7	780	310	57	13	7.4	3.6	6.9		4534.16
	2	14:52	H	9.7	1.4	30	10.3	282	8.6	3.5	0.3	26.6	1.8	4.5	650	400	49	11	7.5	5	0	1	4993.46
	1	15:02	H	17.7	1.5	31	9.9	282	8.6	3.4	0.3	16.4	1.8	3.4	610	300	37	9	7.5	0.5	1		2572.82
	4	15:21	WV1,H	15.2	1	31	11.9	278	8.8	3.6	0.3	21.4	2.5	3.3	700	290	41	9	7.7	1	6.7	1	3866.67
	5	15:38	WV1,H	13.1	0.8	31	12.2	278	8.9	6.5	0.4	38.9	4.5	6.2	820	330	72	14	7.4	4	1.7		4895.52
	6	15:58	D	16.3	1.1	30	11.4	278	8.8	4.1	0.3	26.1	3.4	4.5	690	270	44	10	7.3	3.3	0		4558.82
	7	16:12		17.8	0.8	31	12.6	277	8.9	6.4	0.3	32	5	5	690	280	52	10	7	0	6.7		3591.55
	101	16:20	WV5	18.7	1.1	29	11.2	280	8.8	5.3	0.6	33.7	3	4.8	640	290	43	10	7	0	1		3301.78
	28	16:36		13.1	1.1	30	9.4	272	8.7	4.8	0.2	21.2	3.2	4.2	590	260	39	8	7.6	5	0		4335.66
	32	16:42		14.2	0.9	31	9.5	272	8.8	4.5	0.3	16.7	3.7	4	550	260	39	7	7.5	1.7	0		3170.73
	29	16:49	C3	11.9	0.9	31	10.3	273	8.8	6.6	0.3	26.9	4.2	4.9	680	310	48	9	7.2	0.5	0		4012.50
	102	16:56	C3	21.3	0.8	30	10.6	271	8.8	5.4	0.3	22.1	4.7	4.7	630	320	42	9	7.8	0	0		3757.96
	33	17:02	WV1	8.5	1	32	9.2	273	8.8	5.6	1	14.3	3.8	3.5	590	330	38	10	7.4	0	0	1	3210.81
	34	17:14	S2,WV1	7.2	1	32	10.5	257	8.8	5	0.2	10.6	3.9	2.5	530	280	28	8	7.3	0	3.3		2117.07
	36	17:22	S2,WV1,B	7.9	0.9	31	11.4	257	8.8	5.7	0.2	17.7	5	3.9	620	300	40	8	7.2	0.8	3.3	2	2486.77
	35	17:28	S2,WV1	8.5	0.7	31	11.7	261	8.9	9	0.4	16.6	6.6	3.7	600	360	39	10	7.2	0	0		2686.27
7/9/2007	103	7:50	C1,S2	14.9	0.7	28	5.8	262	7.4	11.4	0.7	19.2	6.8	2.3	700	470	63	17	6.4	2.5	4.2		2609.93
	31	7:08	C1,C3	10.2	0.7	27	4.1	269	7.4	8.5	0.4	21.3	6.1	2.2	730	530	68	28	6.4	5.2	53		4015.38
	2601	8:12	C1,S2	8.4	0.8	28	6.3	270	7.7	9.5	0.4	33.7	4.6	3.1	730	380	61	12	6.4	300	873.3		2950.00
	26	8:18	C1,C3	11.7	0.8	28	5.6	269	7.6	13.5	0.4	26	5.4	2.6	620	450	68	19	6.5	546.7	30		2855.26
	2602	8:24	C1,S2	15.3	0.8	27	5.3	268	7.6	10.2	0.5	19.3	6.3	2.2	670	520	65	24	6.7	300	251.7		3154.93
	25	8:35	WV1,S2	7.2	0.7	28	5.7	269	7.6	11.1	0.4	34.7	5.9	3.9	870	440	82	20	6.5	25.3	100.2		3539.68
	24	9:05	C3,WD2	9.8	0.8	28	5.7	268	7.5	11.5	0.6	34.1	6.3	3.6	760	450	74	19	6.3	16	33.3		2246.58
	23	9:14	S2,WV1,WD2	8.4	0.7	28	6.4	268	7.6	11.7	0.6	38.7	5.4	3.6	900	440	73	17	6.3	15	22.3		2951.61

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	2201	9:28	S2,WV1,WD2	4.7	0.7	28	6.7	270	7.8	8.7	0.5	38.9	4.6	3.5	840	390	71	16	6.2	6.5	31		1716.22
	22	9:37	S2,WV1,WD2	12.1	0.8	28	6.1	268	7.7	10.7	0.4	28.1	4.9	3.4	830	410	63	19	6.2	4	75		2357.14
	2202	9:47	S2,WV1,WD2	14.7	0.8	28	5.4	268	7.7	11.1	0.6	24.4	5.8	2.5	810	480	59	25	6.3	9	14		1682.93
	2101	9:55	C3,WD4	5.7	0.9	28	5.8	269	7.8	7.8	0.6	27.3	4.2	2.7	800	510	68	22	6.4	38	63.3		2114.29
	21	10:02	C3,WD4	9.8	0.8	28	5.8	268	7.7	9.2	0.6	26.7	5.2	2.5	790	500	69	23	6.4	23.5	343.3		2772.41
	2102	10:08	C3,WD4	11.3	0.9	28	5.8	268	7.7	10.8	0.6	26.2	5.2	2.7	830	460	65	24	6.6	18	1086.7		2507.04
	2001	10:23	S2,WD3	2.7	0.9	28	7.3	272	8	12.3	0.3	36.3	3.5	3.3	660	370	60	10	6.8	4	4.7		1662.50
	20	10:26	C3-WD3	6.4	0.9	28	7.1	272	8	7.7	0.3	35.1	4.2	3.3	740	310	63	12	6.6	8.7	31		2316.46
	2002	10:34	C3-WD3	12.4	0.8	28	5.9	268	7.8	11.7	0.6	27.6	4.7	2.7	620	510	61	18	6.4	6.5	6.8		2440.00
	19	10:35	S2,WD4	9.4	0.8	28	5.1	266	7.9	11.7	0.7	22.1	4.7	2.2	640	430	65	26	6.4	18	1		2239.58
	18	10:53	S2,WD4	10.3	0.9	28	5.9	269	7.8	8	0.4	23.2	4	2.7	720	450	62	20	6.4	18.3	22		2087.50
	17	11:05	S2,WD4	11.8	0.9	28	5.7	267	7.8	12.4	0.5	23.8	3.8	2.9	610	430	60	20	6.2	6	20		2935.90
	16	11:21	C3,WD3	8.4	1	29	5.7	275	7.7	10.8	0.4	22.6	2.9	2.9	550	410	53	13	6.5	24.8	33.3	1	2333.33
	15	11:38	C3,WD3	9.8	0.9	30	7.7	280	8.1	PrM	0.2	26.6	2.2	3.7	PrM	370	PrM	7	6.9	5.5	19.5		2559.52
	14	11:52	H	15.2	1	29	7	274	8	9.9	0.3	29	3.2	3.2	510	320	50	8	6.8	2	6.4		2344.37
	13	12:00	H	13.4	1	30	6.7	273	7.8	6.7	0.4	15.1	2.7	2	510	380	45	12	6.3	7	16.7		2023.81
	12	12:09	H	12.5	0.8	29	7.2	269	8	11.4	0.4	25.9	3.8	3.1	600	390	61	17	6.5	4	3.6		2088.61
	10	12:25	H	10.8	1.1	29	6.3	277	8	8.1	0.3	24.8	2.5	3	500	290	46	7	6.8	8	40		2000.00
	9	12:37	H	5.4	1	30	6.4	281	8	9.3	0.2	22.7	2.9	3.3	540	320	49	8	6.7	7.6	40		1637.36
	11	13:45	H	10.3	1.1	31	8.4	278	8.4	11.4	0.2	20.5	1.4	3.9	480	300	41	8	6.6	3	INT		2406.98
	8	14:03	S2,WD3	8.7	1	31	9.2	273	8.6	13.9	0.2	22.9	2.6	3.9	540	360	45	12	6.5	4.4	4.9		2472.05
	30	14:15	B	12.1	0.9	30	8.1	269	8.3	8.9	0.2	27.7	3.4	3.1	560	370	48	11	6.5	2	3.8	1	2273.97
	3	14:30	C3,WV2,WD3	9.7	0.9	30	8.3	274	8.3	11.6	0.4	32.3	3.4	3.9	570	370	50	12	6.8	8.8	23.5		1920.45
	2	14:41	C3,WV2,WD3	9.1	1	30	8.4	271	8.4	8.9	0.3	27.3	2.8	3.7	550	300	47	12	6.8	4.8	20.7		2593.55

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	1	14:50	C3,WV2,WD3	16.6	0.9	31	9.2	272	8.5	10.5	0.2	21.8	2.3	2.9	520	330	39	11	6.8	2.5	8.3	1	3337.84
	4	15:08	C3,WV2,WD3	13.9	1	32	9.4	274	8.6	12.7	0.3	20.9	1.9	3.7	520	330	40	11	6.7	3.5	6.7		2127.17
	5	15:22	C3,WV2,WD3	13.1	0.9	31	8.9	270	8.5	10.5	0.3	24.6	2.4	3.7	580	330	45	14	6.5	4.4	3.3		2582.42
	6	15:46	C3,WV2,WD3	15.6	0.8	31	8.8	269	8.6	12.6	0.4	45.3	3.2	5.4	680	310	60	17	6.6	17.5	12		2333.33
	101	15:54	S2,WV4	19.8	0.9	29	7.9	268	8.5	14.9	0.5	39.8	5.6	4.1	700	420	65	20	6.8	2	2.8		2819.44
	7	16:01	S2,WV1,WD1	18.1	0.8	31	10.6	270	8.5	13.2	0.2	27.8	2.5	3.8	550	310	43	11	6.6	1	0		1843.75
	28	16:19	WV4,B,C3,WD3	12.6	1	31	8.5	278	8.6	14.4	0.2	24.3	2	4.1	500	290	35	8	7.3	0.5	3		2366.01
	32	16:39	S2,WV2,WD1	14.3	1.1	32	9	277	8.7	12.1	0.2	16.5	1.9	3.8	470	270	30	8	7.3	2.5	INT		2439.02
	29	16:45	C2,S2,WV1	12.3	0.8	31	8.8	277	8.6	18.6	0.2	27.3	2.2	4.4	540	300	38	8	7.4	5	2.5		2444.44
	102	16:52	WV4,S2	20.4	1	30	8.7	273	8.7	12.1	0.2	21.6	2.3	3.8	510	340	35	8	7.2	2	0		3181.10
	33	16:58	WV1,S2	6.1	0.9	32	9.5	275	8.9	18.4	0.3	21.5	2.3	4.8	570	320	45	9	7.2	3	2.5		2621.62
	34	17:08	C2,WD5	7.4	0.9	32	9.2	268	8.8	19.1	0.2	16.3	3.7	3.8	460	350	25	6	7.6	8.5	1.7		2625.00
	36	17:16	C2,WD5,P2	8.1	0.7	31	10	267	8.9	23.7	0.2	22.4	4.2	5	560	340	35	7	7	36.7	6.7		3014.49
	35	17:25	S2 and P2	6.8	0.8	31	11.3	263	9	17.5	0.2	31.3	6.1	5.9	620	330	48	10	7.3	2	0		2835.82
7/23/2007	103	7:51	S2,WV1	23.8	0.6	26	3.3	187	7	17	2.8	3.4	7.9	1.7	810	650	116	85	3.2	10	1.3		4172.41
	31	8:09	C1,WV1,D	9.5	0.7	26	3.6	182	7.1	13.1	2.8	4.4	6	1.3	820	850	113	87	3.1	3.3	0		4077.52
	26	8:21	C1,WV1	11.6	0.6	27	3.6	182	7.2	18.2	2.3	4.7	6.4	1.3	820	700	112	89	3.1	1.5	0		3478.99
	25	8:32	C1,WV1,S2	7.6	0.6	27	3.5	182	7.2	12.8	2.7	8.1	6.4	1.6	810	730	118	86	3.1	8	5	1	3909.09
	24	8:46	C1,WV1	9.2	0.6	26	3.7	86	7.4	15.3	2.9	5.5	6.6	1.5	950	740	116	86	3.1	4	4.4		5509.09
	23	8:57	WV1,C5	8.8	0.6	26	3.9	178	7.2	16.5	2.7	10.5	7.2	1.9	840	710	126	88	3.1	10	11.7		11488.37
	22	9:15	WV2,C5	13.5	0.6	27	3.5	182	7.2	16	2.6	5.9	7	1.3	850	700	117	87	3.1	4	0		7923.08
	21	9:21	WV2,C5	10.6	0.6	27	3.5	183	7.3	12.1	4.1	6.6	5.7	1.2	990	750	116	90	3.1	1.5	0.9		6056.60
	20	9:37	WV1,C5	6.8	0.6	26	3.3	86	7.3	15.2	2.9	9.8	5.4	1.5	1060	790	115	84	3.2	5.3	185		5261.54
	19	9:53	WV2,C5	9.3	0.6	27	3.5	161	7.3	14.2	3.5	13.8	5.7	1.8	1070	760	125	90	3.1	4.5	256.7	1	5439.02

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	17	10:40	WV2,C2	12.5	0.6	27	3.6	185	7.3	12.4	2.3	10.1	6.1	1.6	880	720	119	87	3.2	5.6	9		4833.33
	18	10:46	S3,WD2	10.2	0.7	27	3.9	172	7.3	15.2	2.5	12	6.2	2.1	1020	730	118	86	3.2	6	101.7		5132.08
	16	11:01	S3,WD2	8.4	0.7	28	4.1	186	7.3	10.6	3	9.5	5.5	1.6	1010	720	108	78	3.2	240	1070		3937.50
	15	11:16	S3,WV5,WV1	10.4	0.9	28	5.4	203	7.5	9.6	1.6	21.5	3.3	2.2	970	630	73	41	3.7	12	INT		2336.73
	14	11:29	C4,WV5,B	15.7	0.9	27	4.1	188	7.4	11.5	3.1	12	4.2	1.4	1040	700	98	70	3.3	2.4	3.2		3800.00
	13	11:42	C4,WV2	13.3	0.7		4	159	7.3	12.9	2.4	12.6	5.2	2	1040	770	115	84	3.3	4.4	7.4		4537.31
	12	11:56	C4,WV2	11.6	0.7	27	4.2	163	7.3	11.6	3.2	10.8	5	1.7	1040	680	115	86	3.2	4	3		6072.07
	10	12:13	C4,WV2	11.6	0.7	28	7.2	199	7.8	6.3	1.3	26.1	3.8	2.5	930	510	68	32	3.7	5	2.3		3887.64
	9	12:21	C4,WV2	5.7	0.7	28	4.6	168	7.5	8.3	2.7	10.3	3.7	1.4	1010	660	85	59	3.6	2.8	4.2		3734.94
	11	13:28	C3,WV2	10.5	0.9	28	6.1	194	7.6	7.7	1.5	20.7	4.3	2.5	990	560	82	44	3.5	5.2	3.3		6897.64
	8	13:47	C3,WV2	9.7	0.6	29	6.7	190	7.7	15.8	3	13.4	4.6	2	950	600	93	62	3.4	5.2	21		5868.85
	1	14:11	S2,WV3	15.7	0.6	27	3.9	192	7.3	19.6	3.5	13.8	6	2.1	900	780	110	79	3.5	8.3	3.8	1	3636.36
	2	14:23	S2,WV3	8.8	0.8	28	4.3	194	7.4	15.3	2.3	23.2	6	2.7	1070	810	109	75	3.5	2.4	45		6509.80
	3	14:34	S2,WV3	10.3	0.7	29	3.8	189	7.3	18.6	3	8.5	5.6	1.8	990	680	105	78	3.3	1.6	5		6290.91
	30	14:50	S2,WV5	12.4	0.7	29	4.8	188	7.4	14.4	3	22.1	6.4	2.9	1070	690	116	78	3.3	2.3	INT	1	6808.99
	4	15:04	S2,WV2,WV1	13.8	0.7	29	4.9	190	7.5	17.2	2.6	14	4.3	2.2	840	680	106	76	3.4	2.8	10		4205.88
	6	15:48	S2,WV1,WV2	17.1	0.7	28	4.6	188	7.4	11.1	3.1	18.3	5.5	2.6	1050	780	115	82	3.3	1.3	50		4958.33
	5	16:00	S2,WV1,WV5 (B)	11.5	0.8	29	5.3	188	7.5	17	2.4	13.6	4.3	2.2	1030	750	107	81	3.3	3.2	100		9113.64
	7	16:13	S2,WV1,WV2	18	0.6	29	5.2	190	7.5	12.4	2.8	15.3	4.6	2.7	1000	670	112	79	3.4	6.5	283.3		4814.16
	101	16:21	S2,WV5	18.3	0.7	28	4.5	184	7.4	15.4	3.8	18.2	6.2	2.7	1040	760	122	87	3.2	9.7	85		4754.72
	28	16:38	S2,WV2	13.4	1.1	28	6.7	228	7.8	7.9	1.1	30.2	3.9	3.2	670	380	52	17	4.9	1.2	INT		4571.43
	32	16:44	S2,WV2	14.8	1	29	8.8	225	8.4	7.3	0.5	40.2	3.2	4.8	680	320	55	15	4.9	1.2	0		5372.88
	2901	16:56	S2,WV1	3.9	0.7	29	7.5	218	8.1	5.9	0.9	41.2	4.8	4.9	790	390	68	24	4.6	1.1	INT		5294.12
	29	17:02	S2,WV1,S2,WV5	13.1	0.9	29	8.4	225	8.4	4	0.7	50.1	2.7	4.5	690	310	59	17	4.9	1.1	3.8		4859.65

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	2902	17:08	S2,WV3	17.6	0.9	29	8.4	230	8.4	4.7	0.7	33	2.4	4.5	630	310	49	12	5	4.8	3	1	3348.84
	102	17:13	S2,WV5	20.3	1	29	8.5	238	8.6	3.7	0.5	26.8	2	4.3	580	320	44	10	5.4	0.8	47.2		5543.21
	3301	17:22	S2,WV1	3.5	0.8	30	10.3	232	8.9	6	0.4	38.6	2.6	6.3	630	320	53	12	5.5	10.8	102		5267.61
	33	17:29	S2,WV5	7.3	0.7	30	9.8	224	8.8	4.5	0.5	37.1	2.5	5.5	650	310	54	11	5.4	0.2	0		3987.50
	3302	17:33	S2,WV5	10.2	0.9	30	10	233	8.7	3.5	0.4	34.8	2.4	5.4	630	300	55	12	5.2	2.1	10		4389.61
	3501	17:45	S2,WV1	4.4	0.9	30	8.6	257	8.7	4.2	0.4	27.7	1.5	5.6	620	330	46	10	6	1.6	4.6		3737.50
	35	17:51	S2,WV1	8.8	1	30	8.7	258	8.6	3.7	0.3	28.7	1.9	5.1	650	340	49	10	6	2	20		4107.14
	3502	17:58	S2,WV2	12	0.9	30	8.9	257	8.7	3.9	0.3	27.4	1.5	5.3	620	360	49	10	6.1	2.4	21.3		4493.51
	3601	18:07	S2 ,WV1	1.7	0.9	30	7.6	265	8.5	3.7	0.3	20.2	2.4	4.9	580	280	40	7	6.3	3.6	108		4869.57
	36	18:14	S2 ,WV1	8.4	0.9	29	8.2	263	8.7	3	0.2	23.5	2	4.7	640	290	41	7	6.4	0.8	0	1	3766.23
	3602	18:22	S2 ,WV1	11.7	1	29	7.7	264	8.6	3.5	0.3	20.9	1.4	5.1	570	320	40	7	6.5	1.6	38.5		6246.58
	34	18:27	S2 ,WV1	8.4	0.9	30	8.5	266	8.6	3.9	0.3	19.3	1.6	5.6	600	310	39	9	6.6	4.5	13.3		4280.00
8/3/2007	25	9:03	C5,H,WV1	7.8	0.8	29	7.4	200	7.2	5.1	0.7	63.6	3.3	5.2	970	410	140	82	3.7	4.8	6.7		5840.91
	24	9:20	C5,H,WV1	9.5	0.9	29	7.1	200	7.3	4.4	0.9	41.4	2.9	3.3	650	390	105	66	3.8	5	17.5		2680.41
	23	9:36	C5,H,WV1	9.3	1	29	7.8	200	7.3	5.7	0.8	64.3	3.3	5.2	800	400	133	80	3.7	4.4	983.3		4936.17
	20	9:57	C3,WV3	6.9	0.8	29	8.1	200	7.5	6.1	0.6	61.4	3.2	5	900	430	135	83	3.8	3.6	186.7		2088.89
	18	10:25	C3,WV3	10.5	0.9	29	7.8	199	7.6	5.5	0.7	32.9	2.9	2.5	550	340	93	60	3.5	5.3	420		2122.22
	16	10:42	C3,WV3	8.7	0.8	29	8.7	198	7.8	7.3	0.5	62.4	3.3	5.8	1020	430	142	88	3.5	2.7	160		2288.89
	15	11:01	S1,WV4	10.1	1	29	9.2	194	8	2.3	0.6	19.9	1.4	2.3	570	320	57	32	3.4	1.6	7.8	1	1770.49
	14	11:19	---	14.9	1	29	7.2	197	7.8	5.7	0.8	33.2	2.5	3.2	680	360	92	58	3.5	0.5	8.4		2226.76
	10	11:45	S2	11.4	1	29	8.2	195	7.9	3.8	0.7	33.4	2.2	3.4	700	340	81	47	3.5	3.6	74	1	2377.78
	33	12:10	S2,WV4	7.3	1.1	30	8.9	223	8.3	2.8	0.3	17.3	1.2	2.8	540	300	38	15	4.6	0.4	95		1646.03
	Party cove	12:27	S2,WV3	9.3	1.1	30	8.9	227	8.4	2.4	0.4	21.2	1.7	2.8	580	310	38	13	4.8	1.3	INT		727.76
8/6/2007	103	8:08	C1,WD2	22.9	0.9	29	5.1	205	7.4	3.9	0.6	20.8	2.8	1.5	590	360	85	60	3.7	1	31	1	2868.69

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	31	8:18	C3,WD5	11.3	1.2	28	5.2	204	7.4	3.4	0.5	30.2	3	2.4	700	430	100	67	3.6	1.5	421.7		9696.43
	26	8:28	C3,WD2	11.8	1.2	29	5.3	203	7.4	4.2	0.4	24.4	2.2	1.6	640	360	91	61	3.7	4	4		2597.40
	25	8:39	C1,WD4	7.7	0.9	29	5.4	203	7.4	5.1	0.5	31.7	3.5	2.7	730	400	100	65	3.7	28.4	145		2675.50
	24	8:52	C1,WD4	8.8	1.2	29	6	203	7.4	4.3	0.4	30.6	3.2	2.4	700	400	100	61	3.8	4.4	106.7	1	1905.88
	23	9:01	C1	8.8	0.9	29	6.4	203	7.4	3	0.4	23	3.7	3.1	730	400	98	59	3.7	3.8	10		2312.50
	22	9:15	C1,WD5	12.1	0.9	29	5.9	202	7.3	4.1	0.4	23.4	3.4	2.3	710	360	96	59	3.6	2.8	23.3		2685.71
	21	9:25	C1,WD5	10.8	1.1	29	6.3	203	7.1	5	0.4	27.6	3.2	2.2	690	350	100	62	3.7	7.2	21.3		2076.92
	20	9:38	C1,WD5	6.7	1.1	29	7.1	202	7.6	4.4	0.4	24.1	2.8	3.3	710	400	98	58	3.8	5.2	306.7		4082.19
	19	9:51	C1,WD4	9.6	1.2	29	5.5	203	7.5	3.4	0.5	19.4	3.1	2.3	620	390	94	66	3.6	3.2	113.3		2988.24
	18	9:57	C1,WD2	10.6	1.3	29	5.8	202	7.5	2.6	0.5	16	2.6	1.9	580	340	84	61	3.7	33.3	10		1114.58
	17	10:05	C1,WD5	12.4	1.2	29	5.4	202	7.5	3.8	0.4	14.2	2.1	1.8	590	350	84	59	3.7	10	3.3		1783.78
	16	10:15	C1,WV2	8.6	1.4	29	5.5	201	7.2	2.5	0.5	16	2.2	1.8	610	370	87	61	3.7	6.5	0		1393.62
	15	10:28	C1,WD4	10.1	1.4	30	7.3	216	7.6	3.3	0.4	20.4	2	2.4	620	340	73	46	3.7	4	200		2929.41
	14	10:37	C1,WV2	15.3	1.3	29	6.4	201	7.3	3.3	0.4	18	2.4	2.3	630	340	80	49	3.7	0.5	14.7		1988.51
	13	11:05	C1,WD4	13.9	1.5	30	6	200	7.4	3.1	0.5	14.7	4	1.8	680	350	82	58	3.7	8.8	83.3		1719.10
	12	11:16	C1,WD2	11.8	1.5	30	6.6	220	7.3	2.6	0.4	13.6	2.4	1.9	640	330	77	55	3.8	1.6	45		2734.18
	11	11:29	C1,WD2	11.3	1.3	30	8.2	199	7.8	2.3	0.3	22.2	3.9	3.1	730	350	79	46	3.5	0.8	36.7		1935.06
	10	11:43	C1,WD5	10.1	1.2	29	6	200	7.6	3.4	0.5	17	0.5	2.3	680	350	80	49	3.7	3.6	66.7		1961.54
	9	11:52	S2,WD2	5.4	1.3	30	5.8	201	7.5	4.4	0.5	14.3	3.2	2	640	410	79	52	3.6	32.7	INT		1512.82
	102	12:09	S3,WD4	20.3	1.3	30	6.6	211	7.7	3.7	0.4	19.3	2.3	2.6	650	390	55	27	4.1	1.6	0	1	2010.00
	33	12:19	S3,WD4	8.7	1.2	30	7.5	213	8	3.7	0.5	20.6	1.9	3.4	670	380	57	26	4	4	3.3	1	2545.45
	1	13:26	S2,WD2	12.9	1.2	31	7.6	200	7.9	2.7	0.4	14.2	1.5	2	600	420	67	47	3.6	0.5	2.3	1	1630.06
	2	13:37	S2,WD2	8.7	1.2	31	6.6	201	7.7	3.2	0.6	14	2.1	2.5	640	390	73	49	3.6	2.7	60.5		1547.17
	3	13:45	S2,WV2	10.4	1.1	31	7.3	201	7.7	3.6	0.7	14.5	1.7	1.3	630	400	68	46	3.6	1.3	34		1663.16

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	30	13:56	S2,WV5	12	1.2	30	7.3	202	7.8	5.4	0.6	18.9	2.6	2.6	700	390	83	58	3.6	133.3	160		2573.33
	4	14:07	S2,WD4	14.6	1.2	31	8.7	202	8.1	2.3	0.6	11	1.1	1.2	600	410	67	47	3.6	0.5	13.3		712.23
	5	14:30	S2,WD4	11.6	1.1	31	9	198	8.3	2.9	0.5	19.8	1.2	2.5	660	410	75	52	3.6	1.6	53.3		914.89
	6	14:44	S2,WD2	17	1.3	31	7.8	202	8.2	3.5	0.4	18.4	0.9	2.4	670	380	75	52	3.5	2.4	0		1408.16
	7	14:53	S2,WD2	18.3	1.1	32	8.9	200	7.9	3.1	0.5	15.2	0.2	2.1	650	450	75	52	3.8	1.2	4.4		936.59
	101	15:01	S2,WD4,WV5	18.4	1.3	30	6.2	202	8.2	2.9	0.5	22.4	0	3	700	320	83	55	3.6	1.2	1.3		1385.54
	8	15:11	S2,WD5	9.7	1.3	31	8.3	201	7.9	4.4	0.5	17	4.6	2.2	590	340	84	61	3.8	1.6	2.7		977.01
	28	15:28	S2,WD2	13.1	1.2	31	7.9	215	7.9	2.5	0.4	19	0.3	3	700	310	45	17	4.2	1.3	7.8		851.85
	32	15:36	S3,WD4	14.5	1.2	31	8.2	214	8.2	2.8	0.4	16.5	0.9	3.2	650	330	43	16	4.1	0.4	6.7		728.16
	29	15:43	S3,WV1	11.5	1.1	31	8.3	214	8.3	3.3	0.4	19.6	2	3.7	700	340	48	18	4.1	1.3	8.3		1083.33
	36	16:08	C2,WD5	7.2	1.2	31	8.4	231	8.4	3.1	0.4	21.5	1.2	4.1	730	320	42	11	5.2	3.2	0		1664.52
	34	16:17	S2,WD2	4.2	1	31	8.5	235	8.5	2.3	0.3	16.9	1.2	4	710	320	35	9	4.8	1.2	2.5		1433.33
	35	16:25	S3,WV1	8.3	1	31	8.8	231	8.5	2.3	0.3	19.4	1.2	4	700	350	41	12	4.8	1.6	1		1473.68
	Party cove	16:34	S2,WD4	9.3	1	31	7.6	222	8	2.7	0.3	23.1	1.6	3.9	740	340	47	14	4.3	2	2		2950.62
8/20/2007	103	8:55	WD4,P1,C5 C2	15.3	1.3	29	4.1	224	7.4	1.8	0.3	19.9	1.5	1.7	740	500	76	53	4	2	45		2018.46
	31	9:05	WD4,P1,C5 C2	8.8	1	30	4	224	7.4	4.1	0.4	21.7	3.9	2.1	830	500	76	47	4.1	7.5	138.3		2133.33
	26	9:15	WD4,P1,C5 C2	11.2	1	30	4.2	224	7.5	4.2	0.3	20.6	2.8	2	830	510	74	46	4.2	2.8	210		880.00
	25	9:30	WD4,P1,C5 C2	7	1.2	30	4.3	225	7.5	4.6	0.2	24	4.7	2.3	840	480	78	45	4.4	53.2	760		1470.00
	24	9:45	WD1,P2	9.2	1	30	4	226	7.5	3.8	0.3	21.5	3.6	2.2	890	510	77	46	4.5	47	INT		1168.00
	23	9:55	P1,WD1	7.8	1.3	30	4	225	7.7	3.5	0.3	24.9	3.2	2.6	830	560	78	46	4.2	46.5	1350	1	816.00
	22	10:07	P1,WD1	8.8	1.2	30	3.9	225	7.6	4.9	0.3	24.2	4.7	2.6	780	560	80	46	4.4	4	220		1200.00
	21	10:17	P1	9.9	1.3	30	4	225	7.6	4.3	0.2	22.2	2.9	2.1	780	510	74	46	4.1	15.6	78.3		1066.67
	20	10:30	P1	5.2	1.4	30	4.7	224	7.7	3.4	0.3	23.1	2.8	2.2	820	510	73	42	4.4	55	226.7		824.00
	19	10:45	P1	8.4	1.5	30	4.2	224	7.7	3.8	0.3	17.9	2.9	2.1	740	590	70	43	4.2	12.8	1040		1048.00

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	18	11:10	P,WD4	9.4	1	29	3.9	224	7.6	4.3	0.2	16.9	3.3	2.2	830	530	71	44	3.6	20.9	720		1463.92
	17	11:48	P,WD3	10.2	1.4	30	4	224	7.6	3.6	0.3	15.8	3.7	1.7	780	570	71	45	3.6	14.4	860		1450.00
	16	12:00	P1,WD3	7.6	1	30	4.1	223	7.6	5.2	0.3	16.7	4.8	2.6	800	560	73	44	3.6	98.3	4880		1171.17
	15	12:16	WD3,C5 C2	9.2	1.5	30	4	220	7.6	3.2	0.3	16.9	2.4	1.9	820	590	69	44	3.6	21.8	INT	1	917.91
	14	12:35	WD3	14.8	1.7	29	4.2	222	7.4	2.5	0.3	19.9	2	2	780	550	71	43	3.6	20.1	INT		1131.15
	13	13:00	WD4	13	1.4	30	3.9	223	7.4	2.6	0.2	17.4	2.3	2	760	550	69	46	3.6	56.3	106.7		1575.76
	12	13:58	C5,C2	11.3	1.3	30	3.9	223	7.5	3.5	0.4	20.5	2.9	2.1	790	540	72	45	3.6	15.7	126.7		1000.00
	11	14:15	C5,WD4	8.3	1.2	30	4.7	221	7.6	3.2	0.3	19.5	3.1	2.3	820	560	65	40	3.4	2	103.3		952.00
	10	14:30	C5,WV1	10.3	1.3	30	3.5	238	7.6	3.2	0.3	14.7	2.6	2	860	530	77	49	3.4	18.4	880		930.43
	9	14:45	C5,WV1,C3	5.2	1.2	29	3.9	218	7.6	3.7	0.2	17.2	3.8	PrM	810	520	79	47	3.5	221.7	1560		2196.36
	8	15:00	C4,WD4	9.2	1.1	29	4.6	221	7.6	4.2	0.3	16.6	3.8	PrM	830	580	73	43	3.8	30.3	INT		1077.97
	101	15:13	C4,WD4	17.2	1.7	30	4.4	221	7.6	1.8	0.3	15.7	1	PrM	810	590	69	44	3.4	2	126.7		547.69
	1	15:30	S3	15.6	1.6	30	4.1	216	7.6	3.3	0.3	14.1	2.3	PrM	790	520	69	44	3.3	10.5	INT	1	424.00
	3	15:47	S2,WD4	9.8	1	30	4.8	218	7.8	5.3	0.4	19.9	4.5	PrM	800	500	76	44	3.4	2	660	1	1190.70
	2	15:54	S2,WD2	8.1	1.2	30	4.5	218	7.7	3.5	0.3	16.2	3.2	PrM	820	590	72	46	3.6	4	660		426.09
	30	16:06	S2	12	1.4	30	4.4	220	7.7	3.5	0.3	12.5	2.5	PrM	750	500	69	46	3.4	7.3	2140	2	1437.50
	4	16:17	S2,WD4	13.5	1.4	30	4.4	219	7.6	2.8	0.8	13.3	1.7	PrM	770	480	67	45	3.3	12.6	673.3		398.31
	5	17:02	S2,WD3	12.1	1.4	30	4.5	219	7.6	2.7	0.3	13.9	2.3	PrM	750	570	69	47	3.6	25.3	INT		325.93
	6	17:10	S2,WD4	16.8	1.3	30	4.7	219	7.8	3.5	0.3	15.3	2.2	PrM	730	520	68	44	3.4	13.2	INT	1	1189.66
	7	17:17	S2,WD4	16.4	1.2	30	4.8	220	7.7	3	0.3	16.3	2	PrM	760	590	69	44	3.5	31.4	1146.7		848.21
	28	17:30	S2,WV4	12.7	1.1	30	5.4	216	7.9	3.2	1.5	33.1	1.4	PrM	630	460	64	28	3.6	3.6	6.7		1086.54
	32	17:38	S2,WV4	14.2	1.3	30	4.8	215	7.9	4.9	0.6	22.2	1.4	3.1	650	540	59	31	3.4	4.8	500		2149.53
	29	17:45	S2,WV4	12.8	1.2	30	4.9	215	7.8	3.4	0.3	25.3	1.3	3.1	600	470	61	33	3.3	3.6	6.7		844.66
	102	17:52	S2,WV5	19.2	1.6	30	4.6	217	7.8	1.7	0.3	18.3	0.2	2.6	530	500	58	32	3.4	1.2	0		1444.44

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	33	17:56	S2,WV1,WV5 (B)	8.5	1.3	30	5.6	217	7.9	2.6	0.4	23.6	0.9	3.3	630	540	57	28	3.5	2.1	0		415.93
	36	18:09	S2,WV1,WD3	7.4	1.2	30	5.3	229	8	3.5	0.3	25.8	1.1	3.7	620	520	49	13	3.9	10	45		428.57
	35	18:16	S2,WV1,WD4	7.8	1.2	30	5.6	226	8	2.3	0.4	27.6	0.9	4	590	400	52	15	3.9	5.2	16.7		401.71
	34	18:22	S2,WV1,WD4	6.9	1.2	30	5.8	233	8.2	2.6	0.4	29.8	1.4	4	750	320	50	13	4.1	5.2	10		6010.81
5/22/2008	103	11:00	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.5	7.8	---	---
	26	11:14	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	7.7	---	---
	25	11:27	C5,AG	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	7.2	13.3	---	---
	24	11:41	FW,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1.7	---	---
	23	11:50	C5,B	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	19	18.5	---	---
	20	12:09	C4,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	16.7	63	---	---
	19	12:24	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5.5	10.4	---	---
	16	12:38	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	6.7	0	---	---
	15	12:56	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.3	2.5	---	---
	14	13:19	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	8.5	---	---
	9	13:39	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4	0	---	---
	7	14:00	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4.4	2.1	---	---
	101	14:08	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.4	3.3	---	---
	30	14:17	WV5,CR	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	7.7	---	---
	4	14:32	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	15.5	5.7	---	---
5/27/2008	103	10:26	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	4.2	---	---
	26	10:36	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	70	0	---	---
	25	10:48	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	65	123.3	---	---
	24	11:03	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	331	300	---	---
	23	11:20	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	753.3	1220	---	---

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
7/3/2008	20	11:46	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	27.5	63.3	---	---
	19	12:00	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	34.5	12.3	---	---
	16	12:22	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	136.7	60	---	---
	15	12:44	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	29	68.3	---	---
	14	13:00	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	35.2	32	---	---
	9	13:23	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	21.7	10	---	---
	7	13:36	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13	40	---	---
	4	13:52	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	30	37.1	---	---
	30	14:06	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.5	0	---	---
	101	14:15	C5,D	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	22.1	23.3	---	---
	103	9:55	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.8	2.4	---	---
	26	10:15	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.3	0	---	---
	25	10:25	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	21.6	16	---	---
	24	10:40	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	23	22.6	---	---
	23	10:50	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	107	600	---	---
	20	11:10	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	11.5	100	---	---
	19	11:35	C3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	111.7	420	---	---
	16	11:50	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	26	8	---	---
	15	12:05	C2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	42.2	12	---	---
	14	12:30	C2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13.5	1.7	---	---
	9	12:45	C2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	170	273.3	---	---
	7	13:20	C2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8.5	40	---	---
	101	13:30	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0	---	---
	4	13:45	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	15	0	---	---

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	30	14:00	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	20	80	---	---
7/7/2008	103	9:11	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	6	0	---	---
	26	9:20	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	14	9.4	---	---
	25	9:34	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.3	10.5	---	---
	24	9:51	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8	37.1	---	---
	23	10:02	S2,WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	11	43	---	---
	20	10:29	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	10.7	15.6	---	---
	19	10:52	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	6.7	8	---	---
	16	11:09	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8	9.2	---	---
	15	11:24	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	14	8.5	---	---
	14	11:32	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	3.3	---	---
	9	12:07	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.3	22.7	---	---
	7	12:21	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.8	0	---	---
	4	12:35	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	8.3	---	---
	30	12:51	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	20	---	---
	101	13:00	S2,WD4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.5	6.7	---	---
8/28/2008	103	9:00	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	---	---
	26	9:14	C3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	---	---
	25	9:27	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.1	0	---	---
	24	9:39	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	6.7	---	---
	23	9:48	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	9.2	---	---
	20	10:05	WV1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.5	8	---	---
	19	10:35	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.9	0	---	---
	16	10:48	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0	---	---

Date	Site	Time	F Notes	z	SD	Temp	DO	cond	pH	w-turb	f-turb	Chl	NVSS	VSS	TN	DN	TP	DP	Cl	EC	FC	BT	DNA
	15	11:03	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.3	0	---	---
	14	11:22	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	0	---	---
	9	11:45	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.7	1.7	---	---
	30	12:02	WV5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	---	---
	4	12:13	WV3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	4	---	---
	7	12:36	WV3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.2	3.7	---	---
	101	12:45	WV3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	0	---	---
9/2/2008	103	8:56	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0.5	---	---
	26	9:05	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.7	0	---	---
	25	9:16	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8.8	9.3	---	---
	24	9:30	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.4	4.3	---	---
	23	9:40	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.8	13.9	---	---
	20	9:55	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.4	6.7	---	---
	19	10:11	WD1,C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.2	INT	---	---
	16	10:31	S2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12.7	0	---	---
	15	10:50	C3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	19	0	---	---
	14	11:08	S3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0.7	---	---
	9	11:30	S4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	7.5	0	---	---
	30	11:49	C3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.2	5.7	---	---
	4	12:15	C4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	6.8	0	---	---
	7	12:30	C5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	5.5	---	---
	101	12:38	WV5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.2	6.7	---	---

Appendix 4. 2007 Descriptive statistics for all water quality measurements in each site and cove: sample size or number of times sampled (n), mean, median, maximum, and minimum values.

Parameter	Site	N	Mean	Median	Max	Min
Sampling Depth (m)	1	7	16.0	16.4	17.7	12.9
	2	7	8.6	8.7	9.7	7.6
	3	7	10.3	10.2	11.8	9.7
	4	7	14.3	13.9	15.2	13.5
	5	7	12.5	12.2	13.8	11.5
	6	7	16.7	17.0	17.3	15.6
	7	7	17.5	17.8	18.3	16.3
	8	7	9.4	9.2	10.0	8.7
	9	7	5.5	5.4	6.1	5.2
	10	7	10.5	10.3	11.8	9.2
	11	7	10.7	11.0	12.2	8.3
	12	7	11.9	11.8	13.0	11.3
	13	7	13.2	13.2	13.9	12.7
	14	7	15.3	15.3	15.7	14.8
	15	7	9.9	9.9	10.4	9.2
	16	7	8.3	8.4	8.6	7.6
	17	7	11.6	11.8	12.5	10.2
	18	7	10.2	10.3	10.6	9.4
	19	7	8.8	8.7	9.6	8.0
	20	7	6.7	6.4	9.9	5.2
	21	7	10.1	9.9	10.8	9.6
	22	7	11.3	11.0	13.5	8.8
	23	7	8.5	8.7	9.1	7.8
	24	7	8.9	9.2	9.9	6.8
	25	7	7.2	7.2	8.2	5.5
	26	7	11.3	11.6	11.8	9.5
	28	7	12.8	12.9	13.4	11.9
	29	7	12.3	12.3	13.1	11.5
	30	7	11.4	12.0	12.4	9.9
	31	7	9.9	9.5	12.0	8.3
	32	6	14.2	14.3	14.8	13.0
	33	7	7.6	7.3	8.7	6.1
	34	7	6.6	6.9	8.4	4.2
	35	7	7.7	7.8	8.8	6.6
	36	7	7.6	7.4	8.4	7.1
	101	7	18.8	18.4	21.6	17.2
	102	7	21.4	20.3	28.1	19.2
	103	7	18.6	15.3	24.7	14.1

Parameter	Site	N	Mean	Median	Max	Min
Secchi Depth (m)	1	7	1.1	1.0	1.6	0.6
	2	7	1.1	1.0	1.4	0.8
	3	7	1.0	1.0	1.2	0.7
	4	7	1.1	1.0	1.4	0.7
	5	7	1.0	0.9	1.4	0.8
	6	7	1.0	1.1	1.3	0.7
	7	7	0.9	1.0	1.2	0.6
	8	7	1.0	1.0	1.3	0.6
	9	7	1.0	1.0	1.3	0.7
	10	7	1.0	1.1	1.4	0.8
	11	7	1.1	1.1	1.3	0.8
	12	7	1.0	0.9	1.5	0.7
	13	7	1.0	1.0	1.5	0.7
	14	7	1.1	1.0	1.7	0.7
	15	7	1.0	0.9	1.5	0.7
	16	7	0.9	0.9	1.4	0.7
	17	7	1.0	0.9	1.4	0.6
	18	7	0.9	0.9	1.3	0.7
	19	7	1.0	0.9	1.5	0.6
	20	7	0.9	0.9	1.4	0.6
	21	7	0.9	0.9	1.3	0.6
	22	7	0.9	0.8	1.2	0.6
	23	7	0.9	0.9	1.3	0.6
	24	7	0.9	0.8	1.2	0.6
	25	7	0.8	0.7	1.2	0.6
	26	7	0.9	0.9	1.2	0.6
	28	7	1.1	1.1	1.2	1.0
	29	7	1.0	1.0	1.2	0.9
	30	7	1.0	1.0	1.4	0.7
	31	7	0.9	1.0	1.2	0.7
	32	6	1.1	1.1	1.3	0.9
	33	7	0.9	0.9	1.3	0.7
	34	7	1.0	1.0	1.2	0.9
	35	7	0.9	1.0	1.3	0.7
	36	7	1.0	1.1	1.2	0.7
	101	7	1.0	0.9	1.7	0.5
	102	7	1.1	1.0	1.6	0.8
	103	7	0.8	0.8	1.3	0.6

Parameter	Site	N	Mean	Median	Max	Min
Temperature (°C)	1	7	28.5	30.1	31.0	24.5
	2	7	28.3	29.9	30.7	24.4
	3	7	28.5	30.0	31.0	24.0
	4	7	28.9	30.1	31.7	24.3
	5	7	28.7	30.1	31.4	23.5
	6	7	28.4	30.0	31.0	24.0
	7	7	28.9	30.1	31.6	24.5
	8	7	28.7	29.4	31.1	24.4
	9	7	27.7	29.4	29.8	23.1
	10	7	27.7	29.0	29.6	23.8
	11	7	28.3	29.5	31.1	24.4
	12	7	27.5	28.8	29.7	23.2
	13	6	27.6	29.5	29.7	22.4
	14	7	27.3	28.4	29.4	23.2
	15	7	27.8	29.0	29.7	23.8
	16	7	27.4	28.2	29.8	24.3
	17	7	27.2	28.3	29.7	24.0
	18	7	27.2	28.1	29.4	23.6
	19	7	27.0	27.9	29.6	23.7
	20	7	27.1	27.7	29.5	24.2
	21	7	26.9	27.6	29.6	23.8
	22	7	26.9	27.6	29.6	24.0
	23	7	26.9	27.3	29.6	24.0
	24	7	26.9	27.2	29.5	24.2
	25	7	26.9	27.5	29.6	24.1
	26	7	26.9	27.4	29.7	24.2
	28	7	28.6	30.2	30.8	24.5
	29	7	28.6	30.0	31.1	24.5
	30	7	28.3	29.6	30.4	24.2
	31	7	26.6	27.2	29.7	23.7
	32	6	29.5	30.2	31.8	24.9
	33	7	29.0	29.9	31.8	24.3
	34	7	29.4	30.1	31.6	25.1
	35	7	29.0	29.8	31.1	24.8
	36	7	28.9	29.7	30.9	24.5
	101	7	27.8	29.2	29.7	23.4
	102	7	28.3	29.5	30.4	24.5
	103	7	26.6	27.1	29.4	23.4

Parameter	Site	N	Mean	Median	Max	Min
Dissolved Oxygen (mg/L)	1	6	7.0	7.4	9.9	3.9
	2	6	7.0	7.3	10.3	4.3
	3	6	7.0	7.3	10.4	3.8
	4	6	8.0	8.7	11.9	4.4
	5	6	8.1	8.8	12.2	4.5
	6	6	7.5	7.7	11.4	4.6
	7	6	8.4	8.8	12.6	4.8
	8	6	8.3	8.3	12.3	4.6
	9	6	6.3	6.1	9.2	3.9
	10	6	6.7	6.8	9.3	3.5
	11	6	7.7	8.3	10.2	4.7
	12	6	6.9	6.9	12.1	3.9
	13	6	6.6	6.4	11.3	3.9
	14	6	6.6	6.7	10.5	4.1
	15	6	7.0	7.5	10.1	4.0
	16	6	6.2	5.6	10.4	4.1
	17	6	5.9	5.5	10.0	3.6
	18	6	6.0	5.8	10.4	3.9
	19	6	5.7	5.3	9.8	3.5
	20	6	6.5	6.8	10.1	3.3
	21	6	5.8	5.7	9.3	3.5
	22	6	5.8	5.8	9.6	3.5
	23	6	6.0	6.4	8.8	3.9
	24	6	5.7	5.8	8.9	3.7
	25	6	5.6	5.6	8.7	3.5
	26	6	5.6	5.5	8.9	3.6
	28	6	7.9	8.2	9.7	5.4
	29	6	8.3	8.6	10.3	4.9
	30	6	7.3	7.7	11.2	4.4
	31	6	5.2	4.6	8.6	3.6
	32	6	8.1	8.6	9.5	4.8
	33	6	8.9	9.3	11.6	5.6
	34	6	8.8	8.9	10.5	5.8
	35	6	9.8	10.0	12.4	5.6
	36	6	8.8	9.0	11.4	5.3
	101	6	7.0	6.9	11.2	4.4
	102	6	8.0	8.6	10.6	4.6
	103	6	5.5	5.4	8.3	3.3

Parameter	Site	N	Mean	Median	Max	Min
Conductivity (µS/cm)	1	7	241.4	250.0	282.0	191.7
	2	7	242.9	258.0	282.0	193.6
	3	7	243.0	258.0	282.0	189.4
	4	7	241.9	255.0	278.0	190.1
	5	7	240.7	254.0	278.0	188.2
	6	7	241.4	254.0	279.0	188.3
	7	7	241.0	253.0	278.0	189.5
	8	7	242.0	253.0	280.0	189.9
	9	7	240.3	255.0	283.0	168.3
	10	7	248.2	265.0	282.0	198.7
	11	7	243.3	255.0	280.0	193.7
	12	7	240.2	249.0	280.0	162.5
	13	7	237.7	251.0	279.0	158.5
	14	7	242.1	253.0	279.0	187.7
	15	7	247.6	260.0	280.0	203.1
	16	7	242.1	251.0	281.0	185.7
	17	7	241.2	250.0	281.0	184.5
	18	7	239.4	249.0	281.0	171.5
	19	7	237.5	248.0	282.0	161.0
	20	7	227.9	253.0	279.0	86.1
	21	7	240.9	247.0	281.0	182.8
	22	7	240.8	249.0	280.0	182.1
	23	7	240.6	248.0	282.0	177.8
	24	7	227.0	247.0	280.0	86.2
	25	7	241.5	249.0	282.0	182.3
	26	7	240.5	247.0	280.0	182.0
	28	7	249.9	267.0	278.0	215.0
	29	7	248.9	263.0	277.0	214.0
	30	7	242.2	257.0	281.0	188.4
	31	7	241.0	248.0	280.0	182.0
	32	6	246.4	248.6	277.0	214.0
	33	7	247.4	259.0	275.0	213.0
	34	7	256.7	260.0	277.0	233.2
	35	7	252.4	257.8	273.0	226.3
	36	7	254.7	259.0	277.0	229.0
	101	7	240.6	249.0	280.0	183.7
	102	7	249.4	262.0	274.0	211.0
	103	7	240.1	246.0	280.0	186.6

Parameter	Site	N	Mean	Median	Max	Min
pH	1	7	8.1	8.0	8.7	7.3
	2	7	7.9	7.7	8.6	7.4
	3	7	7.9	7.8	8.6	7.3
	4	7	8.2	8.1	8.8	7.5
	5	7	8.1	8.3	8.9	7.5
	6	7	8.0	8.0	8.8	7.4
	7	7	8.0	7.9	8.9	7.5
	8	7	8.0	7.9	8.8	7.6
	9	7	7.7	7.6	8.4	7.1
	10	7	7.9	7.8	8.5	7.6
	11	7	8.0	7.9	8.5	7.6
	12	7	7.8	7.7	8.7	7.3
	13	7	7.7	7.6	8.6	7.3
	14	7	7.8	7.6	8.7	7.3
	15	7	7.9	7.8	8.8	7.5
	16	7	7.7	7.7	8.6	7.2
	17	7	7.8	7.7	8.6	7.3
	18	7	7.8	7.7	8.6	7.3
	19	7	7.8	7.7	8.4	7.3
	20	7	7.8	7.7	8.5	7.3
	21	7	7.7	7.7	8.4	7.1
	22	7	7.7	7.7	8.4	7.2
	23	7	7.6	7.7	8.2	7.2
	24	7	7.6	7.5	8.2	7.4
	25	7	7.6	7.6	8.0	7.2
	26	7	7.6	7.6	7.9	7.2
	28	7	8.3	8.5	8.7	7.8
	29	7	8.4	8.5	8.8	7.8
	30	7	7.9	7.8	8.7	7.2
	31	7	7.6	7.4	8.2	7.1
	32	6	8.4	8.5	8.8	7.9
	33	7	8.6	8.8	8.9	7.9
	34	7	8.7	8.8	8.9	8.2
	35	7	8.7	8.9	9.1	8.0
	36	7	8.6	8.8	8.9	8.0
	101	7	8.0	8.0	8.8	7.3
	102	7	8.4	8.6	8.8	7.7
	103	7	7.6	7.4	8.1	7.0

Parameter	Site	N	Mean	Median	Max	Min
Whole Water Turbidity (NTU)	1	7	7.2	4.8	19.6	2.7
	2	7	6.4	4.2	15.3	3.2
	3	7	7.9	5.3	18.6	3.6
	4	7	7.0	4.2	17.2	2.3
	5	7	7.5	6.5	17.0	2.7
	6	7	6.9	6.7	12.6	3.5
	7	7	7.6	7.3	13.2	3.0
	8	7	7.9	5.5	15.8	4.2
	9	7	6.5	7.1	9.3	3.3
	10	7	5.5	6.1	8.1	3.2
	11	7	6.0	7.5	11.4	2.3
	12	7	7.7	8.0	12.1	2.6
	13	7	6.4	6.6	12.9	2.6
	14	7	6.7	6.3	11.5	2.5
	15	6	5.9	4.6	10.1	3.1
	16	7	6.7	5.2	10.8	2.5
	17	7	7.9	7.0	12.4	3.6
	18	7	7.6	7.0	15.2	2.6
	19	7	7.4	5.5	14.2	3.4
	20	7	7.1	6.6	15.2	3.4
	21	7	7.0	5.4	12.1	4.3
	22	7	8.0	5.6	16.0	4.1
	23	7	7.9	5.6	16.5	3.0
	24	7	7.7	6.5	15.3	3.8
	25	7	7.6	7.6	12.8	4.3
	26	7	8.4	5.5	18.2	3.8
	28	7	5.7	3.5	14.4	2.5
	29	7	6.5	4.2	18.6	3.3
	30	7	7.2	7.3	14.4	3.2
	31	7	7.6	8.5	13.1	3.4
	32	6	5.9	4.7	12.1	2.8
	33	7	6.6	5.3	18.4	2.6
	34	7	6.1	3.9	19.1	2.3
	35	7	6.6	4.5	17.5	2.3
	36	7	6.6	3.5	23.7	2.6
	101	7	7.9	6.8	15.4	1.8
	102	7	4.9	3.7	12.1	1.7
	103	7	7.5	6.3	17.0	1.8

Parameter	Site	N	Mean	Median	Max	Min
Filtrate Turbidity (NTU)	1	7	1.4	0.4	3.5	0.2
	2	7	1.2	0.6	3.5	0.3
	3	7	1.6	0.7	5.1	0.3
	4	7	1.4	0.8	4.6	0.3
	5	7	1.4	0.5	4.8	0.3
	6	7	1.7	0.4	5.8	0.3
	7	7	1.4	0.5	5.1	0.2
	8	7	1.5	0.5	4.9	0.2
	9	7	1.4	0.5	4.4	0.2
	10	7	0.9	0.5	2.4	0.3
	11	7	1.3	0.4	5.3	0.2
	12	7	1.7	0.4	6.6	0.3
	13	7	1.4	0.5	5.0	0.2
	14	7	1.5	0.4	4.9	0.3
	15	7	0.9	0.4	2.4	0.2
	16	7	1.8	0.5	6.5	0.3
	17	7	1.6	0.5	6.4	0.3
	18	7	1.9	0.5	7.6	0.2
	19	7	1.9	0.7	6.5	0.3
	20	7	1.9	0.5	7.6	0.3
	21	7	2.1	0.6	8.2	0.2
	22	7	1.8	0.4	7.4	0.3
	23	7	2.1	0.6	9.3	0.3
	24	7	1.9	0.8	7.3	0.3
	25	7	1.8	0.5	7.4	0.3
	26	7	1.9	0.4	8.0	0.3
	28	7	0.8	0.9	1.5	0.2
	29	7	0.7	0.4	2.0	0.2
	30	7	1.5	0.6	4.7	0.2
	31	7	1.8	0.5	6.9	0.3
	32	6	0.5	0.5	1.2	0.2
	33	7	0.7	0.5	1.3	0.3
	34	7	0.4	0.3	1.0	0.2
	35	7	0.5	0.4	0.9	0.2
	36	7	0.5	0.3	1.4	0.2
	101	7	2.1	0.6	7.8	0.3
	102	7	0.5	0.4	1.0	0.2
	103	7	2.0	0.7	7.6	0.3

Parameter	Site	N	Mean	Median	Max	Min
Total Chlorophyll (µg/L)	1	7	18.8	16.4	26.7	13.8
	2	7	19.9	18.3	27.3	14.0
	3	7	19.1	16.5	32.3	8.5
	4	7	17.9	18.5	26.3	11.0
	5	7	22.4	19.8	38.9	13.6
	6	7	22.4	18.4	45.3	10.6
	7	7	21.3	16.3	32.0	10.6
	8	7	22.3	21.4	35.6	13.4
	9	7	20.1	19.9	28.8	10.3
	10	7	25.2	21.8	52.8	14.7
	11	7	22.4	20.7	32.4	17.3
	12	7	24.5	20.5	59.0	10.3
	13	7	20.8	15.1	44.5	12.4
	14	7	26.5	19.9	61.9	11.4
	15	7	24.7	21.5	46.2	10.9
	16	7	24.7	16.7	52.9	9.5
	17	7	24.1	15.8	65.4	10.0
	18	7	23.3	16.9	62.0	8.3
	19	7	25.5	19.4	69.9	5.9
	20	7	25.4	24.1	47.4	7.6
	21	7	24.3	24.3	51.9	6.6
	22	7	24.6	24.2	57.7	5.9
	23	7	29.4	24.9	65.1	9.4
	24	7	27.0	29.0	61.8	5.5
	25	7	28.3	31.7	56.8	8.1
	26	7	22.4	24.4	42.6	4.7
	28	7	28.7	26.1	47.2	19.0
	29	7	30.1	26.9	50.1	19.6
	30	7	22.4	22.1	34.5	12.5
	31	7	21.8	21.7	42.5	4.4
	32	6	24.2	19.5	40.2	16.5
	33	7	43.3	23.6	116.0	14.3
	34	7	25.7	19.3	60.3	10.6
	35	7	34.3	28.7	71.2	16.6
	36	7	24.5	22.4	40.4	17.7
	101	7	24.4	22.4	39.8	7.9
	102	7	24.5	22.1	33.2	18.3
	103	7	22.4	19.9	54.7	3.4

Parameter	Site	N	Mean	Median	Max	Min
Total Suspended Solids (mg/L)	1	6	6.6	5.9	10.8	3.5
	2	6	6.0	5.7	8.7	4.6
	3	6	5.7	5.8	7.4	3.0
	4	6	5.6	6.1	6.9	2.3
	5	6	6.7	6.4	10.7	3.7
	6	6	6.5	7.0	8.6	3.3
	7	6	6.3	6.8	10.0	2.3
	8	6	7.0	7.0	7.8	6.5
	9	6	5.7	5.7	7.0	4.7
	10	7	5.7	5.7	8.0	2.8
	11	7	6.6	6.8	9.3	5.3
	12	7	6.1	6.7	9.2	3.6
	13	7	5.7	5.8	7.2	4.1
	14	7	5.9	5.6	8.7	4.0
	15	7	6.0	5.9	8.3	4.3
	16	7	6.7	7.1	8.6	4.0
	17	7	6.1	6.2	8.9	3.9
	18	7	6.1	5.5	8.3	4.2
	19	7	6.3	6.4	8.8	3.8
	20	7	6.1	6.8	7.5	3.1
	21	7	6.2	6.7	7.7	4.2
	22	7	6.8	7.3	8.3	4.3
	23	7	7.3	7.3	9.1	5.2
	24	7	6.7	6.4	9.9	3.2
	25	7	7.4	7.6	9.8	5.2
	26	7	6.1	6.0	8.0	3.8
	28	6	6.0	6.6	7.4	3.3
	29	7	6.7	6.6	9.1	4.4
	30	6	6.9	7.1	9.3	5.1
	31	7	6.4	6.4	8.3	4.1
	32	6	6.3	6.7	8.0	4.1
	33	7	8.2	7.3	14.5	4.2
	34	7	6.7	6.4	9.0	5.2
	35	7	8.3	7.8	12.0	4.9
	36	7	6.8	6.7	9.2	4.8
	101	6	6.9	7.5	9.7	3.0
	102	7	6.2	6.1	9.3	2.8
	103	7	6.8	7.8	9.6	3.2

Parameter	Site	N	Mean	Median	Max	Min
Non-Volatile Suspended Solids (mg/L)	1	7	3.3	2.3	6.0	1.5
	2	7	3.2	3.0	6.0	1.8
	3	7	3.2	3.2	5.6	1.6
	4	7	2.7	2.5	4.3	1.1
	5	7	3.1	3.1	4.5	1.2
	6	7	3.2	3.2	5.5	0.9
	7	7	3.0	2.8	5.0	0.2
	8	7	3.8	4.3	4.6	2.4
	9	7	3.2	3.2	4.1	2.1
	10	7	2.8	2.6	4.3	0.5
	11	7	3.4	3.9	5.3	1.4
	12	7	3.5	3.2	5.0	2.4
	13	7	3.4	2.8	5.2	2.3
	14	7	3.2	3.2	4.2	2.0
	15	7	3.0	2.4	5.2	1.9
	16	7	3.8	3.7	5.5	2.2
	17	7	3.7	3.8	6.1	2.1
	18	7	3.7	3.3	6.2	2.6
	19	7	3.8	3.9	5.7	2.3
	20	7	3.6	3.6	5.4	1.7
	21	7	4.0	3.7	5.7	2.7
	22	7	4.3	3.7	7.0	2.7
	23	7	4.4	3.7	7.2	3.2
	24	7	4.2	3.6	6.6	1.8
	25	7	4.7	4.7	6.4	3.4
	26	7	3.9	3.6	6.4	2.2
	28	7	2.3	2.1	3.9	0.3
	29	7	2.8	2.7	4.2	1.3
	30	7	3.6	3.4	6.4	1.6
	31	7	4.3	3.9	6.1	2.7
	32	6	2.6	2.6	4.3	0.9
	33	7	2.9	2.5	4.5	0.9
	34	7	2.4	2.3	3.9	1.2
	35	7	3.3	3.0	6.6	0.9
	36	7	2.6	2.3	5.0	1.1
	101	7	3.4	3.3	6.2	0.0
	102	7	2.6	2.3	4.7	0.2
	103	7	4.6	4.3	7.9	1.5

Parameter	Site	N	Mean	Median	Max	Min
Volatile Suspended Solids (mg/L)	1	6	3.1	2.9	5.1	2.0
	2	6	2.9	2.6	4.5	1.9
	3	6	2.6	2.0	4.7	1.3
	4	6	2.7	3.0	3.7	1.2
	5	6	3.5	3.1	6.2	2.2
	6	6	3.1	2.5	5.4	1.9
	7	6	3.2	3.2	5.0	1.7
	8	6	3.2	3.2	4.8	2.0
	9	6	2.6	2.5	4.1	1.4
	10	7	2.9	2.5	5.6	2.0
	11	7	3.2	3.1	4.0	2.3
	12	7	2.6	2.1	6.0	1.0
	13	7	2.3	2.0	4.4	1.3
	14	7	2.7	2.3	5.5	1.4
	15	7	3.0	3.2	4.5	1.9
	16	7	2.8	2.6	4.9	1.6
	17	7	2.4	1.8	5.0	1.6
	18	7	2.4	2.1	4.5	1.5
	19	7	2.5	2.2	4.9	1.5
	20	7	2.6	2.4	3.9	1.4
	21	7	2.1	2.1	3.5	1.2
	22	7	2.5	2.3	4.2	1.3
	23	7	2.9	2.9	4.4	1.8
	24	7	2.5	2.2	4.3	1.4
	25	7	2.8	2.7	4.2	1.6
	26	7	2.2	2.0	3.6	1.3
	28	6	3.6	3.7	4.2	3.0
	29	7	3.9	4.0	4.9	2.6
	30	6	3.2	3.2	3.6	2.6
	31	7	2.1	2.1	3.5	1.3
	32	6	3.8	3.7	4.8	3.1
	33	7	5.3	4.8	10.1	3.3
	34	7	4.3	4.0	6.7	2.5
	35	7	5.0	4.8	7.3	3.7
	36	7	4.2	4.1	5.0	3.3
	101	6	3.2	3.0	4.8	1.5
	102	7	3.6	3.6	4.7	2.6
	103	7	2.2	1.7	4.2	1.3

Parameter	Site	N	Mean	Median	Max	Min
Total Nitrogen (µg/L)	1	7	728.6	660.0	1020.0	520.0
	2	7	774.3	820.0	1070.0	550.0
	3	7	790.0	800.0	990.0	570.0
	4	7	735.7	770.0	890.0	520.0
	5	7	817.1	820.0	1030.0	580.0
	6	7	821.4	730.0	1050.0	670.0
	7	7	801.4	760.0	1000.0	550.0
	8	7	807.1	830.0	1030.0	540.0
	9	7	815.7	810.0	1010.0	540.0
	10	7	765.7	830.0	930.0	500.0
	11	7	821.4	820.0	1110.0	480.0
	12	7	854.3	940.0	1040.0	600.0
	13	7	831.4	760.0	1070.0	510.0
	14	7	861.4	910.0	1110.0	510.0
	15	6	886.7	900.0	1060.0	620.0
	16	7	858.6	820.0	1210.0	550.0
	17	7	834.3	880.0	1040.0	590.0
	18	7	830.0	830.0	1020.0	580.0
	19	7	845.7	820.0	1070.0	620.0
	20	7	884.3	820.0	1100.0	710.0
	21	7	828.6	790.0	1000.0	600.0
	22	7	841.4	830.0	1030.0	690.0
	23	7	848.6	840.0	1000.0	670.0
	24	7	880.0	940.0	960.0	700.0
	25	7	882.9	840.0	1110.0	730.0
	26	7	830.0	830.0	1060.0	620.0
	28	7	648.6	630.0	870.0	500.0
	29	7	688.6	690.0	900.0	540.0
	30	7	834.3	750.0	1070.0	560.0
	31	7	825.7	820.0	960.0	700.0
	32	6	635.0	650.0	810.0	470.0
	33	7	762.9	650.0	1220.0	570.0
	34	7	628.6	600.0	910.0	440.0
	35	7	715.7	650.0	960.0	590.0
	36	7	622.9	620.0	730.0	560.0
	101	7	825.7	810.0	1040.0	640.0
	102	7	604.3	580.0	800.0	510.0
	103	7	805.7	810.0	940.0	590.0

Parameter	Site	N	Mean	Median	Max	Min
Dissolved Nitrogen (µg/L)	1	7	512.9	520.0	780.0	300.0
	2	7	561.4	590.0	810.0	300.0
	3	7	541.4	500.0	790.0	310.0
	4	7	500.0	480.0	690.0	290.0
	5	7	567.1	570.0	910.0	330.0
	6	7	547.1	520.0	860.0	270.0
	7	7	564.3	590.0	880.0	280.0
	8	7	531.4	580.0	860.0	290.0
	9	7	538.6	520.0	790.0	320.0
	10	7	470.0	510.0	740.0	290.0
	11	7	515.7	560.0	850.0	290.0
	12	7	564.3	540.0	940.0	330.0
	13	7	578.6	550.0	930.0	320.0
	14	7	557.1	550.0	860.0	320.0
	15	7	505.7	590.0	640.0	330.0
	16	7	575.7	560.0	910.0	370.0
	17	7	600.0	570.0	960.0	350.0
	18	7	587.1	530.0	940.0	340.0
	19	7	600.0	590.0	930.0	390.0
	20	7	571.4	510.0	950.0	310.0
	21	7	582.9	510.0	940.0	330.0
	22	7	592.9	560.0	940.0	360.0
	23	7	592.9	560.0	910.0	400.0
	24	7	611.4	510.0	930.0	400.0
	25	7	600.0	480.0	970.0	400.0
	26	7	578.6	510.0	950.0	360.0
	28	7	364.3	380.0	460.0	260.0
	29	7	387.1	340.0	520.0	300.0
	30	7	544.3	500.0	840.0	290.0
	31	7	621.4	530.0	910.0	330.0
	32	6	370.0	325.0	540.0	260.0
	33	7	428.6	380.0	650.0	310.0
	34	7	337.1	320.0	500.0	280.0
	35	7	390.0	360.0	500.0	330.0
	36	7	364.3	330.0	520.0	290.0
	101	7	582.9	590.0	940.0	290.0
	102	7	391.4	390.0	500.0	320.0
	103	7	564.3	500.0	830.0	360.0

Parameter	Site	N	Mean	Median	Max	Min
Total Phosphorus (µg/L)	1	7	62.1	61.7	110.4	37.2
	2	7	64.5	51.0	109.1	46.5
	3	7	66.3	57.4	104.6	49.9
	4	7	61.2	55.6	105.8	39.7
	5	7	72.4	72.1	106.7	44.8
	6	7	70.0	66.8	115.1	43.7
	7	7	70.3	69.2	111.5	42.8
	8	7	69.3	72.9	93.1	44.5
	9	7	66.3	64.9	84.7	48.2
	10	7	62.2	59.2	80.3	45.6
	11	7	62.3	65.0	82.2	37.2
	12	7	79.6	77.2	115.2	60.6
	13	7	74.3	73.5	114.7	45.0
	14	7	73.9	72.7	98.3	50.2
	15	6	69.3	71.1	76.6	60.3
	16	7	78.5	81.3	107.5	52.6
	17	7	78.9	73.0	118.6	60.3
	18	7	77.4	70.5	117.8	60.9
	19	7	82.4	78.7	125.0	64.8
	20	7	83.9	73.0	115.0	53.4
	21	7	80.7	74.8	115.6	54.1
	22	7	80.8	75.6	117.0	59.9
	23	7	85.3	78.3	126.2	64.0
	24	7	82.8	76.5	116.1	60.8
	25	7	86.0	81.9	117.7	59.3
	26	7	79.8	77.8	112.3	56.3
	28	7	47.0	44.7	63.7	32.4
	29	7	48.6	48.2	61.1	32.6
	30	7	71.7	70.1	115.5	38.2
	31	7	81.0	78.5	113.0	51.6
	32	6	45.1	44.0	58.9	29.9
	33	7	58.6	56.6	90.9	38.1
	34	7	40.1	34.7	73.7	25.2
	35	7	50.8	49.1	69.5	39.2
	36	7	40.3	39.5	48.6	35.0
	101	7	75.2	69.2	121.6	43.3
	102	7	44.7	44.0	57.6	33.4
	103	7	79.1	76.2	115.8	59.8

Parameter	Site	N	Mean	Median	Max	Min
Dissolved Phosphorus (µg/L)	1	7	36.5	36.4	79.4	9.4
	2	7	36.3	35.2	74.7	10.9
	3	7	38.0	43.5	78.1	12.0
	4	7	35.9	41.6	75.5	9.0
	5	7	43.1	47.2	80.7	14.2
	6	7	42.2	43.5	81.7	10.2
	7	7	41.7	44.1	79.3	10.0
	8	7	39.3	42.8	61.6	11.7
	9	7	35.8	41.7	58.7	8.1
	10	7	28.9	25.6	49.1	7.0
	11	7	32.1	39.9	46.4	7.8
	12	7	46.4	44.6	85.5	16.7
	13	7	45.3	46.1	83.7	12.2
	14	7	39.0	42.9	69.7	8.4
	15	7	29.2	31.6	46.1	7.2
	16	7	43.6	44.1	77.7	12.9
	17	7	47.8	44.9	86.9	19.3
	18	7	47.2	43.8	85.5	16.6
	19	7	50.0	43.3	90.1	17.1
	20	7	44.7	41.8	84.0	12.2
	21	7	49.9	46.0	90.2	15.6
	22	7	48.0	45.8	87.2	17.9
	23	7	47.5	45.8	87.8	16.6
	24	7	47.7	46.2	86.2	17.7
	25	7	48.2	45.3	85.9	17.3
	26	7	48.1	46.2	88.7	17.4
	28	7	15.1	16.3	28.3	7.6
	29	7	16.2	17.0	32.5	7.5
	30	7	41.8	45.7	78.4	9.4
	31	7	50.7	47.1	86.8	15.5
	32	6	14.5	12.5	30.5	7.2
	33	7	21.3	16.4	48.7	9.0
	34	7	10.5	9.2	15.0	6.0
	35	7	14.9	11.2	36.6	9.5
	36	7	10.2	8.8	16.1	7.4
	101	7	45.5	44.1	87.2	10.0
	102	7	16.1	10.1	32.4	8.4
	103	7	46.7	52.5	84.7	16.4

Parameter	Site	N	Mean	Median	Max	Min
Chloride Ions (mg/L)	1	7	5.7	6.8	7.9	3.3
	2	7	5.7	6.8	7.7	3.5
	3	7	5.7	6.8	7.7	3.3
	4	7	5.8	6.7	8.0	3.3
	5	7	5.7	6.5	7.9	3.3
	6	7	5.6	6.6	7.6	3.3
	7	7	5.6	6.6	7.6	3.4
	8	7	5.7	6.5	8.0	3.4
	9	7	5.8	6.7	7.9	3.5
	10	7	5.9	6.8	8.7	3.4
	11	7	5.7	6.6	7.8	3.4
	12	7	5.6	6.5	7.6	3.2
	13	7	5.6	6.3	7.8	3.3
	14	7	5.7	6.8	7.7	3.3
	15	7	5.9	6.9	8.2	3.6
	16	7	5.6	6.5	7.6	3.2
	17	7	5.6	6.2	7.6	3.2
	18	7	5.6	6.4	7.6	3.2
	19	7	5.7	6.4	7.6	3.1
	20	7	5.9	6.6	8.2	3.2
	21	7	5.7	6.4	8.0	3.1
	22	7	5.7	6.2	8.0	3.1
	23	7	5.7	6.3	8.2	3.1
	24	7	5.7	6.3	8.1	3.1
	25	7	5.8	6.5	8.3	3.1
	26	7	5.7	6.5	7.7	3.1
	28	7	6.3	7.3	8.9	3.6
	29	7	6.1	7.2	8.5	3.3
	30	7	5.7	6.5	7.8	3.3
	31	7	5.7	6.4	7.7	3.1
	32	6	5.8	6.1	7.5	3.4
	33	7	6.2	7.2	8.4	3.5
	34	7	6.4	7.2	7.6	4.1
	35	7	6.4	7.2	8.1	3.9
	36	7	6.4	7.0	8.2	3.9
	101	7	5.6	6.8	7.7	3.2
	102	7	6.2	7.2	8.1	3.4
	103	7	5.7	6.4	8.2	3.2

Parameter	Site	N	Mean	Median	Max	Min
Fecal Coliform (CFU/100 mL)	1	6	6.2	6.0	43.8	1.0
	2	6	12.3	27.0	60.5	0.0
	3	6	15.6	21.8	34.0	5.0
	4	6	14.8	11.7	48.3	6.7
	5	6	9.0	28.3	166.7	0.0
	6	6	4.2	16.6	50.0	0.0
	7	6	12.5	33.3	283.3	0.0
	8	6	6.8	9.1	21.0	1.6
	9	5	11.3	40.0	113.3	0.0
	10	6	24.5	31.0	95.0	2.3
	11	5	8.5	5.6	36.7	3.1
	12	6	7.1	3.6	45.0	2.8
	13	6	10.0	18.3	83.3	0.0
	14	6	9.0	10.6	14.7	3.2
	15	5	18.6	48.9	200.0	0.0
	16	6	28.2	45.6	1070.0	0.0
	17	6	14.6	16.5	45.0	3.3
	18	6	21.7	21.0	101.7	10.0
	19	6	22.0	35.5	256.7	1.0
	20	6	42.9	60.7	306.7	2.8
	21	6	13.8	14.9	343.3	0.9
	22	6	7.6	14.3	75.0	0.0
	23	6	23.3	19.7	103.3	10.0
	24	6	17.1	56.7	193.3	0.0
	25	6	26.0	35.5	145.0	3.6
	26	6	5.8	8.4	50.0	0.0
	28	5	1.1	3.0	7.8	0.0
	29	6	1.3	3.1	8.3	0.0
	30	5	20.0	45.0	160.0	1.7
	31	6	8.1	22.4	421.7	0.0
	32	4	0.8	3.0	6.7	0.0
	33	6	1.2	2.9	10.0	0.0
	34	6	5.2	5.0	13.3	1.7
	35	6	0.7	0.5	20.0	0.0
	36	6	0.8	1.7	7.5	0.0
	101	6	5.4	3.1	85.0	1.0
	102	6	1.2	1.2	47.2	0.0
	103	6	2.0	1.8	31.0	0.0

Parameter	Site	N	Mean	Median	Max	Min
Fecal coliform (CFU/100 mL)	1	6	6.2	6.0	43.8	1.0
including August 20	2	7	21.8	33.3	660.0	0.0
	3	7	26.7	23.5	660.0	5.0
	4	7	25.6	13.3	673.3	6.7
	5	6	9.0	28.3	166.7	0.0
	6	6	4.2	16.6	50.0	0.0
	7	7	23.9	60.0	1146.7	0.0
	8	6	6.8	9.1	21.0	1.6
	9	6	25.7	67.5	1560.0	0.0
	10	7	40.8	40.0	880.0	2.3
	11	6	12.8	12.2	103.3	3.1
	12	7	10.8	3.6	126.7	2.8
	13	7	14.0	20.0	106.7	0.0
	14	6	9.0	10.6	14.7	3.2
	15	5	18.6	48.9	200.0	0.0
	16	7	58.9	57.8	4880.0	0.0
	17	7	26.2	20.0	860.0	3.3
	18	7	35.8	22.0	720.0	10.0
	19	7	38.1	51.0	1040.0	1.0
	20	7	54.4	90.5	306.7	2.8
	21	7	17.7	21.3	343.3	0.9
	22	7	12.3	15.3	220.0	0.0
	23	7	41.6	22.3	1350.0	10.0
	24	6	17.1	56.7	193.3	0.0
	25	7	42.1	47.6	760.0	3.6
	26	7	9.7	11.9	210.0	0.0
	28	6	1.5	4.8	7.8	0.0
	29	7	1.7	3.8	8.3	0.0
	30	6	43.6	55.0	2140.0	1.7
	31	7	12.2	40.0	421.7	0.0
	32	5	2.9	6.0	500.0	0.0
	33	7	0.9	2.5	10.0	0.0
	34	7	5.7	6.7	13.3	1.7
	35	7	1.1	1.0	20.0	0.0
	36	7	1.3	3.3	45.0	0.0
	101	7	8.5	3.3	126.7	1.0
	102	7	0.8	0.0	47.2	0.0
	103	7	3.2	2.0	45.0	0.0

Parameter	Site	N	Mean	Median	Max	Min
E. coli (CFU/100 mL)	1	7	1.8	2.5	10.5	0.0
including August 20	2	7	4.7	4.8	13.3	2.4
	3	7	3.9	3.6	13.3	1.3
	4	7	3.7	3.5	14.0	0.5
	5	7	6.4	4.4	25.3	1.6
	6	7	3.0	3.3	17.5	0.0
	7	7	3.1	6.5	31.4	0.0
	8	7	2.9	4.4	30.3	0.0
	9	7	7.0	7.6	221.7	0.0
	10	7	12.8	18.4	33.3	3.6
	11	7	1.5	2.0	6.0	0.0
	12	7	7.0	6.7	20.0	1.6
	13	7	8.7	6.7	56.3	4.4
	14	7	6.8	7.0	100.0	0.5
	15	7	13.0	14.0	36.3	4.0
	16	7	38.9	24.8	240.0	6.5
	17	7	10.7	13.0	18.0	5.6
	18	7	16.1	18.3	33.3	6.0
	19	7	8.2	8.5	18.0	3.2
	20	7	15.9	10.0	133.3	5.2
	21	7	4.5	7.2	23.5	0.0
	22	7	3.1	4.0	24.0	0.0
	23	7	22.8	15.0	380.0	3.8
	24	7	14.6	16.0	100.0	4.0
	25	7	20.1	25.3	53.2	6.0
	26	7	4.3	3.5	546.7	0.0
	28	7	1.5	1.3	7.0	0.0
	29	7	1.3	1.3	5.0	0.0
	30	7	7.4	6.7	133.3	2.0
	31	7	4.2	3.5	13.3	1.5
	32	6	1.9	2.1	4.8	0.4
	33	7	2.0	3.0	40.0	0.0
	34	7	2.8	5.2	8.5	0.0
	35	7	1.1	2.0	6.0	0.0
	36	7	2.5	3.2	36.7	0.0
	101	7	1.9	2.0	13.3	0.0
	102	7	0.8	1.2	5.0	0.0
	103	7	1.8	2.0	10.0	0.0

Appendix 5. Number and type of septic and discharge permits in coves, visible lagoons, fecal coliform and *E. coli* values exceeding standards, and number of *B. thetaiotaomicron* detections during May-August 2007 and 2008 holiday sampling. *SCAT=self contained advanced treatment system, UV=ultraviolet radiation, con=conventional septic, LPP=low pressure pipe system, DRIP=drip irrigation, UK=unknown, HOLD=holding tank, FILTR=filtration, CHLOR=chlorination, RECIRC=recirculation system, O2=aeration, SAND=sand filtration, LAND APP=land application, SLDG HAUL=sludge hauler, LAG=lagoon, SUBD=subdivision, RSRT=resort, STM=stream, SWIM=swimming pool, APT=apartments, STPK=state park.

Cove			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14/15**	**15**	**15/16**	**16**
% Urban			23	21	23	37	32	59	96	20	57	38	12	37	26	15		13
Housing Units			50	46	33	213	148	210	199	101	326	601	38	256	228	463		176
Septic Permits	Number permits									7			1		1	11	2	17
	Tank size (gal*10^2)									15-Oct			12.5		10	10-12.5	12.5	15-Oct
	pre-treatments	fixed film																
		SCAT											1			2	1	2
		MicroFast																2
		Ecopod																2
		UV																
	post-treatments	con																
		LPP								4						3	1	5
		DRIP											1				1	3
		Tank only								4					1	8		9
Discharge Permits	Number permits					0	1		0						1	1		
	People served					UK	0		UK						234	49		
	Facility type					LAG	QUARY		LAG						SUBD	RSRT		
	Tons sewage sludge					UK	NA		UK						5	0		
	Type of treatment	UK				1			1									
		None					1											
		septic														1		
		HOLD																
		FILTR																
		CHLOR													1			
		RECIRC														1		
		O2													1			
		UV																
		SAND														1		
		LAND APP																
		SLDG HAUL													1	1		
Indicator bacteria	*B. thetaiotaomicron*		5	1	2	1	1 (strong)	1	1		1	1 (weak)		1	1 (strong)	2		2
	E. coli 2007										222							200, 240
	E. coli 2008										170							137
	Fecal coliform 2007								1,147		1,560							1,070; 4,880
	Fecal coliform 2008																	

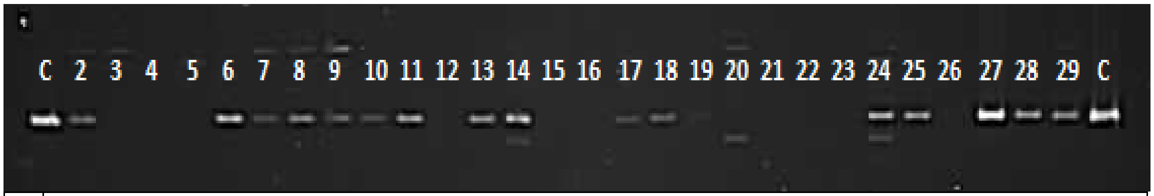
Appendix 5 continued.

Cove			17	17/18	18	18/19	19	20	21	23/24	24	25	26	28	29	30	33	36
% Urban			40		23		33	19	92	26	15	11	13	13	2	42	1	0
Housing Units			77		62		29	36	185	327	83	199	45	514	24	19	0	0
Septic Permits	Number permits		9	4	2	1	4	4				8	3					
	Tank size (gal*10^2)		15-Oct	10-12.5	10/12.5	10	20-Oct	15-Oct				10-12.5	10					
	pre-treatments	fixed film	1															
		SCAT					1	2										
		MicroFast		2								1						
		Ecopod																
		UV						1				1						
	post-treatments	con	1									5						
		LPP	2	1	1		3	1				3						
		DRIP		1				1										
		Tank only	6	2	1	1	1	1					1					
Discharge Permits	Number permits							3		1	3	3	2	0			1	
	People served							44		0 (STM)	525	236	18	UK			8	
	Facility type							SUBD		SUBD	SUBD/SWM	SUBD/APT	SUBD	LAG (3)			STPK	
	Tons sewage sludge							6		NA	11	2	1	UK			2	
	Type of treatment	UK												1				
		None								1								
		septic										2						
		HOLD						1				1						
		FILTR									1							
		CHLOR						3			3	2	1					
		RECIRC																
		O2						3			2	1	1				1 (ditch)	
		UV										1						
		SAND										2						
		LAND APP						1										
		SLDG HAUL						3			2	3	1				1	
Indicator bacteria	*B. thetaiotaomicron*		1 (strong)		1 (strong)		2 (1 strong)	1 (strong)	1	2	2	2	1	1 (strong)	1	3 (1 strong)	3	2 (1 strong)
	E. coli 2007							133		380			547			133		
	E. coli 2008									753	331							
	Fecal coliform 2007						1,040		1,087	1,350						2,140		
	Fecal coliform 2008									1,220								

Appendix 6. Total phosphorus, total nitrogen, chlorophyll, Secchi depth, and fecal coliform site means in 1981 and 1982. Notes: *sampled May-August, **sampled July-August, ***sampled May-June, n=7 samples for most values.

Reservoir Arm	Site	Dam	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll (µg/L)	Secchi Depth (m)	Fecal Coliform (CFU/100 mL)	Notes
Osage	103	43.2	39.8	647.1	12.2	1	0.7	*
	26	42.9	64.4	--	26.6	0.8	3.3	*
	25	42.4	25.3	--	15.6	1.6	--	**
	24	42	33.8	--	16.8	1.5	--	**
	23	42	71.2	604.5	19.9	0.9	124.8	*
	22	41.6	60.3	560	19.6	0.9	148.5	*
	21	40.6	23.3	--	13.6	1.8	--	**
	20	39.9	26	--	14.8	1.8	--	**
	19	37	27.3	--	13.5	1.5	--	**
	18	36.7	81.6	--	19	0.8	14.4	*
	17	36.4	28.5	--	15.8	1.6	--	**
	16	35.7	29.3	--	16.7	1.5	--	**
	15	33.8	26	--	14.7	1.7	--	**
	14	33.8	28	--	16.3	1.5	--	**
	13	32.7	28.3	--	15.9	1.5	--	**
	12	32.7	28.8	--	17.6	1.5	--	**
	11	31.7	46	564.6	17.8	1.1	2	*
	10	30.6	34	--	19.1	1.4	--	**
	9	30.6	56.7	579	19.9	0.9	25.5	*
	8	29.6	52.7	575	22.5	0.9	9	*
	101	29.3	41	478.3	13.3	1.1	1.8	*
	7	29	22.5	--	11.9	1.7	--	**
	6	28.7	54.2	581.8	18	1.1	47.5	*
	5	28.2	24.3	--	14.4	1.7	--	**
	30	27	39.4	571.7	13	1.1	3.3	*
	4	27	32.5	--	16	1.6	--	**
	3	24.1	33.3	--	14.6	1.4	--	**
	2	23.7	28.8	--	14.9	1.5	--	**
	1	22.5	23.3	--	11.5	1.7	--	**
Grand Glaize	29	2.7	31.9	--	17.4	1.8	--	***
	28	2.7	42.1	533.6	17.4	1.1	6.5	*
	102	2	29.5	575.7	14.6	1.4	0.9	*

Well	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Site	9	14	14D	15	16	17	17D	18	18D	19	19D	20	20D	21	25	101	1	5	5D	28	28D	26	23	3	7	33	24	12
Date	5/29																					6/11					6/25	



Well	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Site	2	4	33	36	36D	16	30	1	25	19	1	30	2902	36	15	10	103	24	102	33	1	23	25	1	3	30	30D	6
Date	6/25					7/9			7/23						8/3		8/6					8/20						

Appendix 7. Confirmation gels for *Bacteroides thetaiotaomicron* detections in Lake of the Ozarks during the 2007 sampling season. Each gel contains a positive *B. thetaiotaomicron* control in the first and last wells. Wells 2-29 contain sample DNA. Samples were run in duplicate (D). The dates of collection and sites for each respective well are listed in the tables below the gel. These samples were rerun several times; however, for many samples with weak signals, *B. thetaiotaomicron* was detected in only ½ to ¾ of the reruns.

Appendix 8. Discharge, rain, wind speed, midnight lake level, and traffic (incoming and outgoing) during 2007 and 2008.

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
1/1/07	1440	---	---	658.23	---	---
1/2/07	1460	---	---	658.21	---	---
1/3/07	1480	---	---	658.18	---	---
1/4/07	1180	---	---	658.18	---	---
1/5/07	532	---	---	658.17	---	---
1/6/07	521	---	---	658.16	---	---
1/7/07	520	---	---	658.15	---	---
1/8/07	513	---	---	658.16	---	---
1/9/07	507	---	---	658.16	---	---
1/10/07	496	---	---	658.16	---	---
1/11/07	502	---	---	658.16	---	---
1/12/07	500	---	---	658.23	---	---
1/13/07	500	---	---	658.30	---	---
1/14/07	500	---	---	658.50	---	---
1/15/07	2130	---	---	658.85	---	---
1/16/07	12300	---	---	658.69	---	---
1/17/07	14900	---	---	658.45	---	---
1/18/07	11800	---	---	658.19	---	---
1/19/07	8280	---	---	658.00	---	---
1/20/07	1770	---	---	658.02	---	---
1/21/07	645	---	---	659.02	---	---
1/22/07	4080	---	---	660.02	---	---
1/23/07	6360	---	---	657.84	---	---
1/24/07	5370	---	---	657.77	---	---
1/25/07	6290	---	---	657.59	---	---
1/26/07	2500	---	---	657.53	---	---
1/27/07	1200	---	---	657.72	---	---
1/28/07	5100	---	---	657.57	---	---
1/29/07	7000	---	---	657.40	---	---
1/30/07	9350	---	---	657.14	---	---
1/31/07	8200	---	---	657.00	---	---
2/1/07	1040	---	---	657.06	---	---
2/2/07	3640	---	---	656.98	---	---
2/3/07	1750	---	---	656.99	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
2/4/07	1100	---	---	656.97	---	---
2/5/07	5800	---	---	656.90	---	---
2/6/07	866	---	---	657.04	---	---
2/7/07	3570	---	---	657.03	---	---
2/8/07	2700	---	---	657.04	---	---
2/9/07	4720	---	---	657.04	---	---
2/10/07	2420	---	---	657.02	---	---
2/11/07	2050	---	---	656.98	---	---
2/12/07	1800	---	---	657.10	---	---
2/13/07	6200	---	---	657.30	---	---
2/14/07	10500	---	---	657.19	---	---
2/15/07	22500	---	---	656.60	---	---
2/16/07	27800	---	---	655.95	---	---
2/17/07	21800	---	---	655.24	---	---
2/18/07	5900	---	---	655.06	---	---
2/19/07	12600	---	---	654.85	---	---
2/20/07	4400	---	---	654.95	---	---
2/21/07	6300	---	---	655.11	---	---
2/22/07	9500	---	---	655.15	---	---
2/23/07	14600	---	---	655.02	---	---
2/24/07	8910	---	---	654.88	---	---
2/25/07	2310	---	---	654.97	---	---
2/26/07	8830	---	---	655.26	---	---
2/27/07	11800	---	---	655.39	---	---
2/28/07	11200	---	---	655.60	---	---
3/1/07	13800	---	---	655.62	---	---
3/2/07	13100	---	---	655.67	---	---
3/3/07	15800	---	---	655.35	---	---
3/4/07	16400	---	---	654.92	---	---
3/5/07	14900	---	---	654.57	---	---
3/6/07	12700	---	---	654.27	---	---
3/7/07	1920	---	---	654.48	---	---
3/8/07	478	---	---	654.78	---	---
3/9/07	561	---	---	655.01	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
3/10/07	483	---	---	655.07	---	---
3/11/07	1110	---	---	655.10	---	---
3/12/07	4560	---	---	655.28	---	---
3/13/07	5730	---	---	655.17	---	---
3/14/07	1320	---	---	655.35	---	---
3/15/07	501	---	---	655.40	---	---
3/16/07	4350	---	---	655.50	---	---
3/17/07	963	---	---	655.51	---	---
3/18/07	1880	---	---	655.54	---	---
3/19/07	7510	---	---	655.43	---	---
3/20/07	6750	---	---	655.37	---	---
3/21/07	8710	---	---	655.40	---	---
3/22/07	1350	---	---	655.77	---	---
3/23/07	471	---	---	656.05	---	---
3/24/07	2310	---	---	656.15	---	---
3/25/07	1850	---	---	656.24	---	---
3/26/07	2680	---	---	656.35	---	---
3/27/07	4160	---	---	656.38	---	---
3/28/07	4180	---	---	656.36	---	---
3/29/07	4720	---	---	656.38	---	---
3/30/07	7120	---	---	656.40	---	---
3/31/07	2420	---	---	656.60	---	---
4/1/07	707	---	---	656.80	---	---
4/2/07	4720	---	---	656.88	---	---
4/3/07	16100	---	---	656.63	---	---
4/4/07	18100	---	---	656.32	---	---
4/5/07	13100	---	---	656.28	---	---
4/6/07	8500	---	---	656.31	---	---
4/7/07	10500	---	---	656.46	---	---
4/8/07	526	---	---	656.82	---	---
4/9/07	9650	---	---	656.82	---	---
4/10/07	9950	---	---	656.70	---	---
4/11/07	11800	---	---	656.44	---	---
4/12/07	14900	---	---	656.09	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
4/13/07	17100	---	---	655.80	---	---
4/14/07	15200	---	---	656.50	---	---
4/15/07	4330	---	---	657.00	---	---
4/16/07	14400	---	---	657.46	---	---
4/17/07	23800	---	---	657.64	---	---
4/18/07	24600	---	---	657.80	---	---
4/19/07	24400	---	---	657.78	---	---
4/20/07	31800	---	---	657.50	---	---
4/21/07	33900	---	---	657.22	---	---
4/22/07	33400	---	---	656.80	---	---
4/23/07	34800	---	---	656.16	---	---
4/24/07	32400	---	---	655.93	---	---
4/25/07	12800	---	---	656.50	---	---
4/26/07	10700	---	---	657.17	---	---
4/27/07	10200	---	---	657.67	---	---
4/28/07	9970	---	---	658.38	---	---
4/29/07	11500	---	---	658.96	---	---
4/30/07	23600	---	---	658.96	---	---
5/1/07	24800	0.1	6.44	658.88	---	---
5/2/07	35700	0.85	4.83	659.10	---	---
5/3/07	37300	0	16.09	658.80	---	---
5/4/07	35800	0	9.66	658.46	---	---
5/5/07	29900	0	12.87	658.46	---	---
5/6/07	30100	0	14.48	658.40	7255	12775
5/7/07	34800	0	14.48	658.11	8857	9270
5/8/07	20000	0.525	0.00	657.68	9157	9017
5/9/07	5800	0.875	0.00	657.60	9475	9164
5/10/07	1850	1.55	3.22	657.68	10019	9434
5/11/07	1160	0	0.00	657.74	13888	11105
5/12/07	1010	0	0.00	657.74	9955	9174
5/13/07	1000	0	0.00	657.80	7735	11581
5/14/07	1070	0	6.44	657.82	9189	9151
5/15/07	927	3.025	9.66	658.15	9135	8662
5/16/07	1140	0	1.61	658.16	9894	9039

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
5/17/07	11400	0.15	1.61	658.29	10971	9767
5/18/07	31400	0	6.44	658.36	14873	11766
5/19/07	36600	0	4.83	658.53	10176	9066
5/20/07	36700	0	4.83	658.58	7127	13132
5/21/07	36700	0	9.66	658.76	9328	9530
5/22/07	36600	0	9.66	659.26	9317	9088
5/23/07	36600	0	9.66	659.58	9998	9343
5/24/07	36500	20.85	9.66	659.71	12207	9745
5/25/07	36600	6.425	8.05	659.70	20842	10455
5/26/07	36500	0.475	4.83	659.24	13335	8110
5/27/07	36500	3.6	9.66	659.14	7777	9957
5/28/07	35600	0	4.83	659.17	6276	20283
5/29/07	34800	0	3.22	659.20	9229	11335
5/30/07	34700	0	6.44	659.01	9322	9290
5/31/07	34600	0.125	4.83	658.90	10397	9441
6/1/07	34300	0	6.44	658.77	14054	10554
6/2/07	31900	58.575	9.66	658.82	9397	8585
6/3/07	31100	0	4.83	658.93	7780	11914
6/4/07	30700	0	8.05	659.22	9710	9815
6/5/07	29200	0	0.00	659.29	9311	9483
6/6/07	29500	0	1.61	659.45	9673	9299
6/7/07	31000	0	25.75	659.57	11400	9693
6/8/07	29600	0	17.70	659.75	15645	11035
6/9/07	31800	0	0.00	659.75	10233	9282
6/10/07	34100	7.075	6.44	659.73	7128	14182
6/11/07	34300	0	9.66	659.50	9464	9698
6/12/07	34200	0	8.05	659.48	9461	9570
6/13/07	34200	0	0.00	659.58	10139	9749
6/14/07	34200	0	4.83	659.54	11101	9847
6/15/07	33100	0	4.83	659.54	15955	11162
6/16/07	30700	0	0.00	659.46	10512	9551
6/17/07	32000	0	0.00	659.36	7867	14964
6/18/07	32500	44.275	12.87	659.41	9780	10095
6/19/07	26900	0	6.44	659.73	9692	9526

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
6/20/07	27700	2.4	4.83	659.88	10380	9820
6/21/07	32500	0	0.00	659.82	12154	10129
6/22/07	30300	0.225	4.83	659.92	16382	11203
6/23/07	27700	0.075	9.66	659.79	10651	9474
6/24/07	19200	0	0.00	659.63	8373	15774
6/25/07	12900	0	3.22	659.33	9935	10855
6/26/07	10800	0	9.66	659.00	9805	9925
6/27/07	4870	3.325	3.22	658.84	10126	10230
6/28/07	4540	1.975	1.61	658.85	10799	9947
6/29/07	16000	0	12.87	659.10	17664	10988
6/30/07	25500	10.925	6.44	659.51	11543	8739
7/1/07	30700	0.85	14.48	659.20	8531	13909
7/2/07	32600	0	9.66	658.91	10463	10576
7/3/07	39800	0	3.22	659.29	---	---
7/4/07	48900	0	3.22	659.50	---	---
7/5/07	49300	0	8.05	659.59	---	---
7/6/07	49400	0	0.00	659.68	15964	12333
7/7/07	49400	0	0.00	659.73	10542	11387
7/8/07	49300	0	0.00	659.68	8542	19147
7/9/07	49400	0	8.05	659.70	10054	10507
7/10/07	49400	0	8.05	659.78	10154	10006
7/11/07	49500	0	6.44	659.87	10718	10310
7/12/07	49500	0	0.00	659.95	12101	10679
7/13/07	49800	0	8.05	659.98	17431	11950
7/14/07	50900	0	0.00	659.99	11743	10175
7/15/07	50900	0	3.22	659.99	8621	16595
7/16/07	50700	0	3.22	660.01	10062	10554
7/17/07	50900	0	9.66	660.01	9988	10092
7/18/07	50900	0	6.44	660.00	10789	10508
7/19/07	50800	1	11.27	660.01	12479	10702
7/20/07	50200	0	0.00	660.04	17921	11830
7/21/07	50200	0	8.05	660.07	11879	10558
7/22/07	50400	0	6.44	660.10	9046	17322
7/23/07	50900	0	4.83	660.06	9890	10661

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
7/24/07	50800	0	0.00	659.98	9861	10049
7/25/07	49100	0	0.00	660.00	10799	10039
7/26/07	50900	0	0.00	659.97	12397	10794
7/27/07	50700	0	8.05	659.98	17222	11960
7/28/07	49800	0.475	6.44	660.00	11609	10423
7/29/07	49800	0	8.05	660.02	9034	16902
7/30/07	50100	0	9.66	660.02	10054	10806
7/31/07	49400	0	4.83	659.96	10160	10134
8/1/07	47500	0	3.22	659.76	10922	10355
8/2/07	42500	0	0.00	659.71	12065	10553
8/3/07	38300	0	0.00	659.73	17599	12036
8/4/07	36900	0	0.00	659.66	11700	10451
8/5/07	36800	0	8.05	659.55	9108	17374
8/6/07	34600	0	6.44	659.55	9850	11051
8/7/07	31600	0	11.27	659.6	9694	10074
8/8/07	34000	0	8.05	659.51	10285	10020
8/9/07	31800	0	6.44	659.36	11703	10647
8/10/07	32600	0	0.00	659.17	16335	11157
8/11/07	25600	0	6.44	658.87	10783	10225
8/12/07	24400	0	0.00	658.71	8275	16249
8/13/07	19300	0	17.70	658.71	9764	10647
8/14/07	16500	0	6.44	658.79	9493	9979
8/15/07	15300	0	0.00	658.60	10056	10130
8/16/07	13600	0	0.00	658.52	11147	9841
8/17/07	7330	0.075	0.00	658.61	16126	10764
8/18/07	3650	0	9.66	658.50	9907	9647
8/19/07	3610	0.2	8.05	658.36	6824	15116
8/20/07	3960	7.125	19.31	658.71	8510	9101
8/21/07	6450	0	12.87	659.00	8610	8572
8/22/07	8950	0	3.22	659.07	9160	8813
8/23/07	5470	0	4.83	659.19	10356	8972
8/24/07	2640	0	8.05	659.65	15739	9792
8/25/07	6300	---	---	659.45	9833	8518
8/26/07	6450	---	---	659.25	7056	14795

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
8/27/07	5560	0	12.87	659.25	8696	9675
8/28/07	9160	0	8.05	659.21	8835	8756
8/29/07	5960	0	0.00	659.40	9279	8836
8/30/07	2850	0	6.44	659.48	10810	9486
8/31/07	3310	0	9.66	659.43	20903	10543
9/1/07	---	---	---	---	13982	8373
9/2/07	---	---	---	---	8461	10283
9/3/07	---	---	---	---	7064	21717
9/4/07	---	---	---	---	9183	10093
9/5/07	---	---	---	---	8884	8823
9/6/07	---	---	---	---	9531	9152
9/7/07	---	---	---	---	13036	10086
9/8/07	---	---	---	---	8438	8000
9/9/07	---	---	---	---	7034	11034
9/10/07	---	---	---	---	8976	8943
9/11/07	---	---	---	---	9061	9149
9/12/07	---	---	---	---	9600	8957
9/13/07	---	---	---	---	10287	9655
9/14/07	---	---	---	---	13816	10831
9/15/07	---	---	---	---	9829	9210
9/16/07	---	---	---	---	7235	11995
9/17/07	---	---	---	---	9190	9112
9/18/07	---	---	---	---	8985	9020
9/19/07	---	---	---	---	9397	9190
9/20/07	---	---	---	---	10504	9533
9/21/07	---	---	---	---	14462	11141
9/22/07	---	---	---	---	9572	9056
9/23/07	---	---	---	---	7266	12130
9/24/07	---	---	---	---	9101	8957
9/25/07	---	---	---	---	9231	9060
9/26/07	---	---	---	---	9320	9011
9/27/07	---	---	---	---	10505	9428
9/28/07	---	---	---	---	15087	10741
9/29/07	---	---	---	---	9612	8511

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
9/30/07	---	---	---	---	7226	12763
1/1/08	1300	---	---	658.7	---	---
1/2/08	5860	---	---	658.6	---	---
1/3/08	2690	---	---	658.3	---	---
1/4/08	1560	---	---	658.3	---	---
1/5/08	1270	---	---	658.3	---	---
1/6/08	1070	---	---	658.3	---	---
1/7/08	1070	---	---	658.3	---	---
1/8/08	1120	---	---	658.3	---	---
1/9/08	2120	---	---	658.8	---	---
1/10/08	7200	---	---	659	---	---
1/11/08	9480	---	---	659.4	---	---
1/12/08	5100	---	---	659.7	---	---
1/13/08	4370	---	---	659.5	---	---
1/14/08	10000	---	---	659.4	---	---
1/15/08	9860	---	---	659.2	---	---
1/16/08	10400	---	---	659	---	---
1/17/08	12400	---	---	658.9	---	---
1/18/08	11100	---	---	658.6	---	---
1/19/08	8420	---	---	658.2	---	---
1/20/08	5540	---	---	657.9	---	---
1/21/08	11400	---	---	657.8	---	---
1/22/08	13500	---	---	657.5	---	---
1/23/08	14100	---	---	657	---	---
1/24/08	10300	---	---	656.6	---	---
1/25/08	15100	---	---	656.5	---	---
1/26/08	6620	---	---	656	---	---
1/27/08	1790	---	---	655.9	---	---
1/28/08	5590	---	---	656	---	---
1/29/08	4750	---	---	655.9	---	---
1/30/08	9180	---	---	655.9	---	---
1/31/08	8380	---	---	655.7	---	---
2/1/08	2980	---	---	655.7	---	---
2/2/08	3180	---	---	655.7	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
2/3/08	1420	---	---	655.6	---	---
2/4/08	2410	---	---	655.7	---	---
2/5/08	1430	---	---	655.6	---	---
2/6/08	5630	---	---	655.9	---	---
2/7/08	6990	---	---	656	---	---
2/8/08	6270	---	---	656.5	---	---
2/9/08	1940	---	---	656.6	---	---
2/10/08	5300	---	---	656.6	---	---
2/11/08	15600	---	---	656.3	---	---
2/12/08	16100	---	---	656.3	---	---
2/13/08	16500	---	---	656.1	---	---
2/14/08	13100	---	---	655.8	---	---
2/15/08	8420	---	---	655.7	---	---
2/16/08	3860	---	---	655.9	---	---
2/17/08	4270	---	---	656	---	---
2/18/08	13000	---	---	657.1	---	---
2/19/08	19800	---	---	657.3	---	---
2/20/08	20300	---	---	657.6	---	---
2/21/08	20300	---	---	657.7	---	---
2/22/08	25300	---	---	657.6	---	---
2/23/08	25300	---	---	657.3	---	---
2/24/08	25400	---	---	657	---	---
2/25/08	25800	---	---	656.5	---	---
2/26/08	26400	---	---	656.4	---	---
2/27/08	27100	---	---	656.4	---	---
2/28/08	27900	---	---	656.3	---	---
2/29/08	27800	---	---	656	---	---
3/1/08	27800	---	---	655.8	---	---
3/2/08	27700	---	---	655.5	---	---
3/3/08	19600	---	---	655.3	---	---
3/4/08	15400	---	---	656	---	---
3/5/08	14900	---	---	656.7	---	---
3/6/08	23600	---	---	657	---	---
3/7/08	23100	---	---	657	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
3/8/08	22900	---	---	657.1	---	---
3/9/08	22800	---	---	657.1	---	---
3/10/08	22700	---	---	657.2	---	---
3/11/08	22700	---	---	657.1	---	---
3/12/08	22800	---	---	657.1	---	---
3/13/08	22700	---	---	657.1	---	---
3/14/08	22800	---	---	657.1	---	---
3/15/08	22900	---	---	656.9	---	---
3/16/08	22700	---	---	657	---	---
3/17/08	22800	---	---	656.9	---	---
3/18/08	24300	---	---	656.6	---	---
3/19/08	26800	---	---	658.2	---	---
3/20/08	24900	---	---	659.6	---	---
3/21/08	24600	---	---	660	---	---
3/22/08	24400	---	---	659.6	---	---
3/23/08	28200	---	---	659.2	---	---
3/24/08	28200	---	---	658.7	---	---
3/25/08	28300	---	---	658.5	---	---
3/26/08	28300	---	---	658.6	---	---
3/27/08	28300	---	---	658.7	---	---
3/28/08	28400	---	---	658.8	---	---
3/29/08	28400	---	---	658.9	---	---
3/30/08	28800	---	---	659	---	---
3/31/08	28700	---	---	659.3	---	---
4/1/08	52100	---	---	660.7	---	---
4/2/08	47900	---	---	660.1	---	---
4/3/08	47400	---	---	659.2	---	---
4/4/08	47300	---	---	658.8	---	---
4/5/08	46500	---	---	658.4	---	---
4/6/08	46300	---	---	658.4	---	---
4/7/08	46400	---	---	658.4	---	---
4/8/08	42400	---	---	658.5	---	---
4/9/08	42500	---	---	658.5	---	---
4/10/08	44700	---	---	658.5	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
4/11/08	50400	---	---	659.9	---	---
4/12/08	20800	---	---	659.7	---	---
4/13/08	23300	---	---	659.4	---	---
4/14/08	27200	---	---	659.6	---	---
4/15/08	46600	---	---	659.5	---	---
4/16/08	49000	---	---	659.6	---	---
4/17/08	49100	---	---	659.6	---	---
4/18/08	49300	---	---	659.7	---	---
4/19/08	49100	---	---	659.9	---	---
4/20/08	49100	---	---	659.8	---	---
4/21/08	49100	---	---	659.8	---	---
4/22/08	49000	---	---	659.8	---	---
4/23/08	49100	---	---	659.8	---	---
4/24/08	49400	---	---	659.8	---	---
4/25/08	50100	---	---	660.1	---	---
4/26/08	49800	---	---	660.1	---	---
4/27/08	49100	---	---	659.8	---	---
4/28/08	49100	---	---	659.8	---	---
4/29/08	49000	---	---	659.7	---	---
4/30/08	48600	---	---	659.5	---	---
5/1/08	45300	0	25.75	659.4	---	---
5/2/08	45100	1.075	11.27	659.3	---	---
5/3/08	41300	0	16.09	659.2	---	---
5/4/08	37700	0	0.00	659	---	---
5/5/08	37700	0	0.00	659	---	---
5/6/08	29000	0.575	1.61	659	---	---
5/7/08	28700	4.15	14.48	659.1	---	---
5/8/08	36100	0.125	14.48	659.6	---	---
5/9/08	39600	0	1.61	659.6	---	---
5/10/08	39300	1.6	0.00	659.5	---	---
5/11/08	39800	0.05	28.97	659.6	---	---
5/12/08	39600	0	0.00	659.5	---	---
5/13/08	39800	0	12.87	659.6	---	---
5/14/08	39600	0	9.66	659.4	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
5/15/08	37300	1.3	4.83	659.4	---	---
5/16/08	39500	0	0.00	659.36	---	---
5/17/08	40300	0	9.66	659.32	---	---
5/18/08	40000	0	8.05	659.36	---	---
5/19/08	38400	0	4.83	659.35	---	---
5/20/08	37700	0	6.44	659.38	---	---
5/21/08	37400	0	0.00	659.34	---	---
5/22/08	34600	0.075	4.83	659.22	---	---
5/23/08	33300	0	9.66	659.19	---	---
5/24/08	26100	1.45	17.70	659.17	---	---
5/25/08	28600	1.85	6.44	659.36	---	---
5/26/08	33200	1.9	9.66	659.54	---	---
5/27/08	34200	0.275	6.44	659.74	---	---
5/28/08	37100	0	17.70	659.71	---	---
5/29/08	37100	0.25	11.27	659.64	---	---
5/30/08	37000	0	17.70	659.46	---	---
5/31/08	29000	0	3.22	659.39	---	---
6/1/08	29500	0	3.22	659.51	---	---
6/2/08	36400	0.35	0.00	659.42	---	---
6/3/08	36300	0	9.66	659.19	---	---
6/4/08	33300	2.8	14.48	659.13	---	---
6/5/08	34100	0	0.00	659.61	---	---
6/6/08	37100	0.325	22.53	659.59	---	---
6/7/08	32800	0	12.87	659.51	---	---
6/8/08	33800	0	11.27	659.53	---	---
6/9/08	33800	1.45	14.48	659.43	---	---
6/10/08	10100	0	9.66	659.11	---	---
6/11/08	4070	0	14.48	659.12	---	---
6/12/08	10500	0	22.53	659.31	---	---
6/13/08	14700	5.325	9.66	659.31	---	---
6/14/08	11800	0	1.61	659.57	---	---
6/15/08	14200	2.25	6.44	659.83	---	---
6/16/08	26000	0.375	8.05	659.88	---	---
6/17/08	18400	0	8.05	659.7	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
6/18/08	10200	0	1.61	659.46	---	---
6/19/08	11600	0	3.22	659.33	---	---
6/20/08	21900	0	0.00	659.17	---	---
6/21/08	30500	0.2	0.00	659.31	---	---
6/22/08	37300	0	0.00	659.04	---	---
6/23/08	37700	0	0.00	658.91	---	---
6/24/08	43500	0	0.00	658.85	---	---
6/25/08	46800	0	9.66	658.81	---	---
6/26/08	13500	0.825	9.66	658.83	---	---
6/27/08	20200	0.025	12.87	659.04	---	---
6/28/08	21200	2.475	11.27	658.75	---	---
6/29/08	20400	0	3.22	658.99	---	---
6/30/08	25700	0	8.05	658.86	---	---
7/1/08	21200	0	0.00	658.84	---	---
7/2/08	29300	0	9.66	658.71	---	---
7/3/08	32900	0.325	9.66	658.24	---	---
7/4/08	39100	0	4.83	659.12	---	---
7/5/08	36100	0	3.22	658.79	---	---
7/6/08	38600	0	1.61	658.69	---	---
7/7/08	42100	0	4.83	658.7	---	---
7/8/08	51200	1	9.66	658.9	---	---
7/9/08	51900	0.25	4.83	658.92	---	---
7/10/08	51900	0	3.22	658.98	---	---
7/11/08	49700	0	1.61	658.96	---	---
7/12/08	51500	0	12.87	658.93	---	---
7/13/08	51600	0	3.22	658.81	---	---
7/14/08	51200	0	0.00	658.73	---	---
7/15/08	50700	0	0.00	658.65	---	---
7/16/08	50600	0	0.00	658.6	---	---
7/17/08	48600	0	6.44	658.56	---	---
7/18/08	42400	0	8.05	658.64	---	---
7/19/08	38700	0	8.05	658.77	---	---
7/20/08	38600	0	1.61	658.87	---	---
7/21/08	38700	0	4.83	658.92	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
7/22/08	36700	0.375	9.66	658.9	---	---
7/23/08	33500	0.025	1.61	658.8	---	---
7/24/08	31000	0	8.05	658.69	---	---
7/25/08	30100	0.375	8.05	658.64	---	---
7/26/08	23300	0.375	3.22	658.57	---	---
7/27/08	20700	0	4.83	658.68	---	---
7/28/08	25500	0.25	12.87	658.84	---	---
7/29/08	23000	0	3.22	658.98	---	---
7/30/08	31600	0.8	9.66	659.28	---	---
7/31/08	17900	0	8.05	659.01	---	---
8/1/08	21500	0	3.22	659.11	---	---
8/2/08	15500	0	0.00	658.73	---	---
8/3/08	10700	0	6.44	658.56	---	---
8/4/08	13100	0	9.66	658.6	---	---
8/5/08	24300	2	8.05	658.81	---	---
8/6/08	18000	0.8	12.87	658.65	---	---
8/7/08	19800	0.05	3.22	659.04	---	---
8/8/08	16200	0	1.61	658.79	---	---
8/9/08	12200	0	0.00	658.66	---	---
8/10/08	3890	0	0.00	658.16	---	---
8/11/08	10100	0	4.83	658.08	---	---
8/12/08	8450	0	8.05	657.98	---	---
8/13/08	3310	0	1.61	657.83	---	---
8/14/08	3440	0.425	0.00	657.76	---	---
8/15/08	2650	0	0.00	657.92	---	---
8/16/08	1630	0	4.83	657.94	--	---
8/17/08	1690	0	0.00	658.07	---	---
8/18/08	1510	0	0.00	658.2	---	---
8/19/08	1680	0	1.61	658.3	---	---
8/20/08	1120	1.15	8.05	658.41	---	---
8/21/08	5770	1.275	9.66	658.56	---	---
8/22/08	6580	0	9.66	658.57	---	---
8/23/08	2280	0	9.66	658.54	---	---
8/24/08	3680	0	3.22	658.38	---	---

Date	Discharge (cfs)	Rain (cm)	Wind Speed (km/hr)	Lake Level (ft)	Incoming Traffic (counts/day)	Outgoing Traffic (counts/day)
8/25/08	1850	0	8.05	658.29	---	---
8/26/08	1990	0	4.83	658.64	---	---
8/27/08	5080	0	3.22	658.68	---	---
8/28/08	4720	2.1	9.66	658.71	---	---
8/29/08	1590	3.8	16.09	658.86	---	---
8/30/08	1040	0	0.00	658.96	---	---
8/31/08	1360	0	0.00	658.87	---	---
9/1/08	2330	0	3.22	658.81	---	---
9/2/08	13400	0	3.22	658.73	---	---
9/3/08	25900	3.25	8.05	658.6	---	---
9/4/08	28900	2.8	20.92	657.89	---	---
9/5/08	14200	0	8.05	657.86	---	---