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Patterns and sources of anthropogenic contaminants in the Otter Creek Watershed, Madison County, Kentucky

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List of Tables

Table

List of Figures

Figure

Abstract

Stream systems are often affected by anthropogenic activities that affect water quality and stream ecosystems. Land use typically determines the type and quantity of anthropogenic contaminants entering natural waters. The Otter Creek watershed (170 km^2; Madison County, Kentucky) consists predominantly of pasture and rural housing, with some cropland. The basin also receives runoff from the town of Richmond and a sewage treatment plant operates within the watershed. We measured concentrations of nutrients (phosphate, ammonium, nitrate) and fecal microbes to discover levels of anthropogenic contaminants affecting water quality and to identify contaminant sources.

We sampled 4 times in the summer field season of 2015 over a variety of conditions. Nutrients were measured colorimetrically using established colorimetric methods. The abundance of *Escherichia coli* was quantified using IDEXX rapid-assay techniques.

Phosphate (0 – 0.5 mg/L) and ammonium (<0.1 mg/L) concentrations were low for all sampling days, whereas nitrate was the dominant anthropogenic nutrient contaminant showing concentrations of 1 to 3 mg/L. Consistently higher levels of phosphate and nitrate were found in the waters of Dreaming Creek, which drains urban Richmond. High ammonium levels were sporadic and associated with pasture. High *E. coli* counts occurred in Dreaming Creek, the upper reaches of Otter Creek, and proximal to pastures.

Both point- and non-point sources exist for contaminants. The sewage treatment plant is a definite point source for nitrate and less so for phosphate and ammonium. Non-point sources include high concentrations of nitrate, phosphate, and fecal microbes occur along Dreaming Creek, likely due to leaky sewage distribution pipes. Spikes in ammonium concentration are associated with cattle pasture, another non-point source.

We also tested contaminant levels immediately before and after a rainfall event associated with tropical storm Bill (June 22). Phosphate and ammonium levels decreased, whereas nitrate increased significantly. *E. coli* counts also increased dramatically, after the rain event.

Introduction

Anthropogenic activities change the chemistry and water quality of streams, rivers, and lakes (Foley et al., 2005, Carpenter et al., 1998**)** and are largely dependent on land use. One of the most common contamination problems is the addition of excess nutrients. Nutrients can come from natural or anthropogenic sources, but those that come from human sources typically degrade water quality and damage ecosystems (Foley et al., 2005). Land use typically determines the type and quantity of nutrients dissolved in fresh waters. Cropland can contribute excess nutrients due to the use of fertilizers. Pasturelands typically contribute excess nutrients and fecal microbes from stock feces. Eutrophication is the result of excess nutrients in freshwater systems that causes algae overgrowth and changes in ecosystem composition (Carpenter et al., 1998). Excess algae leads to an overabundance of decaying organic material in the water, which takes oxygen out of the water. Decreased oxygen amounts then cause a change in the organisms comprising freshwater ecosystems, often leading to decrease or absence of naturally occurring stream organisms. Decreases in oxygen content can also cause sharp decreases in water quality (Carpenter et al., 1998).

Dubrovsky et al. (2010) examined nutrient contamination and summarized findings from water-quality studies conducted between 1992 and 2004 to create a national dataset of nutrient concentrations from across several hydrologic systems within the United States. We use these data to compare the nutrient contamination of the Otter Creek watershed to watersheds throughout the country.

Fecal microbes are another important factor in determining the quality of surface waters. Disease-causing fecal microbes can be hazardous to the health of humans and other organisms. The sources for fecal bacteria are most often anthropogenic, such as leaking sewage systems and septic tanks, or pasturelands. The United States Environmental Protection Agency (U.S. EPA) has established guidelines on what concentrations are acceptable for different activities such as recreation or bathing.

Studies performed by the U.S. EPA the the 1970's and 1980's created these guidelines for acceptable levels of fecal contamination for activities in marine and fresh waters (U.S. EPA, 1986). An initial study tracked rates of illness among recreational water users across different levels of contamination. Using *Escherichia coli*, a common intestinal microbe, as a proxy for the potential occurrence of pathogenic fecal microbes. More recent publications (U.S. EPA, 2004) have set guidelines for levels of contamination as follows: for bathing, less than 235 colony forming units per 100 milliliters (cfu/100 mL) of *E. coli* is recommended. '*Recreation only*' lies between 235 cfu/100 mL and 575 cfu/100 mL. Values above 575 cfu/100 mL is designated as '*no human contact recommended*'.

Otter Creek Watershed

The Otter Creek watershed (Fig. 1) is located in northern Madison County and drains into the Kentucky River to the north with an area of 41,832 acres (169.29 km^2), mainly dominated by pastureland and rural homes with some cropland (River Management Publication, 2000). The rocks in the basin mostly consist of interbedded shales and limestones of the Drakes, Ashlock, and Calloway Creek Limestone formations (KGS Online Geologic Map). There are 4 main stream segments that drain the basin: East Fork, West Fork, Dreaming Creek, and the main Otter Creek trunk. The East and West forks drain rural areas, mainly consisting of widely- separated residences and pastureland. Dreaming Creek drains mainly urban Richmond and eventually enters the central trunk of Otter Creek. The main Otter Creek trunk drains Lake Reba and urban Richmond, but most of the downstream portion contains pastureland. Because land use determines anthropogenic contaminants (Foley et al. 2005), the most likely non-point contaminant sources are pasturelands, septic tank systems, fertilizers, and leakage from sewage distribution pipes. A sewage treatment plant also operates along Otter Creek, which is a possible point source for nutrients.

The goals of this project are to measure nutrient concentrations [phosphate (PO_4^{-3}), nitrate (NO_3^-), and ammonium (NH_4^+)], as well as concentrations of fecal microbes, specifically *Escherichia coli*, throughout the Otter Creek watershed to identify anthropogenic sources of nutrient and fecal microbe contamination. Our objectives were to: (1) quantify the levels of dissolved ammonium, nitrate, phosphate, and *E. coli*; (2) identify plausible sources for these contaminants in the watershed; and (3) compare these values to that of contaminant levels elsewhere in the United States

Methods

We sampled stream waters at 42 sites throughout the watershed (Fig. 1, Table 1). Sampling sites were selected to: (1) gain a representative sampling of the entire watershed; (2) assess nutrient and fecal microbe contributions from tributary streams; and (3) identify sources of anthropogenic contaminants. Samples were taken throughout the watershed, and also at sites with different land use to representatively sample the watershed (Fig. 1, Table 1). Many sample sites occur at confluences of tributaries where samples were taken in the tributary stream, and downstream and upstream of its entry point into the main trunk. Lastly, samples were taken near likely contaminant sources like downstream of a golf course and the sewage treatment plant.

We sampled 4 times during the summer of 2015 under different rainfall and runoff conditions (Fig. 2, Table 2). On June 19 and June 22 (Fig. 2), we sampled before and after a major rain event associated with the tropical storm Bill. Sampling on July 6 was preceded by rain on July 4 and 5, during which all streams were flowing. For the final sample date on July 7, no rain had occurred within the week prior, so there was weak or no flow in smaller streams and tributaries.

For nutrient measuring, samples were pressed through a 0.45 μm filter to remove particulates and larger biota, and placed in pre-acidified vials (H_2SO_4) to kill any living microbes and keep dissolved nutrient species in solution. For fecal microbe measurements, 100 ml samples were collected at the same location as nutrient samples and then the samples were put on ice and transported back to the lab.

We used colorimetric methods to measure nutrient concentrations using a UV-VIS Thermo-Scientific Evolution 201 spectrophotometer. Standards were created for each nutrient –

phosphate (PO_4^{-3}) (Gieskes et al., 1991) nitrate (NO_3^-) and ammonium (NH_4^+) (Gieskes et al., 1991) – spanning the concentrations within the waters. Specific methods for each nutrient are: cadmium reduction for nitrate (Hach, 1986, Eaton et al., 2005a Method), sodium hypochlorite for ammonium (Solorzamo, 1969, Eaton et al. 2005b), and ascorbic acid for phosphate (Strickland and Parsons, 1968, Eaton et al., 2005c). Precision of nutrient measurements is $\pm$ 0.1 milligrams per liter (mg/L) or parts per million (ppm).

Fecal coliform and *E. coli* concentrations were measured using IDEXX Colilert-18 and Quanti-Tray quick-assay methods and reported in colony forming units per 100 milliliters. The maximum count possible without dilution using this method is 2419.6 cfu/100 mL. The Colilert IDEXX methods were approved by the EPA for use in determining concentrations of fecal coliforms (Edberg, 2000). The samples were each spiked with IDEXX Colilert-18 media and then poured into IDEXX quanti-trays containing 48 small wells and 49 large wells, then incubated for 18 hours at 35 degrees celsius. Counts of total coliform bacteria and *E. coli* were performed the following day. The growth media causes wells in the trays to turn yellow, which indicates positive for the presence of fecal coliforms. The number of changed wells can be referenced to the IDEXX Quanti-Tray/2000 MPN table for concentration of fecal coliforms. For determining *E. coli*, the trays are put under a UV light, which causes the *E. coli* containing wells to turn a fluorescent blue. This number is also referenced to determine concentration. The maximum count possible without dilution is 2419.6 colony forming units per 100 milliliters (cfu/100 mL).

Results

Nutrient concentrations varied within each of the subwatersheds of Otter Creek. The West Fork had low concentrations of phosphate and ammonium for each of our sampling dates ranging between 0.0 to 0.1 mg/L (Fig. 3 – 6). Ammonium here was typically low for all sampling days, except for spikes in concentration of 0.3 mg/L at TBC (June 19), 0.9 mg/L at WFU (July 6), and 0.1 mg/L at HBT (July 27).

Nitrate values saw significant increases in West Fork after the first sampling of June 19. Nitrate concentrations all recorded at 0.0 mg/L on June 19. Nitrate values in the West Fork on June 22 ranged between 0.3 to 3.6 mg/L, with station TBC having the maximum value of 3.6 mg/L. Concentrations were relatively higher at each station on July 6, ranging between 0.8 to 2.3 mg/L. July 26 had values between 0.0 to 0.9 mg/L with the maximum of 0.9 mg/L occurring at stations WFU and TBC (Fig. 6).

E. coli concentrations showed consistent contamination throughout the West Fork on sampling dates though concentrations were generally lower on 27 July. June 19 had station HBT-u reach the highest threshold value of 2419.6 cfu/100 mL. The next highest values of 980.4 cfu/100 mL and 727.0 cfu/100 mL occurred at stations HBR and HBT respectively (June 19). June 22 had increased *E. coli* concentrations with 4 stations reaching the measurement threshold and the remaining stations having higher or similar values than the previous sampling date. July 6 continued overall higher concentrations with an average of 998.9 cfu/100 mL and the maximum occurring at station TBC (1732.9 cfu/100 mL) and the minimum at station HBR

(365.4 cfu/100 mL). July 27 had lower concentrations averaging 614.4 cfu/100 mL with stations TBC, WFC, and BER showing higher concentrations.

The East Fork, much like the West Fork, had overall low concentrations of phosphate and ammonium (Fig 1-4), except for generally higher ammonium values on July 27. The highest phosphate concentration of 0.1 mg/L occurs at station 1986E (June 19). Ammonium also had low concentrations with a few exceptions occurring as concentration spikes. These spikes occurred at stations 1986E (0.8 mg/L, June 19), PRW (0.2 mg/L, June 19), and BRL (0.2 mg/L, June 19). July 27 saw generally higher concentrations of ammonium throughout East Fork with values ranging between 0.0 to 0.3 mg/L.

East Fork also had significant increases in nitrate after the first sampling date of June 19. Only station PRE had a measured concentration above 0.0 mg/L $N\text{-}NO_3$ on June 19 of 0.2 mg/L. Nitrate concentrations on June 22 increased across the fork and ranged between 0.0 to 4.6 mg/L. July 6 had concentrations of nitrate ranging between 0.9 to 2.1 mg/L. July 7 had even lower concentrations between 0.0 to 1.2 mg/L.

E. coli counts were typically significant on all sampling dates June 22 showing the highest general values. On June 19 had two stations (1986W, PRE) that reached the maximum value of 2419.6 cfu/100 mL. June 22 had increases in *E. coli* concentrations across the fork with maximum values at station 1986E and 1986W. Five of eight sample sites measured not over 500 cfu/100 mL on July 6. The average microbe count was 440.3 cfu/100 mL with the peak value on July 27 occurring at station 1986W (1203.3 cfu/100 mL).

Ammonium and phosphate along Dreaming Creek had generally higher values compared to the East and West forks. Ammonium in Dreaming Creek measured 0.2 mg/L at station DCP and DCC. June 22, July 6, and 27 sampling along Dreaming Creek had ammonium concentrations of 0 mg/L. Phosphate concentrations along Dreaming Creek maintained at least 0.1 mg/L for all sampling sites across all sampling days, with downstream stations DCP and DCC measuring 0.2 to 0.3 mg/L on certain days (June 19, June 22, July 27).

Nitrate concentrations were lowest on June 19 with higher values averaging 0.5 mg/L on the other sampling days. Stations DCP and DCC had higher values of 1.7 mg/L and 0.3 mg/L, respectively on June 19. Nitrate concentrations on June 22 were uniformly high, ranging between 2.8 to 4.1 mg/L with station DCP recording the maximum value. July 6 had similar concentrations with values between 2.4 to 3.9 mg/L. July 27 had lower concentrations around 1.1 to 2.1 mg/L with station DCP showing the maximum value again.

E. coli concentrations remained relatively high across all sampling dates. Stations DCP and DCG recorded the maximum threshold value of 2419.6 cfu/100 mL on June 19. June 22 had stations DCP, DCG, and DCF all reach the maximum value. Dreaming Creek retained relatively high concentrations on July 6 with concentrations ranging between 1119.9 – 1732.9 cfu/100 mL. The lowest *E. coli* values occurred on July 27 averaging only 880 cfu/100 mL.

Phosphate and ammonium concentrations were generally low in the Otter Creek trunk with the exceptions of values occurring on July 27. Sampling sites had an average $P\text{-}PO_4$ concentration of 0.1 mg/L on June 19, with the peak of 0.3 mg/L occurring at DCC. Phosphate concentrations were similar for June 22 with average concentration at 0.1 mg/L and the maximum of 0.2 mg/L $P\text{-}PO_4$ occurring at stations CC, DCC, and 3906-road. July 6 and 27 had similar concentrations with station STP-dis being the maximum at 0.5 and 0.2 mg/L $P\text{-}PO_4$. Station STP-d also had a concentration of 0.2 mg/L on July 27. Ammonium had low concentrations on June 19 for all sampling sites across the main Otter Creek trunk except for stations DCC, RRM, and 3906-rd, which had concentrations of 0.2 mg/L, 0.1 mg/L, and 0.2 mg/L N-NO_4, respectively. June 22 also had trace concentrations at all sites with the exception of station CC showing 0.1 mg/L N-NH_4. Most sites on July 6 had a concentration of 0 mg/L, but 7 stations recorded 0.1 mg/L (Fig 5). July 27 saw the highest collective ammonium concentration overall in the trunk with values ranging between 0.0 to 0.5 mg/L. The maximum occurred at station BD with a value of 0.5 mg/L

Nitrate values within the main trunk were generally significantly high on all sampling days, except June 19. Nitrate concentrations on June 19 were relatively low overall, with some concentration spikes occurring at station STP-dis, STP-d, OCR, RHB, and 3906-rd, with a maximum value at station STP-dis (2.5 mg/L, Fig. 3). Higher concentrations across most sampling sites occurred on June 22 (Fig 4), when values averaged 2.0 mg/L with a maximum of 6.4 mg/L occurring at station SRC. July 6 had average concentrations of 1.5 mg/L with a maximum of 3.1 mg/L occurring at station STP-dis. Concentrations in the trunk averaged 0.8 mg/L with station STP-dis was the maximum value of 2.8 on July 27.

E. coli counts in the main trunk of Otter Creek were highest in the upper reaches of the watershed with values significantly lower downstream of station EPC. CF and EPC measured the maximum threshold value on June 19. June 22 had 8 stations (LRW, LRR, CF, FMH, DCC-d, BD, BER, and EPC) that reached the threshold, with an average concentration of 1178.5 cfu/100 mL. July 6 had several sites with high concentrations, with concentrations averaging 949.1 cfu/100 mL and 3 stations recording the threshold of 2419.6 cfu/100mL. July 27 had the lowest *E. coli* concentrations of any sampling day with average concentrations of 455.8 cfu/100 mL and only one station CC reaching the maximum of 2419.6 cfu/100 mL.

Discussion

There is evidence for two significant and separate phosphate sources within the Otter Creek watershed. Phosphate generally showed low concentrations for all sampling days within the watershed, but phosphate levels along Dreaming Creek remained consistently higher, indicating a consistent non-point source of phosphate contamination along Dreaming Creek. The most likely, high-volume source here is leaky sewage distribution pipes because upstream of station DCC there is no cattle pasture and residences are on the city sewer system. The sewage treatment plant along Otter Creek (Fig. 1) is a point source of phosphate. Phosphate within the plant discharge is high on July 6 and July 27 (Table 3). Moreover, downstream of the plant phosphate levels remain elevated, but progressively decreases downstream within the main trunk of Otter Creek, from stations STP-d, OCR, RHB and SJR.

Ammonium also had low concentrations for all sampling days, similar to phosphate, but shows spikes in concentration from samples associated with pastureland. For example, stations 1986E (June 19), CC (June 22), and WFU (July 6) are all adjacent to or within pastureland and show anomalous spikes in ammonium concentration. Thus, cattle manure seems to be a non-point-source for ammonium. The sewage treatment plant is a minor source of ammonium on July 27 (Table 3).

Nitrate measurements from all sampling days show higher concentrations than that of phosphate and ammonium. Dreaming Creek has higher nitrate levels for all sampling dates, and high fecal microbe levels (Robin et al., 2015). High co-occurring levels of phosphate (see above), nitrate, and fecal microbes strongly suggests that leaky sewage pipes are a likely source because pastureland and septic systems are eliminated as possible sources. Sewage treatment plant discharge is also a major point source for nitrate contamination, especially on June 19, July 6, and July 27 (Table 3). Pasturelands are a likely non-point source of contamination in other locations because high values occur within or near pastures within subwatersheds and in the upper reaches of the trunk stream.

More than half of the waters fall under the EPA's categorization of *human contact not recommended* with concentrations exceeding 575 cfu/100 mL. High *E. coli* counts are generally coincident with drainage from cattle pastures (stations 1986W, PRE, June 19). Dreaming Creek, which drains out of urban Richmond, shows high concentrations around the maximum of 2419.6 cfu/100 mL. The lack of cattle pasture in the immediate area and the high concentrations of phosphate consistently recorded along Dreaming Creek further supports the idea that leaky sewage distribution pipes are responsible for contamination within the waters there.

Effects of Rainfall

Rainfall can either increase nutrient concentration by washing nutrients into streams, or decrease levels by dilution. Phosphate before and after the rain event of June 22 shows lower concentrations indicates dilution by rainfall. Many sites show no measurable concentration on the post-rain date as compared to the pre-rain sampling date (June 19). Ammonium also shows dilution by rainfall as post-rainfall concentrations (June 22) show almost all sites having no measurable amounts of ammonium relative to pre-rainfall (June 19)

Conversely, nitrate levels increase after the rain event apparently due to being flushed into stream waters. Relative to 0 to 2 mg/L before (June 19), significantly higher concentrations are observed in the East Fork and West Forks and in the lower portion of the trunk stream after the rain event (June 22). After the rain event a dramatic difference in nitrate concentration exists throughout the watershed with many sites having concentrations between 2 and 4 mg/L (June 22).

E. coli counts, like nitrate, saw increases across the watershed due to being flushed out of cattle pastures by rainfall. Average *E. coli* counts were 869 cfu/100 mL pre-storm and 1300 cfu/100 mL post-storm. Eight stations reaching the maximum level of 2419.6 cfu/100 mL after the rainfall event compared to 17 stations before tropical storm Bill.

Overall Comparison to National Levels

Durbrovsky et al. (2010) have established a national data set for nutrient levels in the United States. Figure 6 shows a box and whisker plots for this national data set with median, 95th percentile, and highest values from Otter Creek superimposed on the plots. Data comparison shows that the Otter Creek watershed waters are generally less contaminated than other watersheds throughout the United States for agricultural lands in particular. Median phosphate levels in Otter Creek are generally below the 10^{th} percentile value of national agricultural areas. This is also the case for ammonium. Nitrate contamination values are slightly higher with respect to national levels. The generally lower levels of contamination within Otter Creek compared to other agricultural lands are perhaps explained by land use. Other agricultural lands have larger amounts of crop production, and therefore more fertilizer use compared to Otter Creek. Because of the limited amount of crop production in the Otter Creek watershed compared to other agricultural watersheds, nutrient contamination is overall lower.

Summary

The Otter Creek watershed of Madison County, Kentucky is an area dominated by pastureland, rural housing, and some cropland. Therefore, the most probable contaminants are elevated levels of nutrients and fecal microbes. Likely non-point sources for contaminants are septic tank leakage, cattle manure in pastures, and fertilizer used on cropland and elsewhere. A sewage treatment plant operates within the watershed and acts as a point source for some nutrients.

Phosphate concentrations were low for all sampling days, with consistently higher concentrations on Dreaming Creek and in the sewage plant discharge. Leaky sewage distribution pipes are the likely source for phosphate along Dreaming Creek, whereas the sewage treatment plant is a point source for phosphate.

Ammonium concentrations were also low for all sampling days with spikes in concentration being coincident with pastureland drainage. Cattle manure is a likely non-point source for ammonium. The sewage treatment plant is also a minor point-source for ammonium (July 27)

Nitrate was the most significant nutrient contaminate with concentrations between 1 to 4 mg/L. Dreaming Creek consistently had higher levels, pointing to leaky sewage distribution pipes as a non-point source. The sewage treatment plant was also a significant point-source for nitrate contamination.

E. coli had higher concentrations that were coincident with the drainage of cattle pastures. High concentrations along Dreaming Creek suggest an adjacent source of *E. coli* contamination, which can likely be attributed to leaky sewage pipes. We have no national data set for *E. coli* contamination, but the U.S. EPA designates levels greater than 575 cfu/100 mL as '*no human contact recommended'*.

Pre-and post-rain event concentrations show that contaminants were affected differently by rainfall. Phosphate and ammonium levels were diluted by rainfall overall, whereas nitrate dramatically increased, purportedly being flushed out during the rainfall event *E. coli* also showed increases in concentration across many sampling sites after the rain event. The Otter Creek watershed is generally less contaminated than other agricultural lands in the United States for phosphate, ammonium, and nitrate. (Dubrovsky et al. 2010), likely because of the lack of fertilized cropland, but contamination is significant.

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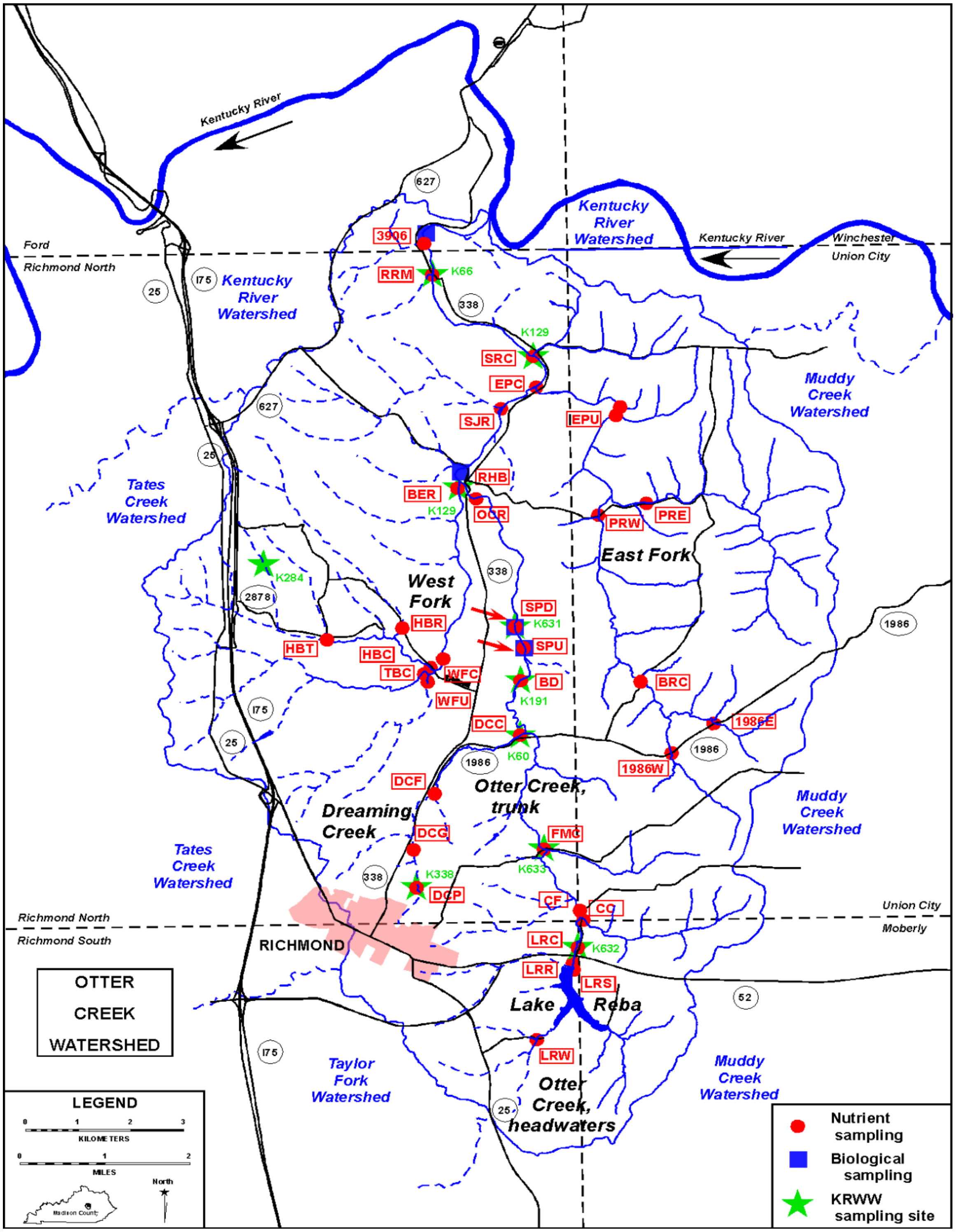

Figure 1. Map of the sampling sites in the Otter Creek watershed. Sampling station designations match those of Table 1. Samples of fish and macroinvertebrates were taken at locations with a blue square. Green stars indicate sampling sites used by the Kentucky River Watershed Watch. Red circles indicate sampling sites used in this study. USGS 7'5 minute quadrangle map was used to construct the map.

Table 1. Table of sampling locations showing station designation, land use, likely contaminants, and number of samples.

Fork	Sample Code	Sampling Site	Runoff Type	Likely Contaminants	Number of Samples
West	WFU	West Branch upstream of Three Forks road	Fields	Nutrients, microbes	1
	TBC-u	Tribble Branch, upstream West Fork confluence	Fields	Nutrients, microbes	1
	TRC	Tribble Branch, downstream West Fork confluence	Fields	Nutrients, microbes	1
	HBT	Hicks Branch tributary, upstream	Fields	Nutrients, microbes	3
	HBR	Hicks Branch road	Fields	Nutrients, microbes	1
	HBC	Hicks Branch confluence	Fields	Nutrients, microbes	1
	WFC	West Fork confluence, downstream Three Fork Rd	Fields	Nutrients, microbes	1
	BER	Bill Eades Road - upstream confluence	Fields, septic systems	Nutrients, microbes	1
East	1986E	Highway 1986, east	Fields, septic systems	Nutrients, microbes	1
	1986W	Highway 1986, west	Fields, septic systems	Nutrients, microbes	1
	BRC	Brookstown Road, confluence 3 streams	Fields, septic systems	Nutrients, microbes	3
	PRW	Peacock Road, west	Fields, septic systems	Nutrients, microbes	1
	PRE	Peacock Road, east	Fields, septic systems	Nutrients, microbes	1
	EPU	East Prong Road crosses stream	Fields, septic systems	Nutrients, microbes	2
	EPU-trib	Tributary near East Prong Road crossing	Fields, septic systems	Nutrients, microbes	1
	EPC	East Prong confluence	Fields, septic systems	Nutrients, microbes	3
Central	DCP*	Dreaming Creek, former ST plant (K338)	Urban, residential	Nutrients, microbes	1
	DCG	Dreaming Creek - downstream golf course	Recreational	Nutrients	1
	DCF	Dreaming Creek ford - intersection Hwy 388/1986	Urban, residential	Nutrients, microbes	1
	DCC*	Dreaming Creek confluence (K60)	Urban, residential	Nutrients, microbes	3
Central	LRW	West Lake Reba input	Urban, residential	Nutrients, microbes	1
	LRS	Lake Reba Spillway	Recreational	Nutrients, microbes	1
	LRR	Lake Reba spillway - road	Urban, residential	Nutrients, microbes	1
	LRC*	Downstream Lake Reba, Concord (K632)	Residential	Nutrients, microbes	1
	CC	Concord stream	Residential, Hwy	Nutrients, microbes	1
	CF	Concord ford	Residential, Hwy	Nutrients, microbes	1
	FMH*	Four Mile Road/Hunter Road confluence (K633)	Fields	Nutrients, microbes	1
	BD*	Beaver Drive (K191)	Fields, septic systems	Nutrients, microbes	1
	BD-trib	Drainage paralleling Beaver drive	Septic systems	Nutrients, microbes	1
	STP-u	Sewage Treatment plant - upstream	Fields, septic systems	Nutrients, microbes	1
	STP-dis	Sewage Treatment plant - effluent discharge	Plant operations	Nutrients, microbes	1
	STP-d	Sewage Treatment plant - downstream	Plant operations	Nutrients, microbes	1
	OCR*	Otter Creek Road, 388 bridge (K129)	Fields, septic systems	Nutrients, microbes	1
	BER	Bill Eades Road - upstream confluence	Fields, septic systems	Nutrients, microbes	1
	RHB	Ky 3377 crosses Otter Creek	Fields, septic systems	Nutrients, microbes	1
	RHB-trib	Tributary paralleling Lost Fork Road	Fields, septic systems	Nutrients, microbes	1
	SJR	Sam Jones Road, Otter Creek	Fields, septic systems	Nutrients, microbes	1
	SJR-trib	Tributary at bridge, Sam Jones Road	Fields, septic systems	Nutrients, microbes	1
	SRC*	Stony Run confluence (K29)	Fields, septic systems	Nutrients, microbes	3
	RRM*	Railroad crossing on Hwy 338 (K66)	Fields, septic systems	Nutrients, microbes	1
	3906 bridge	Road crossing at 3906	Upland, septic system	Nutrients, microbes	1
	3906C	3906 Redhouse Rd confluence	Upland, septic system	Nutrients, microbes	3
				TOTAL	55
		* Sampling site, Kentucky River Watershed Watch			

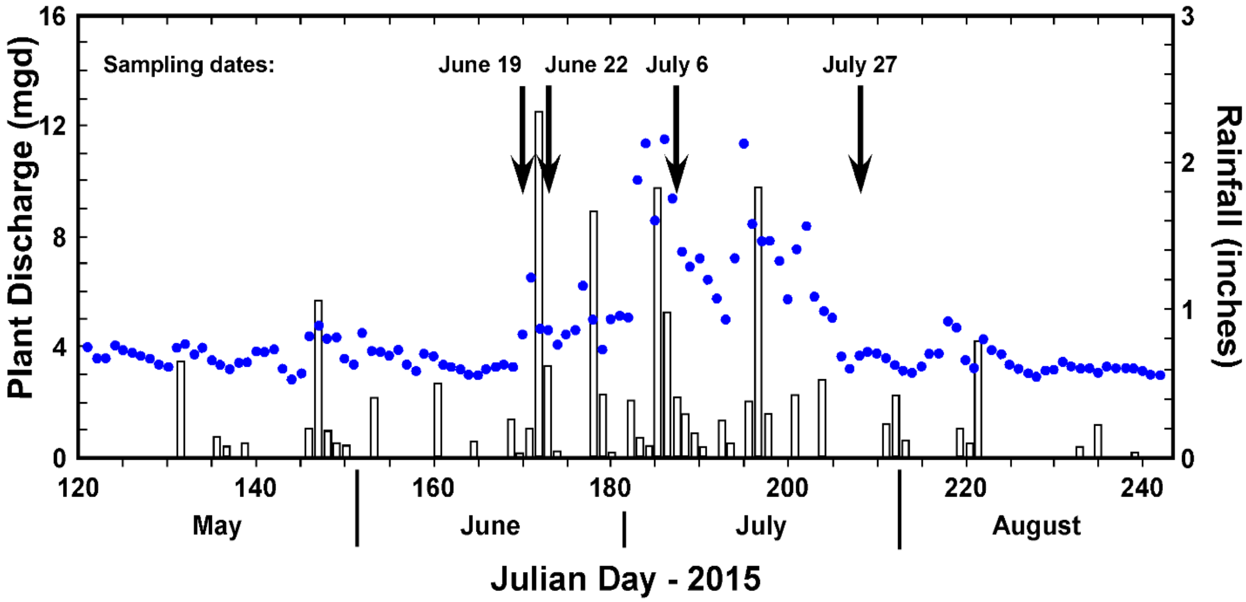

Figure 2. Graph of rainfall (inches) over the 2015 field season represented by white bars. Discharge of the sewage treatment plant along Otter Creek in millions of gallons per day (mgd) represented by the blue dots. The four black arrows indicate sampling dates.

Table 2. Sampling dates and conditions for the field season of 2015.

Sampling Date	**Rainfall History / Stream Conditions**
19 June	Mostly dry, trace rain on day before; smaller streams dry
22 June	Rains from tropical storm Bill peaking two days before sampling; all streams flowing
6 July	Rain on July 4, 5; all streams flowing
27 July	Prior week with no rain; ponded water, weak or no flow in smaller streams

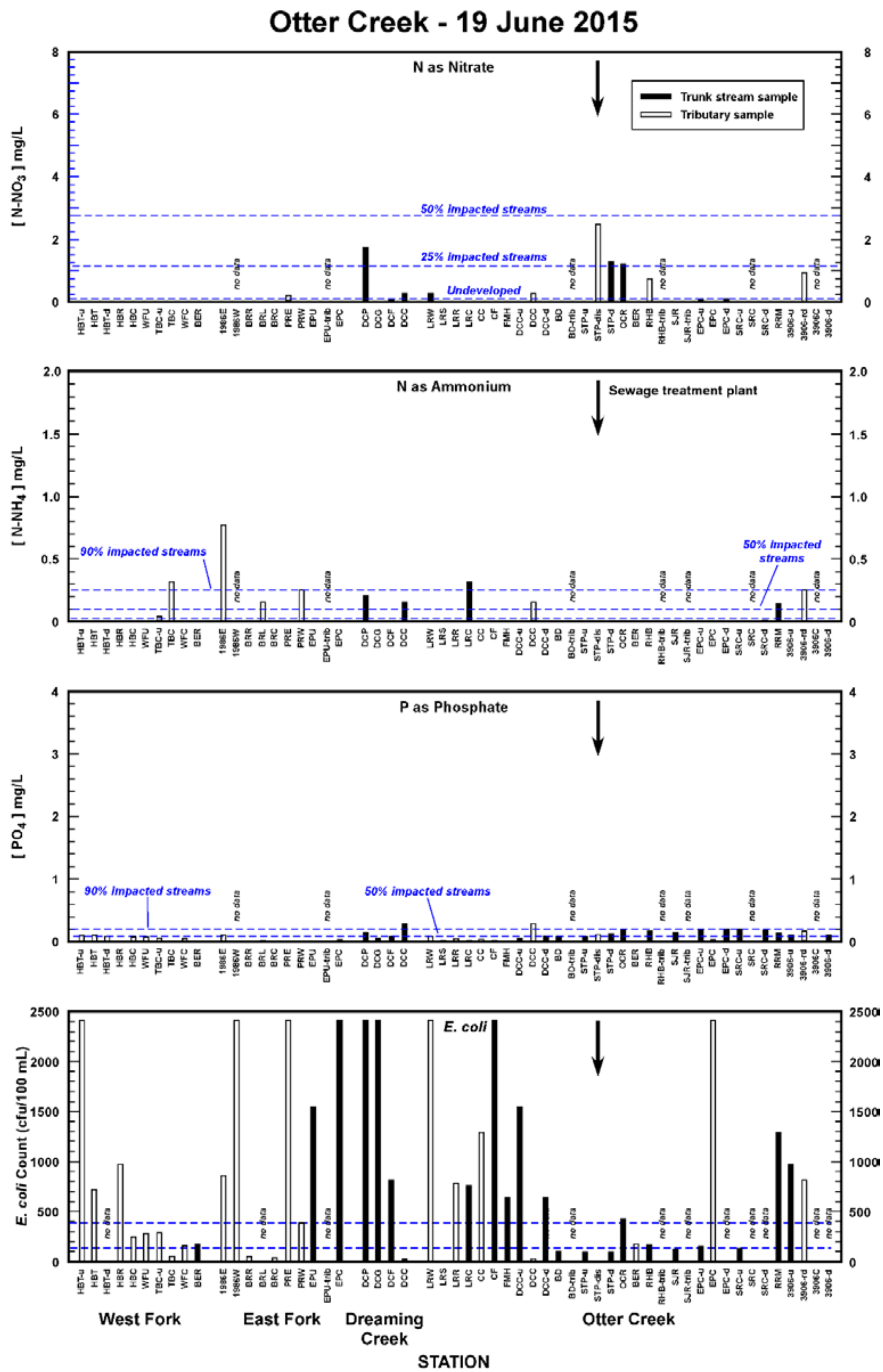

Figure 3. Graphs of nutrient and *E. coli* concentrations for June 19 in milligrams per liter (mg/L) and colony forming units per 100 milliliters (cfu/100 mL) respectively. Station locations and information appear in Table 1 and Figure 1. Stations are organized by sub-watershed (West Fork, East Fork, etc.) and from upstream to downstream.

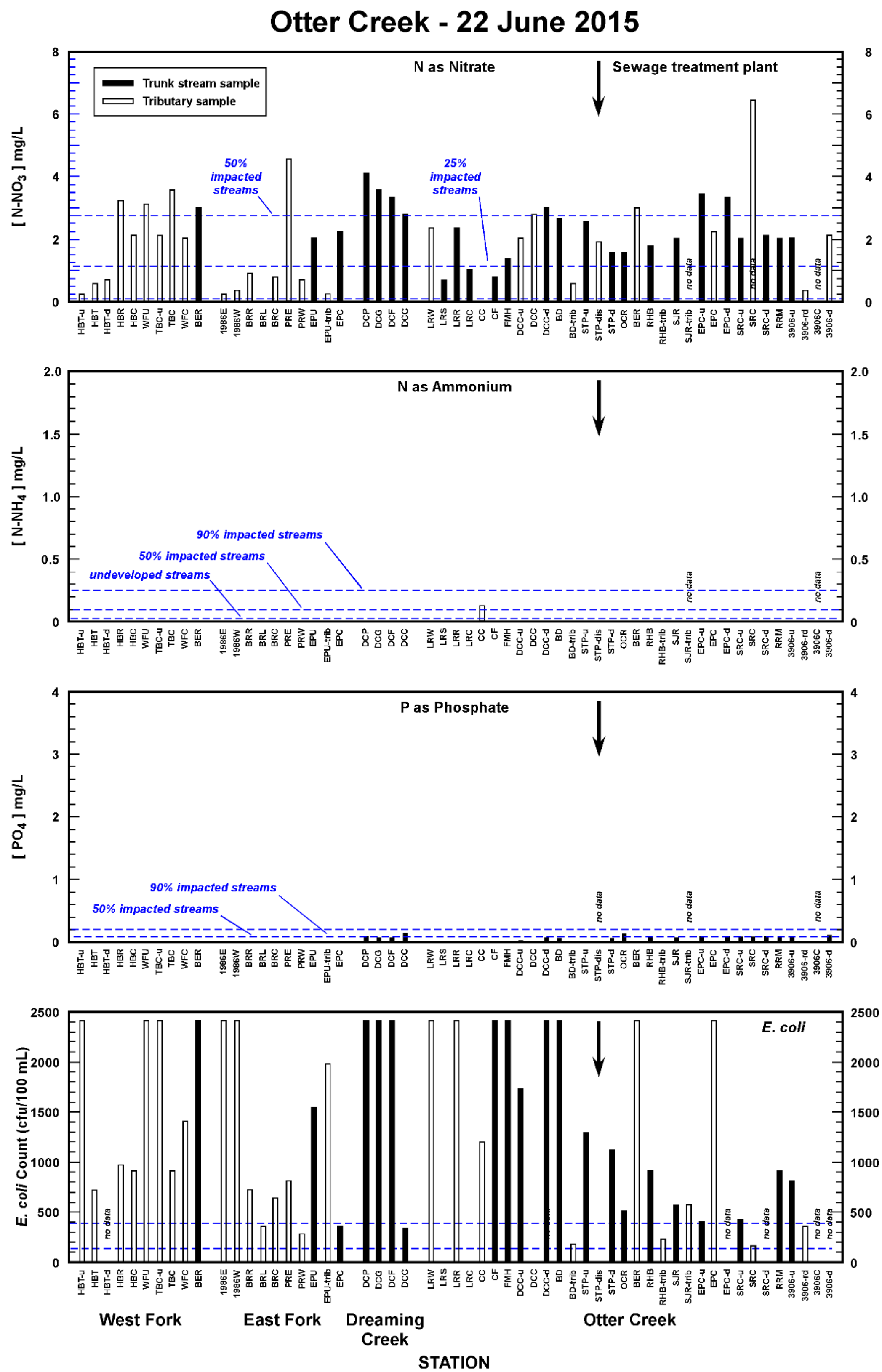

Figure 4. Graphs of nutrient and *E. coli* concentrations for June 22 in milligrams per liter (mg/L) and colony forming units per 100 milliliters (cfu/100 mL) respectively.

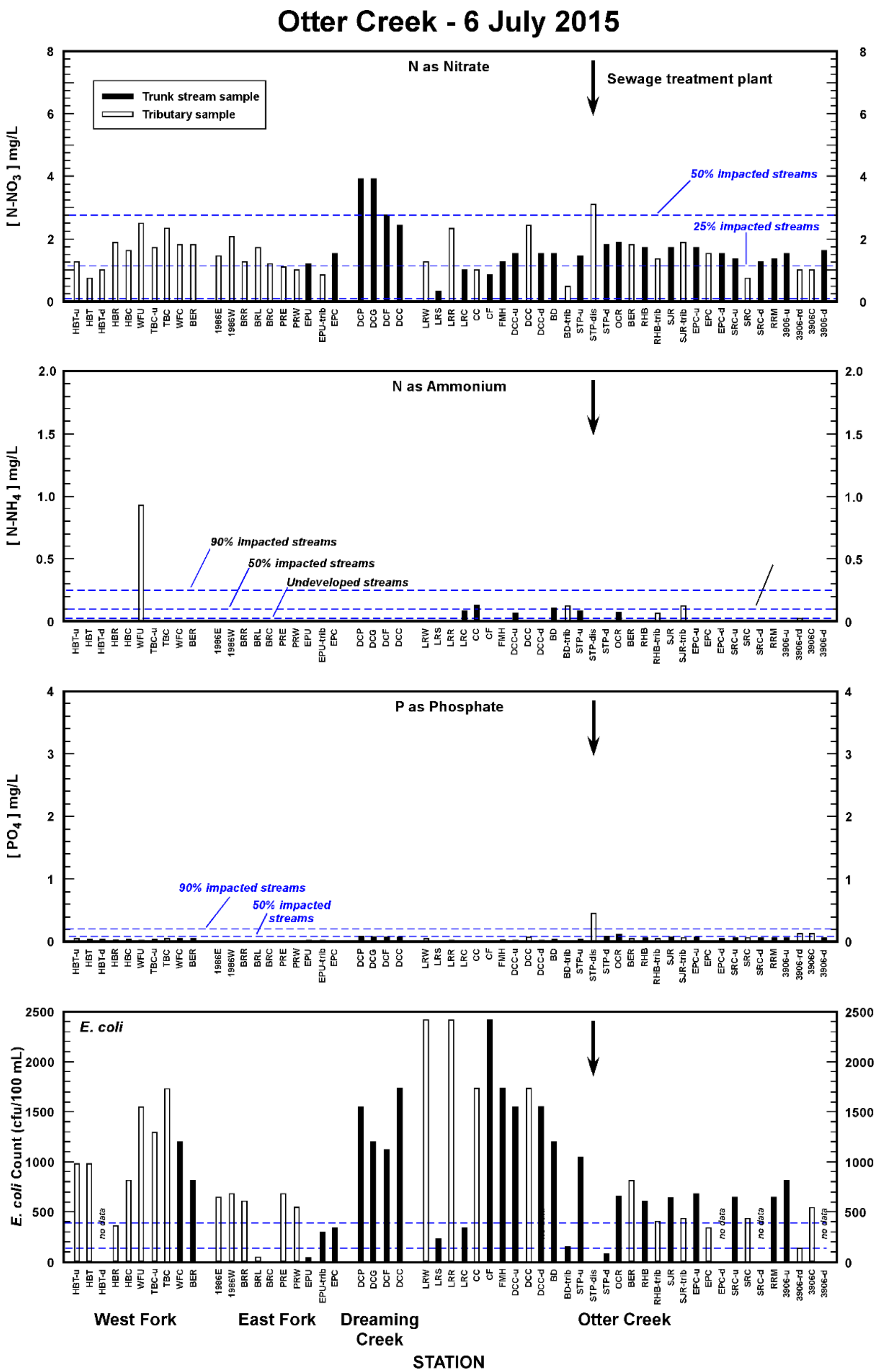

Figure 5. Graphs of nutrient and *E. coli* concentrations for July 6 in milligrams per liter (mg/L) and colony forming units per 100 milliliters (cfu/100 mL) respectively.

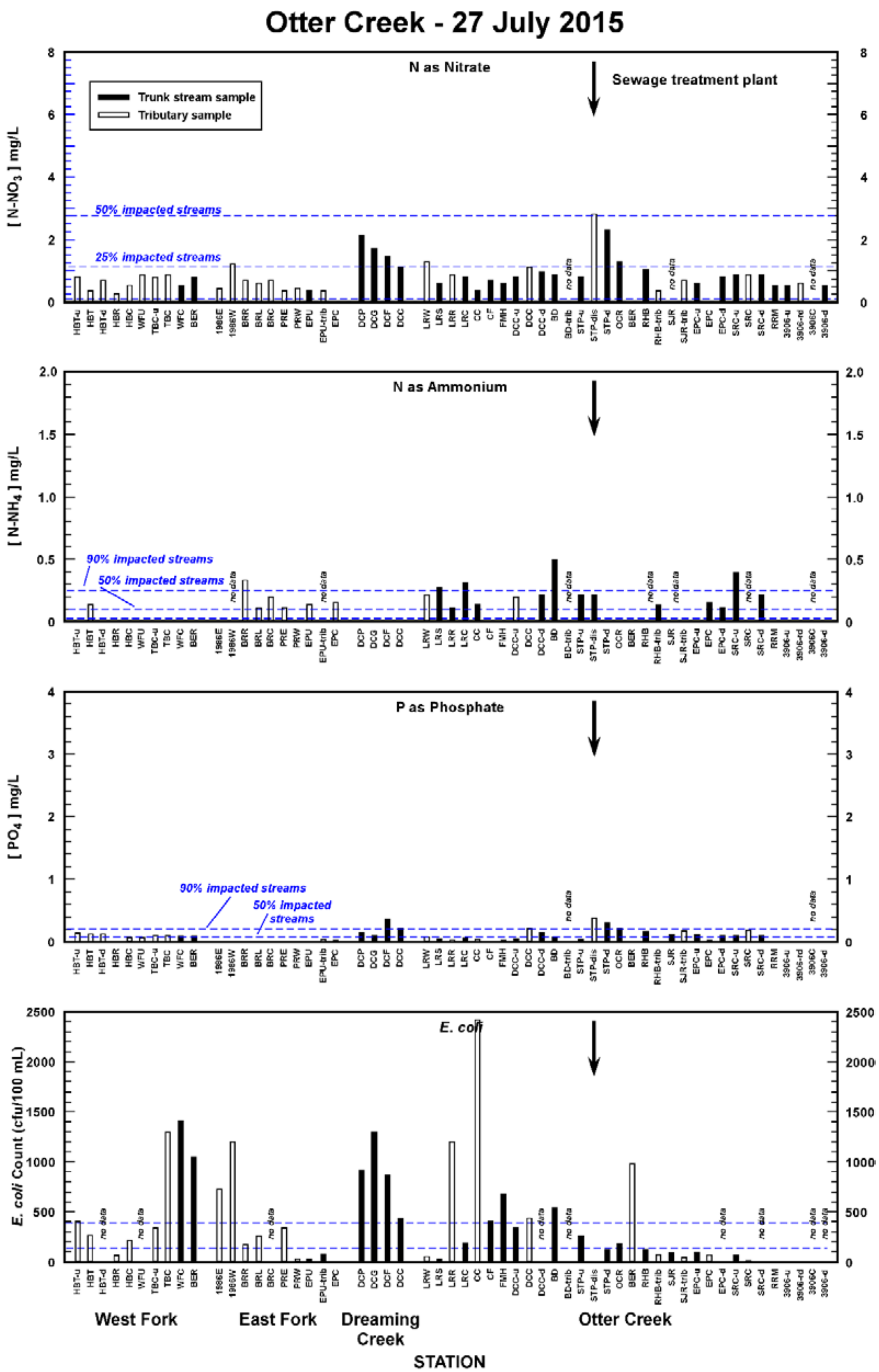

Figure 6. Graphs of nutrient and *E. coli* concentrations for July 27 in milligrams per liter (mg/L) and colony forming units per 100 milliliters (cfu/100 mL) respectively.

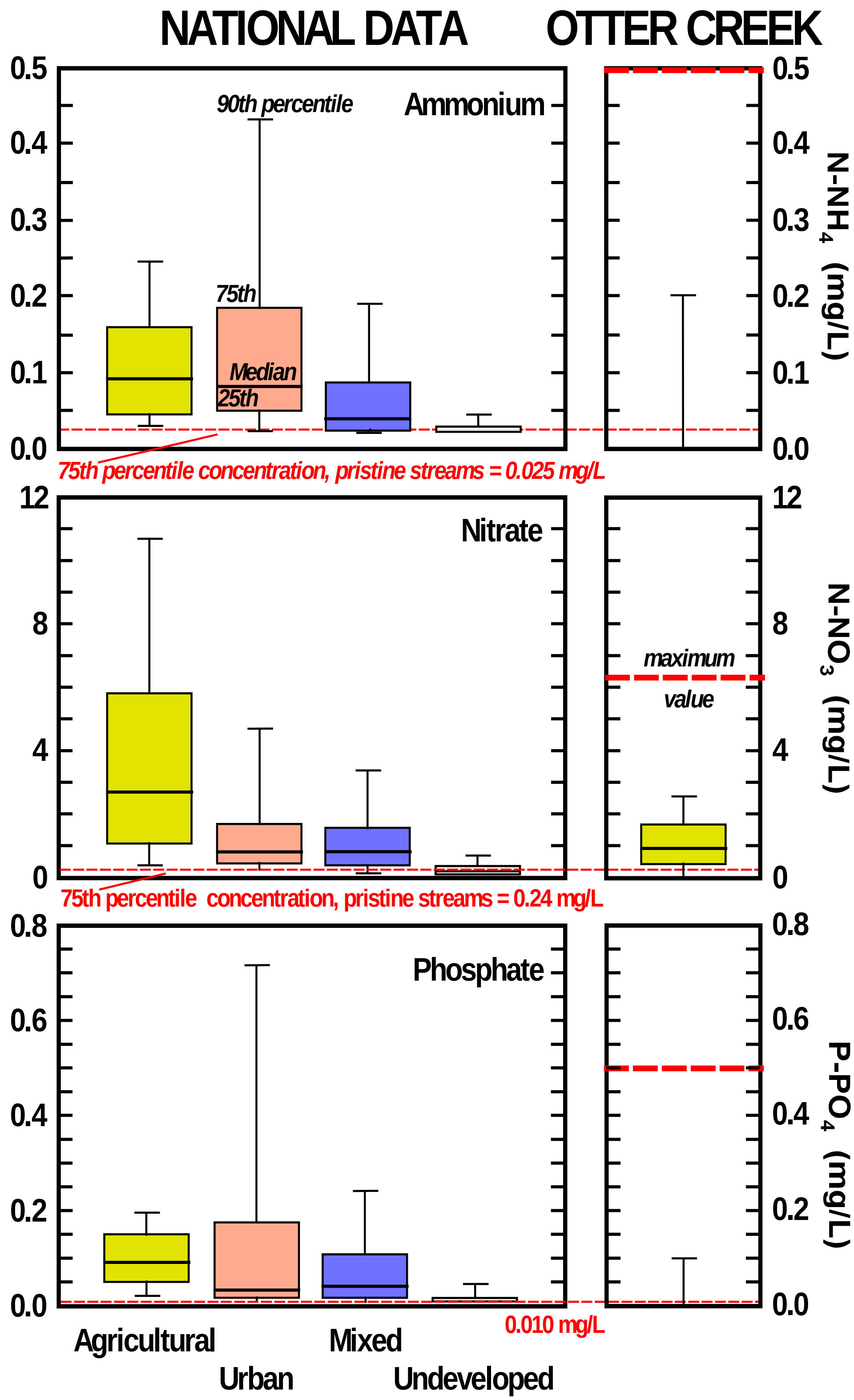

Figure 7. Box and whisker plots showing a national data set from Dubrovsky et al. (2010) compared to data from Otter Creek for 2015. Note the nutrient data are subdivided according to land use.

Table 3. Table showing nutrient concentrations and *E. coli* counts proximal to the sewage treatment plant in Otter Creek in 2015. Nutrient concentration is expressed in milligrams per liter (mg/L) whereas *E. coli* counts are in units of colony-forming units per 100 milliliters (cfu/100 mL).

Date	Station		[N-NH4] (mg/L)	[N-NO3] (mg/L)	[P-PO4] (mg/L)		E. coli (cfu/100 mL)
19-Jun-15	STP-upstream		0	0	0.1		101.4
	STP-discharge		0	2.5	0.1		5
	STP-downstream		0	1.3	0.1		101.4
22-Jun-15	STP-upstream		0	2.6	-		1299.7
	STP-discharge		0	1.9	0.1		6
	STP-downstream		0	1.6	0.1		1119.9
6-Jul-15	STP-upstream		0.1	1.5	0		1046.2
	STP-discharge		0	3.1	0.5		4
	STP-downstream		0	1.8	0.1		88.6
27-Jul-15	STP-upstream		0.2	0.8	0		261.3
	STP-discharge		0.2	2.8	0.2		8.6
	STP-downstream		0	2.3	0.2		122.2

Appendix

Table A1. Nutrient data for the field season of 2015 from Otter Creek. Concentrations expressed as milligrams per liter (mg/L) or parts-per-million (ppm).

Date	Station	[NH4] (mg/L)	[N] (mg/L)	Date	Station	[NH4] (mg/L)	[N] (mg/L)	Date	Station	[NH4] (mg/L)	[N] (mg/L)	Date	Station	[NH4] (mg/L)	[N] (mg/L)
19-Jun	HBT-U	0.0	0.0	22-Jun	HBT-U	0.0	0.0	6-Jul	HBT-U	0.0	0.0	27-Jul	HBT-U	0.0	0.0
19-Jun	HBT	0.0	0.0	22-Jun	HBT	0.0	0.0	6-Jul	HBT	0.0	0.0	27-Jul	HBT	0.2	0.1
19-Jun	HBT-d	0.0	0.0	22-Jun	HBT-d	0.0	0.0	6-Jul	HBT-d	0.0	0.0	27-Jul	HBT-d	0.0	0.0
19-Jun	BW-L			22-Jun	BW-L	0.0	0.0	6-Jul	BW-L	0.1	0.0	27-Jul	BW-L	0.0	0.0
19-Jun	HBR	0.0	0.0	22-Jun	HBR	0.0	0.0	6-Jul	HBR	0.0	0.0	27-Jul	HBR	0.0	0.0
19-Jun	WFU	0.0	0.0	22-Jun	WFU	0.0	0.0	6-Jul	WFU	1.2	0.9	27-Jul	WFU	0.0	0.0
19-Jun	TBC-u	0.0	0.0	22-Jun	TBC-u	0.0	0.0	6-Jul	TBC-u	0.0	0.0	27-Jul	TBC-u	0.0	0.0
19-Jun	TBC	0.4	0.3	22-Jun	TBC	0.0	0.0	6-Jul	TBC	0.0	0.0	27-Jul	TBC	0.0	0.0
19-Jun	HBC	0.0	0.0	22-Jun	HBC	0.0	0.0	6-Jul	HBC	0.0	0.0	27-Jul	HBC	0.0	0.0
19-Jun	WFC	0.0	0.0	22-Jun	WFC	0.0	0.0	6-Jul	WFC	0.0	0.0	27-Jul	WFC	0.0	0.0
19-Jun	BER	0.0	0.0	22-Jun	BER	0.0	0.0	6-Jul	BER	0.0	0.0	27-Jul	BER	0.0	0.0
19-Jun	1986W			22-Jun	1986W	0.0	0.0	6-Jul	1986W	0.0	0.0	27-Jul	1986W	0.0	0.0
19-Jun	1986E	1.0	0.8	22-Jun	1986E	0.0	0.0	6-Jul	1986E	0.0	0.0	27-Jul	1986E	0.0	0.0
19-Jun	1986E A	0.0	0.0	22-Jun	1986E A	0.0	0.0	6-Jul	1986E A	0.0	0.0	27-Jul	1986E A	0.0	0.0
19-Jun	1986E B	0.0	0.0	22-Jun	1986E B	0.1	0.1	6-Jul	1986E B	0.0	0.0	27-Jul	1986E B	0.3	0.3
19-Jun	BRR	0.0	0.0	22-Jun	BRR	0.0	0.0	6-Jul	BRR	0.0	0.0	27-Jul	BRR	0.4	0.3
19-Jun	BRL	0.2	0.2	22-Jun	BRL	0.0	0.0	6-Jul	BRL	0.0	0.0	27-Jul	BRL	0.1	0.1
19-Jun	BRC	0.0	0.0	22-Jun	BRC	0.0	0.0	6-Jul	BRC	0.0	0.0	27-Jul	BRC	0.3	0.2
19-Jun	PRE	0.0	0.0	22-Jun	PRE	0.0	0.0	6-Jul	PRE	0.0	0.0	27-Jul	PRE	0.1	0.1
19-Jun	PRW	0.3	0.2	22-Jun	PRW	0.0	0.0	6-Jul	PRW	0.0	0.0	27-Jul	PRW	0.0	0.0
19-Jun	EPU	0.0	0.0	22-Jun	EPU	0.0	0.0	6-Jul	EPU	0.0	0.0	27-Jul	EPU	0.2	0.1
19-Jun	EPU-trib			22-Jun	EPU-trib	0.0	0.0	6-Jul	EPU-trib	0.0	0.0	27-Jul	EPU-trib	0.0	0.0
19-Jun	EPC	0.0	0.0	22-Jun	EPC	0.0	0.0	6-Jul	EPC	0.0	0.0	27-Jul	EPC	0.2	0.2
19-Jun	DCP	0.3	0.2	22-Jun	DCP	0.0	0.0	6-Jul	DCP	0.0	0.0	27-Jul	DCP	0.0	0.0
19-Jun	DCG	0.0	0.0	22-Jun	DCG	0.0	0.0	6-Jul	DCG	0.0	0.0	27-Jul	DCG	0.0	0.0
19-Jun	DCF	0.0	0.0	22-Jun	DCF	0.0	0.0	6-Jul	DCF	0.0	0.0	27-Jul	DCF	0.0	0.0
19-Jun	DCC	0.2	0.2	22-Jun	DCC	0.0	0.0	6-Jul	DCC	0.0	0.0	27-Jul	DCC	0.0	0.0
19-Jun	LRW	0.0	0.0	22-Jun	LRW	0.0	0.0	6-Jul	LRW	0.0	0.0	27-Jul	LRW	0.3	0.2
19-Jun	LRS	0.0	0.0	22-Jun	LRS	0.0	0.0	6-Jul	LRS	0.0	0.0	27-Jul	LRS	0.4	0.3
19-Jun	LRR	0.0	0.0	22-Jun	LRR	0.0	0.0	6-Jul	LRR	0.0	0.0	27-Jul	LRR	0.1	0.1
19-Jun	LRC	0.4	0.3	22-Jun	LRC	0.0	0.0	6-Jul	LRC	0.1	0.1	27-Jul	LRC	0.4	0.3
19-Jun	CC	0.0	0.0	22-Jun	CC	0.2	0.1	6-Jul	CC	0.0	0.0	27-Jul	CC	0.2	0.1
19-Jun	CC-up			22-Jun	CC-up	0.0	0.0	6-Jul	CC-up	0.0	0.0	27-Jul	CC-up	0.0	0.0
19-Jun	CF	0.0	0.0	22-Jun	CF	0.0	0.0	6-Jul	CF	0.0	0.0	27-Jul	CF	0.0	0.0
19-Jun	FMH	0.0	0.0	22-Jun	FMH	0.0	0.0	6-Jul	FMH	0.0	0.0	27-Jul	FMH	0.0	0.0
19-Jun	DCC-u	0.0	0.0	22-Jun	DCC-u	0.0	0.0	6-Jul	DCC-u	0.1	0.1	27-Jul	DCC-u	0.3	0.2
19-Jun	DCC	0.2	0.2	22-Jun	DCC	0.0	0.0	6-Jul	DCC	0.0	0.0	27-Jul	DCC	0.0	0.0
19-Jun	DCC-d	0.0	0.0	22-Jun	DCC-d	0.0	0.0	6-Jul	DCC-d	0.0	0.0	27-Jul	DCC-d	0.3	0.2
19-Jun	BD	0.0	0.0	22-Jun	BD	0.0	0.0	6-Jul	BD	0.1	0.1	27-Jul	BD	0.6	0.5
19-Jun	BD-trib			22-Jun	BD-trib	0.0	0.0	6-Jul	BD-trib	0.2	0.1	27-Jul	BD-trib		
19-Jun	STP-u	0.0	0.0	22-Jun	STP-u	0.0	0.0	6-Jul	STP-u	0.1	0.1	27-Jul	STP-u	0.3	0.2
19-Jun	STP-dis	0.0	0.0	22-Jun	STP-dis	0.0	0.0	6-Jul	STP-dis	0.0	0.0	27-Jul	STP-dis	0.3	0.2
19-Jun	STP-d	0.0	0.0	22-Jun	STP-d	0.0	0.0	6-Jul	STP-d	0.0	0.0	27-Jul	STP-d	0.0	0.0
19-Jun	OCR	0.0	0.0	22-Jun	OCR	0.0	0.0	6-Jul	OCR	0.0	0.0	27-Jul	OCR	0.0	0.0
19-Jun	BER	0.0	0.0	22-Jun	BER	0.0	0.0	6-Jul	BER	0.0	0.0	27-Jul	BER	0.0	0.0
19-Jun	RHB	0.0	0.0	22-Jun	RHB	0.0	0.0	6-Jul	RHB	0.0	0.0	27-Jul	RHB	0.0	0.0
19-Jun	RHB-trib			22-Jun	RHB-trib	0.0	0.0	6-Jul	RHB-trib	0.1	0.1	27-Jul	RHB-trib	0.2	0.1
19-Jun	SJR	0.0	0.0	22-Jun	SJR	0.0	0.0	6-Jul	SJR	0.0	0.0	27-Jul	SJR	0.0	0.0
19-Jun	SJR-trib			22-Jun	SJR-trib			6-Jul	SJR-trib	0.2	0.1	27-Jul	SJR-trib		
19-Jun	EPC-u	0.0	0.0	22-Jun	EPC-u	0.0	0.0	6-Jul	EPC-u	0.0	0.0	27-Jul	EPC-u	0.0	0.0
19-Jun	EPC	0.0	0.0	22-Jun	EPC	0.0	0.0	6-Jul	EPC	0.0	0.0	27-Jul	EPC	0.2	0.2
19-Jun	EPC-d	0.0	0.0	22-Jun	EPC-d	0.0	0.0	6-Jul	EPC-d	0.0	0.0	27-Jul	EPC-d	0.1	0.1
19-Jun	SRC-u	0.0	0.0	22-Jun	SRC-u	0.0	0.0	6-Jul	SRC-u	0.0	0.0	27-Jul	SRC-u	0.5	0.4
19-Jun	SRC			22-Jun	SRC	0.0	0.0	6-Jul	SRC	0.0	0.0	27-Jul	SRC	0.0	0.0
19-Jun	SRC-d	0.0	0.0	22-Jun	SRC-d	0.0	0.0	6-Jul	SRC-d	0.0	0.0	27-Jul	SRC-d	0.3	0.2
19-Jun	RRM	0.1	0.1	22-Jun	RRM	0.0	0.0	6-Jul	RRM	0.0	0.0	27-Jul	RRM	0.0	0.0
19-Jun	3906-u	0.0	0.0	22-Jun	3906-u	0.0	0.0	6-Jul	3906-u	0.0	0.0	27-Jul	3906-u	0.1	0.1
19-Jun	3906-rd	0.0	0.0	22-Jun	3906-rd	0.0	0.0	6-Jul	3906-rd	0.0	0.0	27-Jul	3906-rd	0.0	0.0
19-Jun	3906C			22-Jun	3906C			6-Jul	3906C	0.0	0.0	27-Jul	3906C		
19-Jun	3906-d	0.3	0.2	22-Jun	3906-d	0.0	0.0	6-Jul	3906-d	0.0	0.0	27-Jul	3906-d	0.0	0.0

		[PO4]	[P]				[PO4]	[P]				[PO4]	[P]				[PO4]	[P]
Date	**Station**	**(mg/L)**	**(mg/L)**		**Date**	**Station**	**(mg/L)**	**(mg/L)**		**Date**	**Station**	**(mg/L)**	**(mg/L)**		**Date**	**Station**	**(mg/L)**	**(mg/L)**
19-Jun	HBT-U	0.3	0.1		22-Jun	HBT-U	0.2	0.1		6-Jul	HBT-U	0.2	0.1		27-Jul	HBT-U	0.2	0.1
19-Jun	HBT	0.4	0.1		22-Jun	HBT	0.2	0.1		6-Jul	HBT	0.1	0.0		27-Jul	HBT	0.2	0.1
19-Jun	HBT-d	0.3	0.1		22-Jun	HBT-d	0.2	0.1		6-Jul	HBT-d	0.1	0.0		27-Jul	HBT-d	0.2	0.1
19-Jun	BW-L				22-Jun	BW-L	0.0	0.0		6-Jul	BW-L	0.1	0.0		27-Jul	BW-L	0.0	0.0
19-Jun	HBR	0.0	0.0		22-Jun	HBR	0.1	0.0		6-Jul	HBR	0.1	0.0		27-Jul	HBR	0.0	0.0
19-Jun	WFU	0.2	0.1		22-Jun	WFU	0.2	0.1		6-Jul	WFU	0.1	0.0		27-Jul	WFU	0.1	0.0
19-Jun	TBC-u	0.2	0.1		22-Jun	TBC-u	0.2	0.1		6-Jul	TBC-u	0.1	0.0		27-Jul	TBC-u	0.2	0.1
19-Jun	TBC	0.2	0.1		22-Jun	TBC	0.2	0.1		6-Jul	TBC	0.2	0.1		27-Jul	TBC	0.2	0.1
19-Jun	HBC	0.0	0.0		22-Jun	HBC	0.2	0.1		6-Jul	HBC	0.1	0.0		27-Jul	HBC	0.1	0.0
19-Jun	WFC	0.2	0.1		22-Jun	WFC	0.2	0.1		6-Jul	WFC	0.2	0.1		27-Jul	WFC	0.1	0.0
19-Jun	BER	0.0	0.0		22-Jun	BER	0.1	0.0		6-Jul	BER	0.2	0.1		27-Jul	BER	0.0	0.0
19-Jun	1986W	0.4	0.1		22-Jun	1986W	0.0	0.0		6-Jul	1986W	0.0	0.0		27-Jul	1986W	0.0	0.0
19-Jun	1986E	0.0	0.0		22-Jun	1986E	0.0	0.0		6-Jul	1986E	0.0	0.0		27-Jul	1986E	0.0	0.0
19-Jun	1986E A	0.0	0.0		22-Jun	1986E A	0.0	0.0		6-Jul	1986E A	0.0	0.0		27-Jul	1986E A	0.0	0.0
19-Jun	1986E B				22-Jun	1986E B	0.0	0.0		6-Jul	1986E B	0.0	0.0		27-Jul	1986E B	0.0	0.0
19-Jun	BRR	0.0	0.0		22-Jun	BRR	0.0	0.0		6-Jul	BRR	0.0	0.0		27-Jul	BRR	0.0	0.0
19-Jun	BRL	0.1	0.0		22-Jun	BRL	0.0	0.0		6-Jul	BRL	0.0	0.0		27-Jul	BRL	0.0	0.0
19-Jun	BRC	0.0	0.0		22-Jun	BRC	0.0	0.0		6-Jul	BRC	0.0	0.0		27-Jul	BRC	0.0	0.0
19-Jun	PRE	0.0	0.0		22-Jun	PRE	0.0	0.0		6-Jul	PRE	0.0	0.0		27-Jul	PRE	0.0	0.0
19-Jun	PRW	0.0	0.0		22-Jun	PRW	0.0	0.0		6-Jul	PRW	0.0	0.0		27-Jul	PRW	0.0	0.0
19-Jun	EPU	0.0	0.0		22-Jun	EPU	0.0	0.0		6-Jul	EPU	0.1	0.0		27-Jul	EPU	0.0	0.0
19-Jun	EPU-trib				22-Jun	EPU-trib	0.0	0.0		6-Jul	EPU-trib	0.1	0.0		27-Jul	EPU-trib	0.1	0.0
19-Jun	EPC	0.1	0.0		22-Jun	EPC	0.0	0.0		6-Jul	EPC	0.0	0.0		27-Jul	EPC	0.0	0.0
19-Jun	DCP	0.5	0.1		22-Jun	DCP	0.3	0.1		6-Jul	DCP	0.3	0.1		27-Jul	DCP	0.2	0.1
19-Jun	DCG	0.2	0.1		22-Jun	DCG	0.3	0.1		6-Jul	DCG	0.3	0.1		27-Jul	DCG	0.2	0.1
19-Jun	DCF	0.3	0.1		22-Jun	DCF	0.3	0.1		6-Jul	DCF	0.2	0.1		27-Jul	DCF	0.6	0.2
19-Jun	DCC	0.9	0.3		22-Jun	DCC	0.5	0.2		6-Jul	DCC	0.3	0.1		27-Jul	DCC	0.3	0.1
19-Jun	LRW	0.3	0.1		22-Jun	LRW	0.2	0.1		6-Jul	LRW	0.2	0.1		27-Jul	LRW	0.1	0.0
19-Jun	LRS	0.1	0.0		22-Jun	LRS	0.0	0.0		6-Jul	LRS	0.0	0.0		27-Jul	LRS	0.1	0.0
19-Jun	LRR	0.2	0.1		22-Jun	LRR	0.1	0.0		6-Jul	LRR	0.1	0.0		27-Jul	LRR	0.0	0.0
19-Jun	LRC	0.1	0.0		22-Jun	LRC	0.1	0.0		6-Jul	LRC	0.0	0.0		27-Jul	LRC	0.1	0.0
19-Jun	CC	0.1	0.0		22-Jun	CC	0.5	0.2		6-Jul	CC	0.1	0.0		27-Jul	CC	0.1	0.0
19-Jun	CC-up				22-Jun	CC-up	0.4	0.1		6-Jul	CC-up	0.0	0.0		27-Jul	CC-up	0.0	0.0
19-Jun	CF	0.1	0.0		22-Jun	CF	0.0	0.0		6-Jul	CF	0.0	0.0		27-Jul	CF	0.0	0.0
19-Jun	FMH	0.1	0.0		22-Jun	FMH	0.0	0.0		6-Jul	FMH	0.1	0.0		27-Jul	FMH	0.0	0.0
19-Jun	DCC-u	0.2	0.1		22-Jun	DCC-u	0.1	0.0		6-Jul	DCC-u	0.1	0.0		27-Jul	DCC-u	0.1	0.0
19-Jun	DCC	0.9	0.3		22-Jun	DCC	0.5	0.2		6-Jul	DCC	0.3	0.1		27-Jul	DCC	0.3	0.1
19-Jun	DCC-d	0.3	0.1		22-Jun	DCC-d	0.3	0.1		6-Jul	DCC-d	0.1	0.0		27-Jul	DCC-d	0.2	0.1
19-Jun	BD	0.3	0.1		22-Jun	BD	0.2	0.1		6-Jul	BD	0.1	0.0		27-Jul	BD	0.1	0.0
19-Jun	BD-trib				22-Jun	BD-trib	0.0	0.0		6-Jul	BD-trib	0.0	0.0		27-Jul	BD-trib		
19-Jun	STP-u	0.3	0.1		22-Jun	STP-u				6-Jul	STP-u	0.1	0.0		27-Jul	STP-u	0.1	0.0
19-Jun	STP-dis	0.4	0.1		22-Jun	STP-dis	0.4	0.1		6-Jul	STP-dis	1.4	0.5		27-Jul	STP-dis	0.6	0.2
19-Jun	STP-d	0.4	0.1		22-Jun	STP-d	0.2	0.1		6-Jul	STP-d	0.3	0.1		27-Jul	STP-d	0.5	0.2
19-Jun	OCR	0.6	0.2		22-Jun	OCR	0.4	0.1		6-Jul	OCR	0.4	0.1		27-Jul	OCR	0.3	0.1
19-Jun	BER	0.0	0.0		22-Jun	BER	0.1	0.0		6-Jul	BER	0.2	0.1		27-Jul	BER	0.0	0.0
19-Jun	RHB	0.5	0.2		22-Jun	RHB	0.3	0.1		6-Jul	RHB	0.2	0.1		27-Jul	RHB	0.2	0.1
19-Jun	RHB-trib				22-Jun	RHB-trib	0.2	0.1		6-Jul	RHB-trib	0.2	0.1		27-Jul	RHB-trib		
19-Jun	SJR	0.5	0.1		22-Jun	SJR	0.3	0.1		6-Jul	SJR	0.3	0.1		27-Jul	SJR	0.2	0.1
19-Jun	SJR-trib				22-Jun	SJR-trib				6-Jul	SJR-trib	0.2	0.1		27-Jul	SJR-trib	0.3	0.1
19-Jun	EPC-u	0.6	0.2		22-Jun	EPC-u	0.4	0.1		6-Jul	EPC-u	0.3	0.1		27-Jul	EPC-u	0.2	0.1
19-Jun	EPC	0.1	0.0		22-Jun	EPC	0.0	0.0		6-Jul	EPC	0.0	0.0		27-Jul	EPC	0.0	0.0
19-Jun	EPC-d	0.6	0.2		22-Jun	EPC-d	0.3	0.1		6-Jul	EPC-d	0.2	0.1		27-Jul	EPC-d	0.2	0.1
19-Jun	SRC-u	0.6	0.2		22-Jun	SRC-u	0.3	0.1		6-Jul	SRC-u	0.2	0.1		27-Jul	SRC-u	0.2	0.1
19-Jun	SRC				22-Jun	SRC	0.3	0.1		6-Jul	SRC	0.2	0.1		27-Jul	SRC	0.3	0.1
19-Jun	SRC-d	0.6	0.2		22-Jun	SRC-d	0.4	0.1		6-Jul	SRC-d	0.2	0.1		27-Jul	SRC-d	0.2	0.1
19-Jun	RRM	0.5	0.1		22-Jun	RRM	0.3	0.1		6-Jul	RRM	0.2	0.1		27-Jul	RRM	0.1	0.0
19-Jun	3906-u	0.3	0.1		22-Jun	3906-u	0.3	0.1		6-Jul	3906-u	0.2	0.1		27-Jul	3906-u	0.1	0.0
19-Jun	3906-rd	0.5	0.2		22-Jun	3906-rd	0.5	0.2		6-Jul	3906-rd	0.4	0.1		27-Jul	3906-rd	0.4	0.1
19-Jun	3906C				22-Jun	3906C				6-Jul	3906C	0.4	0.1		27-Jul	3906C		
19-Jun	3906-d	0.3	0.1		22-Jun	3906-d	0.4	0.1		6-Jul	3906-d	0.2	0.1		27-Jul	3906-d	0.1	0.0

		[NO3]	[N]			[NO3]	[N]			[NO3]	[N]			[NO3]	[N]
Date	Station	(mg/L)	(mg/L)	Date	Station	(mg/L)	(mg/L)	Date	Station	(mg/L)	(mg/L)	Date	Station	(mg/L)	(mg/L)
19-Jun	HBT-U	0.0	0.0	22-Jun	HBT-U	1.2	0.3	6-Jul	HBT-U	5.7	1.3	27-Jul	HBT-U	2.5	0.8
19-Jun	HBT	0.0	0.0	22-Jun	HBT	2.7	0.6	6-Jul	HBT	3.4	0.8	27-Jul	HBT	0.6	0.4
19-Jun	HBT-d	0.0	0.0	22-Jun	HBT-d	3.2	0.7	6-Jul	HBT-d	4.6	1.0	27-Jul	HBT-d	2.2	0.7
19-Jun	BW-L			22-Jun	BW-L	5.6	1.3	6-Jul	BW-L	6.9	1.6	27-Jul	BW-L	4.0	1.1
19-Jun	HBR	0.0	0.0	22-Jun	HBR	14.4	3.2	6-Jul	HBR	8.4	1.9	27-Jul	HBR	0.0	0.0
19-Jun	WFU	0.0	0.0	22-Jun	WFU	13.9	3.1	6-Jul	WFU	11.1	2.5	27-Jul	WFU	2.9	0.9
19-Jun	TBC-u	0.0	0.0	22-Jun	TBC-u	9.5	2.1	6-Jul	TBC-u	7.7	1.7	27-Jul	TBC-u	2.5	0.8
19-Jun	TBC	0.0	0.0	22-Jun	TBC	15.8	3.6	6-Jul	TBC	10.4	2.3	27-Jul	TBC	2.9	0.9
19-Jun	HBC	0.0	0.0	22-Jun	HBC	9.5	2.1	6-Jul	HBC	7.3	1.6	27-Jul	HBC	1.4	0.5
19-Jun	WFC	0.0	0.0	22-Jun	WFC	9.0	2.0	6-Jul	WFC	8.0	1.8	27-Jul	WFC	2.5	0.8
19-Jun	BER	0.0	0.0	22-Jun	BER	13.4	3.0	6-Jul	BER	8.0	1.8	27-Jul	BER	0.0	0.0
19-Jun	1986W			22-Jun	1986W	1.7	0.4	6-Jul	1986W	9.2	2.1	27-Jul	1986W	4.4	1.2
19-Jun	1986E	0.0	0.0	22-Jun	1986E	1.2	0.3	6-Jul	1986E	6.5	1.5	27-Jul	1986E	1.0	0.4
19-Jun	1986E A	0.0	0.0	22-Jun	1986E A	6.1	1.4	6-Jul	1986E A	3.8	0.9	27-Jul	1986E A	4.4	1.2
19-Jun	1986E B			22-Jun	1986E B	6.1	1.4	6-Jul	1986E B	9.2	2.1	27-Jul	1986E B	2.5	0.8
19-Jun	BRR	0.0	0.0	22-Jun	BRR	4.1	0.9	6-Jul	BRR	5.7	1.3	27-Jul	BRR	2.2	0.7
19-Jun	BRL	0.0	0.0	22-Jun	BRL	0.0	0.0	6-Jul	BRL	7.7	1.7	27-Jul	BRL	1.8	0.6
19-Jun	BRC	0.0	0.0	22-Jun	BRC	3.6	0.8	6-Jul	BRC	5.3	1.2	27-Jul	BRC	2.2	0.7
19-Jun	PRE	0.8	0.2	22-Jun	PRE	20.2	4.6	6-Jul	PRE	4.9	1.1	27-Jul	PRE	0.6	0.4
19-Jun	PRW	0.0	0.0	22-Jun	PRW	3.2	0.7	6-Jul	PRW	4.6	1.0	27-Jul	PRW	1.0	0.4
19-Jun	EPU	0.0	0.0	22-Jun	EPU	9.0	2.0	6-Jul	EPU	5.3	1.2	27-Jul	EPU	0.6	0.4
19-Jun	EPU-trib			22-Jun	EPU-trib	1.2	0.3	6-Jul	EPU-trib	3.8	0.9	27-Jul	EPU-trib	0.6	0.4
19-Jun	EPC	0.0	0.0	22-Jun	EPC	10.0	2.3	6-Jul	EPC	6.9	1.6	27-Jul	EPC	0.0	0.0
19-Jun	DCP	7.7	1.7	22-Jun	DCP	18.3	4.1	6-Jul	DCP	17.3	3.9	27-Jul	DCP	8.5	2.1
19-Jun	DCG	0.0	0.0	22-Jun	DCG	15.8	3.6	6-Jul	DCG	17.3	3.9	27-Jul	DCG	6.7	1.7
19-Jun	DCF	0.4	0.1	22-Jun	DCF	14.9	3.4	6-Jul	DCF	12.3	2.8	27-Jul	DCF	5.5	1.5
19-Jun	DCC	1.2	0.3	22-Jun	DCC	12.4	2.8	6-Jul	DCC	10.8	2.4	27-Jul	DCC	4.0	1.1
19-Jun	LRW	1.2	0.3	22-Jun	LRW	10.5	2.4	6-Jul	LRW	5.7	1.3	27-Jul	LRW	4.8	1.3
19-Jun	LRS	0.0	0.0	22-Jun	LRS	3.2	0.7	6-Jul	LRS	1.5	0.3	27-Jul	LRS	1.8	0.6
19-Jun	LRR	0.0	0.0	22-Jun	LRR	10.5	2.4	6-Jul	LRR	10.4	2.3	27-Jul	LRR	2.9	0.9
19-Jun	LRC	0.0	0.0	22-Jun	LRC	4.6	1.0	6-Jul	LRC	4.6	1.0	27-Jul	LRC	2.5	0.8
19-Jun	CC	0.0	0.0	22-Jun	CC	0.0	0.0	6-Jul	CC	4.6	1.0	27-Jul	CC	0.6	0.4
19-Jun	CC-up			22-Jun	CC-up	1.7	0.4	6-Jul	CC-up	4.9	1.1	27-Jul	CC-up	0.6	0.4
19-Jun	CF	0.0	0.0	22-Jun	CF	3.6	0.8	6-Jul	CF	3.8	0.9	27-Jul	CF	2.2	0.7
19-Jun	FMH	0.0	0.0	22-Jun	FMH	6.1	1.4	6-Jul	FMH	5.7	1.3	27-Jul	FMH	1.8	0.6
19-Jun	DCC-u	0.0	0.0	22-Jun	DCC-u	9.0	2.0	6-Jul	DCC-u	6.9	1.6	27-Jul	DCC-u	2.5	0.8
19-Jun	DCC	1.2	0.3	22-Jun	DCC	12.4	2.8	6-Jul	DCC	10.8	2.4	27-Jul	DCC	4.0	1.1
19-Jun	DCC-d	0.0	0.0	22-Jun	DCC-d	13.4	3.0	6-Jul	DCC-d	6.9	1.6	27-Jul	DCC-d	3.3	1.0
19-Jun	BD	0.0	0.0	22-Jun	BD	11.9	2.7	6-Jul	BD	6.9	1.6	27-Jul	BD	2.9	0.9
19-Jun	BD-trib			22-Jun	BD-trib	2.7	0.6	6-Jul	BD-trib	2.2	0.5	27-Jul	BD-trib		
19-Jun	STP-u	0.0	0.0	22-Jun	STP-u	11.4	2.6	6-Jul	STP-u	6.5	1.5	27-Jul	STP-u	2.5	0.8
19-Jun	STP-dis	10.9	2.5	22-Jun	STP-dis	8.5	1.9	6-Jul	STP-dis	13.9	3.1	27-Jul	STP-dis	11.6	2.8
19-Jun	STP-d	5.7	1.3	22-Jun	STP-d	7.1	1.6	6-Jul	STP-d	8.0	1.8	27-Jul	STP-d	9.3	2.3
19-Jun	OCR	5.3	1.2	22-Jun	OCR	7.1	1.6	6-Jul	OCR	8.4	1.9	27-Jul	OCR	4.8	1.3
19-Jun	BER	0.0	0.0	22-Jun	BER	13.4	3.0	6-Jul	BER	8.0	1.8	27-Jul	BER	0.0	0.0
19-Jun	RHB	3.2	0.7	22-Jun	RHB	8.0	1.8	6-Jul	RHB	7.7	1.7	27-Jul	RHB	3.7	1.0
19-Jun	RHB-trib			22-Jun	RHB-trib	0.0	0.0	6-Jul	RHB-trib	6.1	1.4	27-Jul	RHB-trib	0.6	0.4
19-Jun	SJR	0.0	0.0	22-Jun	SJR	9.0	2.0	6-Jul	SJR	7.7	1.7	27-Jul	SJR		
19-Jun	SJR-trib	0.0	0.0	22-Jun	SJR-trib			6-Jul	SJR-trib	8.4	1.9	27-Jul	SJR-trib	2.2	0.7
19-Jun	EPC-u	0.4	0.1	22-Jun	EPC-u	15.4	3.5	6-Jul	EPC-u	7.7	1.7	27-Jul	EPC-u	1.8	0.6
19-Jun	EPC	0.0	0.0	22-Jun	EPC	10.0	2.3	6-Jul	EPC	6.9	1.6	27-Jul	EPC	0.0	0.0
19-Jun	EPC-d	0.4	0.1	22-Jun	EPC-d	14.9	3.4	6-Jul	EPC-d	6.9	1.6	27-Jul	EPC-d	2.5	0.8
19-Jun	SRC-u	0.0	0.0	22-Jun	SRC-u	9.0	2.0	6-Jul	SRC-u	6.1	1.4	27-Jul	SRC-u	2.9	0.9
19-Jun	SRC			22-Jun	SRC	28.5	6.4	6-Jul	SRC	3.4	0.8	27-Jul	SRC	2.9	0.9
19-Jun	SRC-d	0.0	0.0	22-Jun	SRC-d	9.5	2.1	6-Jul	SRC-d	5.7	1.3	27-Jul	SRC-d	2.9	0.9
19-Jun	RRM	0.0	0.0	22-Jun	RRM	9.0	2.0	6-Jul	RRM	6.1	1.4	27-Jul	RRM	1.4	0.5
19-Jun	3906-u	0.0	0.0	22-Jun	3906-u	9.0	2.0	6-Jul	3906-u	6.9	1.6	27-Jul	3906-u	1.4	0.5
19-Jun	3906-rd	4.0	0.9	22-Jun	3906-rd	1.7	0.4	6-Jul	3906-rd	4.6	1.0	27-Jul	3906-rd	1.8	0.6
19-Jun	3906C			22-Jun	3906C			6-Jul	3906C	4.6	1.0	27-Jul	3906C		
19-Jun	3906-d	0.0	0.0	22-Jun	3906-d	9.5	2.1	6-Jul	3906-d	7.3	1.6	27-Jul	3906-d	1.4	0.5

Table A2. Fecal Microbe data for the field season of 2015 from Otter Creek. Counts are expressed as colony forming units per 100 milliliters (cfu/100 mL).

Date	Sample	*EC* Count (cfc / 100 mL)	Date	Sample	*EC* Count (cfc / 100 mL)	Date	Sample	*EC* Count (cfc / 100 mL)	Date	Sample	*EC* Count (cfc / 100 mL)
19-Jun	HBT-u	2419.6	22-Jun	HBT-u	2419.6	6-Jul	HBT-U	980.4	27-Jul	HBT-U	410.6
19-Jun	HBT-C	727	22-Jun	HBT-C	727	6-Jul	HBT	980.4	27-Jul	HBT	272.3
19-Jun	HBT-d		22-Jun	HBT-d		6-Jul	HBT-d		27-Jul	HBT-d	
19-Jun	BW-L		22-Jun	BW-L		6-Jul	BW-L	241.1	27-Jul	BW-L	461.1
19-Jun	HBR	980.4	22-Jun	HBR	980.4	6-Jul	HBR	365.4	27-Jul	HBR	62.4
19-Jun	WFU	290.9	22-Jun	WFU	2419.6	6-Jul	WFU	1553.1	27-Jul	WFU	
19-Jun	TBC-u	298.7	22-Jun	TBC-u	169.6	6-Jul	TBC-u	1299.7	27-Jul	TBC-u	344.8
19-Jun	TBC	53.7	22-Jun	TBC	2419.6	6-Jul	TBC	1732.9	27-Jul	TBC	1299.7
19-Jun	HBC	248.1	22-Jun	HBC	920.8	6-Jul	HBC	816.4	27-Jul	HBC	218.7
19-Jun	WFC	167	22-Jun	WFC	1413.6	6-Jul	WFC	1203.3	27-Jul	WFC	1413.6
19-Jun	BER	185	22-Jun	BER	2419.6	6-Jul	BER	816.4	27-Jul	BER	1046.2
19-Jun	1986W	2419.6	22-Jun	1986W	2419.6	6-Jul	1986W	686.7	27-Jul	1986W	1203.3
19-Jun	1986E	866.4	22-Jun	1986E	2419.6	6-Jul	1986E	648.8	27-Jul	1986E	727
19-Jun	1986E A	1119.9	22-Jun	1986E A	2419.6	6-Jul	1986E A	727	27-Jul	1986E A	517.2
19-Jun	1986E B		22-Jun	1986E B	1553.1	6-Jul	1986E B	197.6	27-Jul	1986E B	
19-Jun	BRR	51.2	22-Jun	BRR	727	6-Jul	BRR	613.1	27-Jul	BRR	172.3
19-Jun	BRL		22-Jun	BRL	365.4	6-Jul	BRL	46.7	27-Jul	BRL	261.3
19-Jun	BRC	42	22-Jun	BRC	648.8	6-Jul	BRC		27-Jul	BRC	
19-Jun	PRW	396.8	22-Jun	PRE	816.4	6-Jul	PRE	686.7	27-Jul	PRE	344.4
19-Jun	PRE	2419.6	22-Jun	PRW	290.9	6-Jul	PRW	547.5	27-Jul	PRW	27.5
19-Jun	EPU	1553.1	22-Jun	EPU	137.4	6-Jul	EPU	46	27-Jul	EPU	27.9
19-Jun	EPU-trib		22-Jun	EPU-trib	1986.3	6-Jul	EPU-trib	298.7	27-Jul	EPU-trib	77.1
19-Jun	EPC	2419.6	22-Jun	EPC	365.4	6-Jul	EPC	344.8	27-Jul	EPC	
19-Jun											
19-Jun	DCP	2419.6	22-Jun	DCP	2419.6	6-Jul	DCP	1553.1	27-Jul	DCP	920.8
19-Jun	DCG	2419.6	22-Jun	DCG	2419.6	6-Jul	DCG	1203.3	27-Jul	DCG	1299.7
19-Jun	DCF	816.4	22-Jun	DCF	2419.6	6-Jul	DCF	1119.9	27-Jul	DCF	866.4
19-Jun	DCC	33.2	22-Jun	DCC	344.8	6-Jul	DCC	1732.9	27-Jul	DCC	435.2
19-Jun											
19-Jun	LRW	2419.6	22-Jun	LRW	2419.6	6-Jul	LRW	2419.6	27-Jul	LRW	58.1
19-Jun	LRS	1	22-Jun	LRS	5	6-Jul	LRS	233.4	27-Jul	LRS	29.9
19-Jun	LRS rd	791.5	22-Jun	LRS rd	2419.6	6-Jul	LRR	2419.6	27-Jul	LRR	1203.3
19-Jun	LRC	770.1	22-Jun	LRC		6-Jul	LRC	344.8	27-Jul	LRC	186
19-Jun	CC	1299.7	22-Jun	CC	1203.3	6-Jul	CC	1732.9	27-Jul	CC	2419.6
19-Jun	CC-up		22-Jun	CC-up	2419.6	6-Jul	CC-up	1986.3	27-Jul	CC-up	2419.6
19-Jun	CF	2419.6	22-Jun	CF	2419.6	6-Jul	CF	2419.6	27-Jul	CF	410.6
19-Jun	FMH	648.8	22-Jun	FMH	2419.6	6-Jul	FMH	1732.9	27-Jul	FMH	686.7
19-Jun	DCC-u	1553.1	22-Jun	DCC-u	1732.9	6-Jul	DCC-u	1553.1	27-Jul	DCC-u	343
19-Jun	DCC	33.2	22-Jun	DCC		6-Jul	DCC	1732.9	27-Jul	DCC	435.2
19-Jun	DCC-d	648.8	22-Jun	DCC-d	2419.6	6-Jul	DCC-d	1553.1	27-Jul	DCC-d	
19-Jun	BD	104.3	22-Jun	BD	2419.6	6-Jul	BD	1203.3	27-Jul	BD	547.5
19-Jun	BD trib		22-Jun	BD trib	184.2	6-Jul	BD-trib	152.9	27-Jul	BD-trib	
19-Jun	STP-u	101.4	22-Jun	STP-u	1299.7	6-Jul	STP-u	1046.2	27-Jul	STP-u	261.3
19-Jun	STP-dis	5	22-Jun	STP-dis	6	6-Jul	STP-dis	4	27-Jul	STP-dis	8.6
19-Jun	STP-d	101.4	22-Jun	STP-d	1119.9	6-Jul	STP-d	88.6	27-Jul	STP-d	122.2
19-Jun	OCR	435.2	22-Jun	OCR	517.2	6-Jul	OCR	658.6	27-Jul	OCR	178.9
19-Jun	BER	185	22-Jun	BER	2419.6	6-Jul	BER	816.4	27-Jul	BER	980.4
19-Jun	RHB	172.3	22-Jun	RHB	920.8	6-Jul	RHB	613.1	27-Jul	RHB	119.8
19-Jun	RHB trib		22-Jun	RHB trib	235.9	6-Jul	RHB-trib	410.6	27-Jul	RHB-trib	74.9
19-Jun	SJR	131.4	22-Jun	SJR	579.4	6-Jul	SJR	648.8	27-Jul	SJR	95.9
19-Jun	SJR trib		22-Jun	SJR trib		6-Jul	SJR-trib	435.2	27-Jul	SJR-trib	46.4
19-Jun	EPC-u	161.5	22-Jun	EPC-u	410.6	6-Jul	EPC-u	686.7	27-Jul	EPC-u	98.8
19-Jun	EPC	2419.6	22-Jun	EPC	365.4	6-Jul	EPC	344.8	27-Jul	EPC	70.3
19-Jun	EPC-d		22-Jun	EPC-d		6-Jul	EPC-d		27-Jul	EPC-d	
19-Jun	SRC-u	135.4	22-Jun	SRC-u	435.2	6-Jul	SRC-u	648.8	27-Jul	SRC-u	69.1
19-Jun	SRC		22-Jun	SRC	166.4	6-Jul	SRC	435.2	27-Jul	SRC	13.5
19-Jun	SRC-d		22-Jun	SRC-d		6-Jul	SRC-d		27-Jul	SRC-d	
19-Jun	RRM	1299.7	22-Jun	RRM	920.8	6-Jul	RRM	648.8	27-Jul	RRM	1732.9
19-Jun	3906-u	980.4	22-Jun	3906-u	816.4	6-Jul	3906-u	816.4	27-Jul	3906-u	1203.3
19-Jun	3906 -road	816.4	22-Jun	3906 -road	365.4	6-Jul	3906-rd	140.3	27-Jul	3906-rd	2419.6
19-Jun	3906-C		22-Jun	3906-C		6-Jul	3906C	547.5	27-Jul	3906C	
19-Jun	3906-d		22-Jun	3906-d		6-Jul	3906-d		27-Jul	3906-d	