EVALUATION OF BACTERIAL WATER QUALTY AROUND THE COASTAL TOWN OF SUWANNEE, FLORIDA

ABSTRACT

Salmonella contamination was detected in 1989 in commercially-harvested oysters from an area around the town of Suwannee, Florida. The contamination was suspected to be caused in part by onsite sewage treatment and disposal systems in the town. A central wastewater treatment plant was constructed in 1997 to alleviate the potential *salmonella* contamination source by abandoning all onsite sewage treatment and disposal systems. Prior to commencement of the wastewater treatment plant operations, a water quality study was conducted around the town of Suwannee during November-December of 1996. Thirteen years after the completion of the wastewater treatment plant and closure of the septic tanks, the same study was repeated in November-December of 2009 to evaluate potential differences in water quality that may be attributed to onsite sewage treatment and disposal systems closure. Both the studies focused on sampling of nutrients, coliforms, and *salmonella* at stations upstream and downstream of the town on the Suwannee River and in canals within the town as well as in a groundwater monitoring well. The 1996 study indicated that there were more occurrences of *salmonella* in the river than in the canals suggesting the town was not the primary source of *salmonella*. The 1996 study also found higher levels of fecal coliforms in the canals than in the rivers suggesting that the town could be a contributor to bacterial contamination. The 2009 study showed that *salmonella* occurrences were equal in the river and the canals again

indicating the canals were not the primary source of *salmonella*. In 2009, total Kjeldahl nitrogen was positively correlated with river flow, whereas nitrate-nitrite exhibited a negative correlation. The total and fecal coliforms were higher in the canals than in the river. However, fecal coliform decreased from 1996 to 2009 in both the canals and the river stations, whereas total coliforms increased from 1996 to 2009. Statistical comparison of the 2009 results with the 1996 results indicated that there were statistically significant changes in fecal coliform in the canals ($P < 0.001$), total coliforms in the river ($P < 0.001$), and total nitrogen in the river ($P = 0.011$).

INTRODUCTION

A cooperative study by the Florida Department of Natural Resources (now the Florida Department of Environmental Protection), the Florida Department of Agriculture and Consumer Services, and the U.S. Food and Drug Administration in 1990 (Glatzer, 1990), investigated an incidence of gastroenteritis in Florida during 1989 and 1990. At least two of the cases were indicative of salmonellosis. Samples of Florida oysters were analyzed for *salmonella*, and about 39 percent of the oysters tested positive for *salmonella*; approximately 90 percent of these oysters were from Suwannee Sound and adjacent areas. In addition, *salmonella* was detected in water samples taken above and below the town of Suwannee. Possible sources identified by Glatzer (1990) were the waterfowl and wildlife in the area. According to the Florida Department of Health and Rehabilitative Services (FDHRS, 1991), now the Florida Department of Health, the town of Suwannee had a total of 717 onsite sewage and treatment disposal systems (OSTDS). Of these, based on agency assessment criteria, seven (i.e., <1 percent) systems were considered adequate. The remaining 710 inadequate OSTDS were identified as another possible source for *salmonella* contamination of the oysters in Suwannee Sound. Because of the number of inadequate OSTDS, plans were approved to abandon them and construct a central wastewater treatment plant (WWTP). The facility became operational in October 1997 and all OSTDS were abandoned and emptied by March 1998.

Prior to commencement of the WWTP operations, a water quality study was conducted around the town of Suwannee during November-December of 1996. Thirteen years after the completion of the wastewater treatment plant and closure of the septic tanks, the same study was repeated in November-December of 2009 to evaluate potential differences in water quality that may be attributed to OSTDS closure.

The intent of the 2009 study was to provide an updated evaluation of the potential environmental improvements of closing the OSTDS and sewering the town to a central WWTP. This paper presents a comparison of the results from the pre-WWTP water quality sampling in November-December 1996 with the post-WWTP sampling in November-December 2009 to evaluate potential improvement of closing the OSTDS. In this study, nitrate-nitrite (NOx), total Kjeldahl nitrogen (TKN), total nitrogen (total N), total and fecal coliforms, and *salmonella* in the vicinity of the town of Suwannee were evaluated. The main aim of this study was to assess the water quality in the Suwannee River around the town of Suwannee before and after the installation of a WWTP and to identify potential benefits of the OSTDS closures.

MATERIALS AND METHODS

This study concentrated on the area surrounding the Town of Suwannee which is located on the Gulf of Mexico, about 2 miles upstream on the Suwannee River in Dixie County, Florida. The study area is tidally-influenced and extends from the mouths of two of the major channels of the Suwannee River (Alligator Pass and Wadley Pass) to a point about 4.5 miles upstream of the river mouth (Figure 1). The Suwannee River at this point is the boundary between Dixie and Levy Counties in northwestern peninsular Florida.

To meet the goal of identifying potential improvements of closing the OSTDS, ten water quality sampling locations were established consisting of nine surface water stations and one groundwater station (monitoring well). These stations were sampled prior to and subsequent to OSTDS closure. The surface water stations included four river stations, two upstream and two downstream of the town, and five canal stations within the town. The surface water stations were sampled from a boat as surface grab samples. The monitoring well was sampled using a peristaltic pump and tubing. Global positioning systems along with visual references were used to position the boat at the same surface water station locations on each survey.

Prior to initiating sampling, a quality assurance project plan (QAPP) was developed documenting methodologies to be used for water quality sampling, sample analyses, data review and verification, and reporting (ECT, 2009). Sampling activities followed protocols published by the Florida Department of Environmental Protection (FDEP, 2008). Based on screening sampling during the 1996 study, the worst-case sampling period for evaluating the OSTDS influence on water quality was during low slack tide as water issued from the canals. Therefore surface water sampling was done over a duration that bracketed the predicted low slack tide on the selected sampling day, which was on Mondays for eight consecutive weeks.

Per the QAPP, to evaluate the integrity of field protocols at least 10 percent of the samples were comprised of quality assurance/quality control (QA/QC) samples consisting of sampling equipment and field blanks as well as field duplicates. Additionally, the laboratory utilized the project samples to generate matrix spikes and matrix spike duplicates to assess the precision and accuracy of analytical procedures. The instrument used for field *in situ* measurements was calibrated at the beginning of each sampling day and had a calibration verification check at the end of the day.

Each water sample was collected as a surface grab sample from within the top 1 foot of the water column. The sample was collected using a pre-cleaned 1-liter sample bottle provided by the laboratory. A new sample bottle was used at each station precluding the need to decontaminate the sampling device between stations and avoiding the potential for station cross-contamination. Each station's sample bottle kit was stored in a sealable (e.g., Zip-Loc®) bag prior to and following sampling to prevent station cross-contamination. Samples were placed on ice immediately following collection and until delivery to the laboratory. Samples were delivered to the laboratory within the 6-hour holding time required for the bacteriological parameters. Samples were analyzed quantitatively for total and fecal coliforms, NOx, TKN, and qualitatively (presence/absence) for *salmonella*. Sample analyses were performed using the EPA-approved methods (EPA, 2009), or methods published in the 20th edition of Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1998).

To help determine if the observed differences were attributable to septic tank closure, water quality data from the 1996 and 2009 sampling events were analyzed using five water quality parameters including total and fecal coliforms, NOx, TKN, and total N. Total N was derived from adding TKN and NOx. A t-test was performed to compare the weekly mean values of water quality parameters for both the canal stations and river stations between 1996 and 2009. Although not all of the parameters passed the normality test, the t-test was still applied to compare the mean values. In addition, a nonparametric test (Mann-Whitney rank sum test) was used to compare the median values to determine if the observed changes were significant.

RESULTS AND DISCUSSION

For a controlled study, it is desirable to keep all variables constant except the study parameter. In this case, the study parameter was the effect of closing septic tanks on water quality. Key parameters that could affect or bias the study are river discharge and variation in the ambient water quality parameters. The Suwannee River discharge for the sampling periods of 1996 and 2009 were comparable (Figure 2). Comparison of ambient water quality parameters including dissolved oxygen, pH, temperature, and specific conductivity also indicated the values were comparable between the 1996 and 2009 studies (Figure 3). Consequently, since the ambient river conditions were comparable during the 1996 and 2009 studies, it enhanced the chance of identifying differences in water quality resulting from septic tank closure.

The summary results from the 1996 and 2009 studies are presented in Table 1. The table provides summary values of the eight sampling events for each year which are grouped into canal stations (includes five stations), river stations (includes four stations), and the monitoring well. A summary of all nine surface water stations is also provided for comparison of the 1996 and 2009 results. A summary of the results for each parameter is provided below.

Salmonella

Salmonella samples were analyzed for presence/absence only in both 1996 and 2009 (Table 1). *Salmonella* in the groundwater well were present in half of the samples as compared to none in 1996. In 2009, *salmonella* were present 63 percent of time over the sampling period both in the river and canal stations. This indicates that *salmonella* issuing from the canals is not the primary source of *salmonella* in the river. In 1996, *salmonella* were present in the river stations 75 percent of the time with 100 percent occurrence at Stations 8, 9, and 10, and no occurrence at Station 7 (not shown in the table). *Salmonella* were present in the five canal stations only 15 percent of the time in 1996. The occurrence of *salmonella* decreased in the river stations from 75 percent to 63 percent from 1996 to 2009; however, in the canal stations, the occurrence increased from 15 percent in 1996 to 63 percent in 2009 (Table 1). The results indicate that the occurrences of *salmonella* were higher in the river than in the canals in 1996 and the same in 2009, indicating the canals were not the primary source of *salmonella*. Also, the percent occurrence of *salmonella* in the canals was higher in 2009 as compared to that in 1996, indicating septic tank closure did not reduce *salmonella* in the canals.

Coliforms

Fecal coliforms in the groundwater well changed significantly from 1996 to 2009 as the fecal coliforms count decreased from 232 mpn/100 mL in 1996 to 1 mpn/100 mL in 2009 (Table 1). The fecal coliform values were much higher in the canals than in the river in both 1996 (537 vs. 170 mpn/100 mL) and 2009 (218 vs. 120 mpn/100 mL) suggesting that the canals are a source of fecal coliforms. This is not surprising given the concentration of fish, birds, and other animals in canal areas. The results also indicate that there was a reduction in fecal coliforms in 2009 in the canals (59 percent), in the river (29 percent), and also in the groundwater (100 percent). The large reduction of fecal coliforms in the canals and the groundwater well can be attributed to the closing of the septic tanks.

Similar to the fecal coliform data, the total coliform values were higher in the canals than the river in both 1996 and 2009, again indicating that the canals are a source of coliforms. However, contrary to the fecal coliforms, the total coliforms increased in 2009 at both the river and canal stations. There was also a large increase in total coliforms in the groundwater well in 2009 as compared to 1996. Consequently, closing the septic tanks did not reduce the total coliform values. Fecal and total coliforms in 1996 and 2009 sampling periods are presented in Figure 4.

Nitrogen

Overall summary of changes in nitrogen in the canal as well as the river stations are presented in Table 1. Nitrogen constituents in the groundwater well showed an improvement in 2009. As compared to 1996, groundwater NOx in 2009 reduced by almost 100 percent, whereas TKN and total N decreased by over 80 percent each (see Table 1). The river NOx was always greater than the canal NOx. The table also shows there was an overall reduction (average of all stations) in NOx in 2009 as compared to 1996. However, the reduction could not be attributed to closing septic tanks because the reduction at the river stations and the reduction at the canal stations both were at 7 percent. For the other nitrogen species, TKN in canals increased from 1996 to 2009, but the values observed in the river were comparable in both 1996 and 2009. The increase in

TKN was offset by the decrease in NOx such that the total nitrogen remained nearly unchanged between 1996 and 2009 (Figure 5).

To illustrate the effects of river flow, the weekly average NOx values for the sampling periods in 1996 and 2009 are plotted with river discharge in Figure 6. The NOx data for the river stations indicated there was a correlation between NOx and river flow. The figure illustrates the strong correlation ($R^2 = 0.78$) between river flow and NOx for 1996 data, whereas the correlation is moderate ($R^2 = 0.56$) for 2009 data. This is partly because the river flow was relatively constant at approximately 5,000 cfs in 2009 sampling events except for one high flow value (see Figure 2).

Statistical Analysis

Of the five parameters tested for the canals, only fecal coliforms were significantly different between the 1996 and 2009 samples. For the river stations, the results indicated that there was a significant increase in total coliform in 2009 as compared to 1996 and statistically significant decrease in total N. Statistical test results are presented in Table 2. Statistical analyses showed that the water quality in canal stations significantly changed with respect to fecal coliform concentrations after installation of the WWTP ($P < 0.001$). Total coliforms in 2009 in the river, on the other hand, were significantly higher ($P < 0.001$) than 1996. The concentration of total N in the river in 2009 was significantly lower at $p < 0.011$ from 1996 concentration.

The significant difference observed in the total coliform data is the result of a large increase in total coliforms in the river from 1996 to 2009 as compared to a relatively small change in the canals. The difference is not the result of large changes in the canals and probably cannot be attributed to septic tank closure. However, the significant difference in the fecal coliform is the result of the observed significant decrease in fecal coliform in the canals from 1996 to 2009. The fecal coliform counts in the river stations changed very little; consequently, the reduction in fecal coliform was unique to the canals and could possibly be attributed to septic tank closure.

CONCLUSIONS

The goal of this study was to evaluate the long-term effects of closing approximately 850 OSTDS in the town of Suwannee and installing a central WWTP. The approach was to sample water quality in the Suwannee River and the canals within the town of Suwannee and compare the results with data collected in 1996 prior to OSTDS closures. The most recent study was conducted during the same season and during comparable river discharge conditions as the 1996 baseline survey conducted prior to septic tank removal. Therefore, this study provides a defensible data set to evaluate potential improvements in the area 13 years after septic tank closure.

The results did not suggest that there was large improvement in water quality in the canals between 1996 and 2009 that could be attributed to closing the OSTDS. However, several specific observations and some improvements were noted:

- *Salmonella* occurrences were equal to or higher in the river than in the canals in both 2009 and 1996, indicating the canals were not the primary source of *salmonella*. The percent occurrence of *salmonella* in the canals was greater in 2009 than in 1996, indicating septic tank closure did not reduce *salmonella* in the canals.
- NOx exhibited a strong correlation with river flow and decreased with increasing river flow. There was consistently more NOx in the river samples than in the canals. There was a slight but significant decrease of 6 percent in total N in the river stations between 1996 and 2009.

- The total and fecal coliform values were higher in the canals than in the river in both 1996 and 2009. Fecal coliform values decreased from 1996 to 2009 in both the canals and the river stations, whereas total coliforms increased from 1996 to 2009. The higher values of coliforms in 2009 in the canals as compared to the river could be from domestic animals or wildlife concentrated near the canals, whereas in 1996, higher coliforms count could have been from a combination of OSTDS and other sources.
- A comparison of the 2009 results with the 1996 results indicated there were three statistically significant changes in the measured parameters between 1996 and 2009:
    - There was a 59-percent decrease in fecal coliform in the canals.
    - There was a 330-percent increase in total coliforms in the river.
    - There was a 6-percent decrease in total N in the river.

  All other observed changes in the surface water samples were not statistically significant.

The results indicated that there was a statistically significant 59-percent reduction of fecal coliform in the canals between 1996 and 2009 that could not be attributed to changes observed in the river stations. Consequently, this reduction could be a benefit of the OSTDS closure. There was also an increase in total coliforms in the canals, but it was less than the increase in the river. No other significant improvements in the water quality of the canals was identified that could be attributed to OSTDS closures.

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Table 1. Average concentrations of water quality parameters in the 1996 and 2009 sampling events. Data are presented for River Stations, Canal Stations, Monitoring Well, and combined River and Canal Stations (All Stations average excluding the Monitoring Well)

Water Quality Parameters	Average Values 1996	Average Values 2009	% Change from 1996
Canal Stations			
Total Coliform (mpn/100ml)	537	654	22
Fecal Coliform (mpn/100ml)	537	218	-59
TKN (mg/L)	0.41	0.47	15
NOx (mg/L)	0.73	0.68	-7
TN (mg/L)	1.14	1.15	1
Salmonella (% presence)	15	63	320
River Stations			
Total Coliform (mpn/100ml)	171	565	330
Fecal Coliform (mpn/100ml)	170	120	-29
TKN (mg/L)	0.39	0.37	-5
NOx (mg/L)	0.88	0.82	-7
TN (mg/L)	1.26	1.19	-6
Salmonella (% presence)	75	63	-16
Monitoring well			
Total Coliform (mpn/100ml)	234	845	361
Fecal Coliform (mpn/100ml)	232	1	-100
TKN (mg/L)	7.44	1.35	-82
NOx (mg/L)	1.88	0.01	-99
TN (mg/L)	9.33	1.36	-85
Salmonella (% presence)	0	50	---
All Stations (except Monitoring Well)			
Total Coliform (mpn/100ml)	374	614	64
Fecal Coliform (mpn/100ml)	374	174	-53
TKN (mg/L)	0.40	0.43	7
NOx (mg/L)	0.79	0.73	-8
TN (mg/L)	1.20	1.15	-4
Salmonella (% presence)	42	63	50

Table 2. Mean and standard deviations of river and canal station in 1996 and 2009. *Indicates significant difference in the canal and river mean values. P value is the probability of being wrong in concluding that there is a true difference between the groups.

	1996		2009		
Parameters	Mean	Standard Deviation	Mean	Standard Deviation	P
Canal Stations					
Fecal Coliform (mpn/100 ml)	537	523	218	174	<0.001*
Total Coliform (mpn/100 ml)	537	523	654	472	0.168
NOx (mg/L)	0.73	0.13	0.68	0.24	0.257
TKN (mg/L)	0.41	0.15	0.47	0.22	0.073
Total N (mg/L)	1.14	0.12	1.15	0.16	0.844
River Stations					
Fecal Coliform (mpn/100 ml)	170	200	120	92	0.169
Total Coliform (mpn/100 ml)	171	200	565	525	< 0.001*
NOx (mg/L)	0.88	0.08	0.82	0.27	0.133
TKN (mg/L)	0.39	0.09	0.37	0.23	0.701
Total N (mg/L)	1.27	0.12	1.19	0.17	0.011*

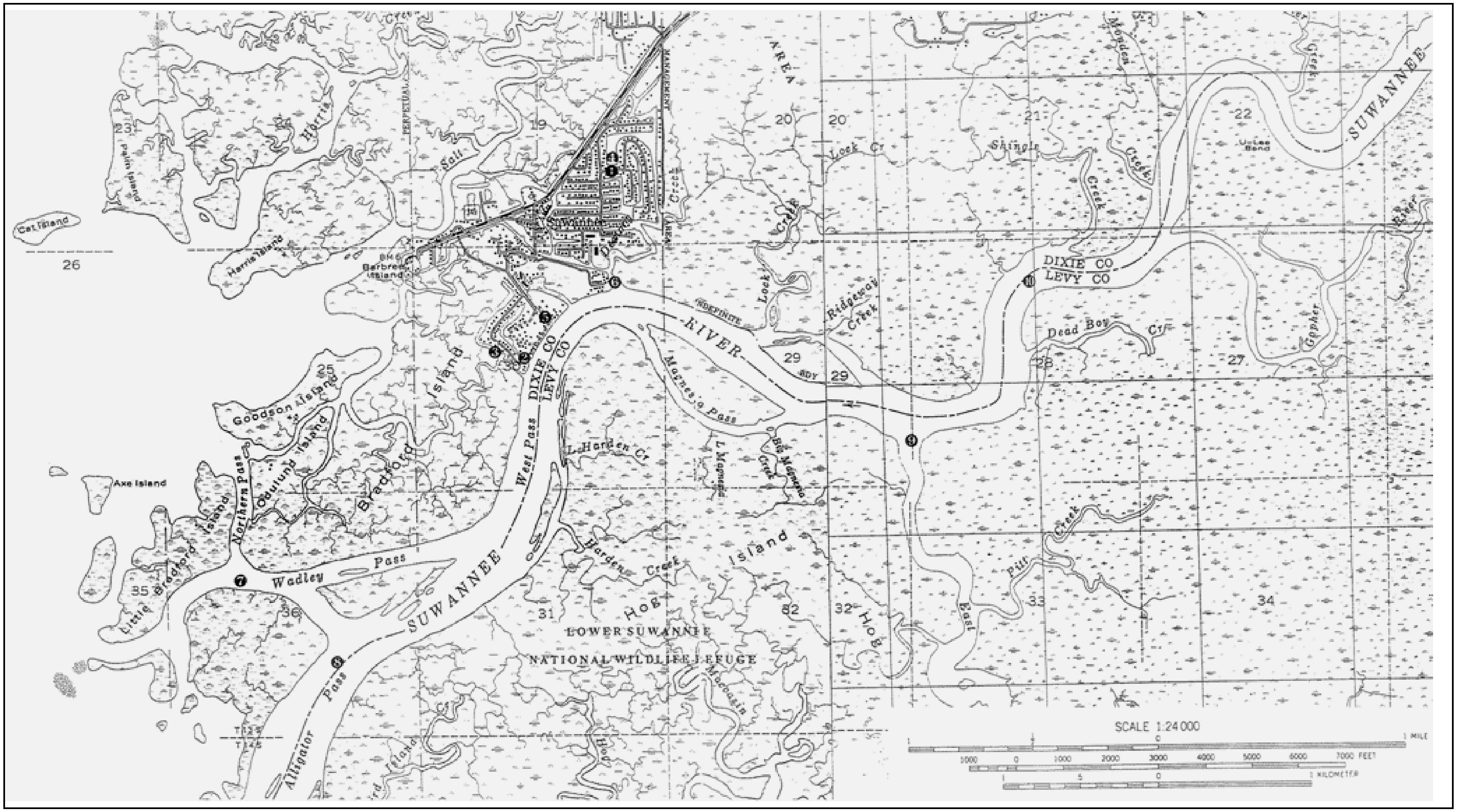

Figure 1. Study area and water quality monitoring stations

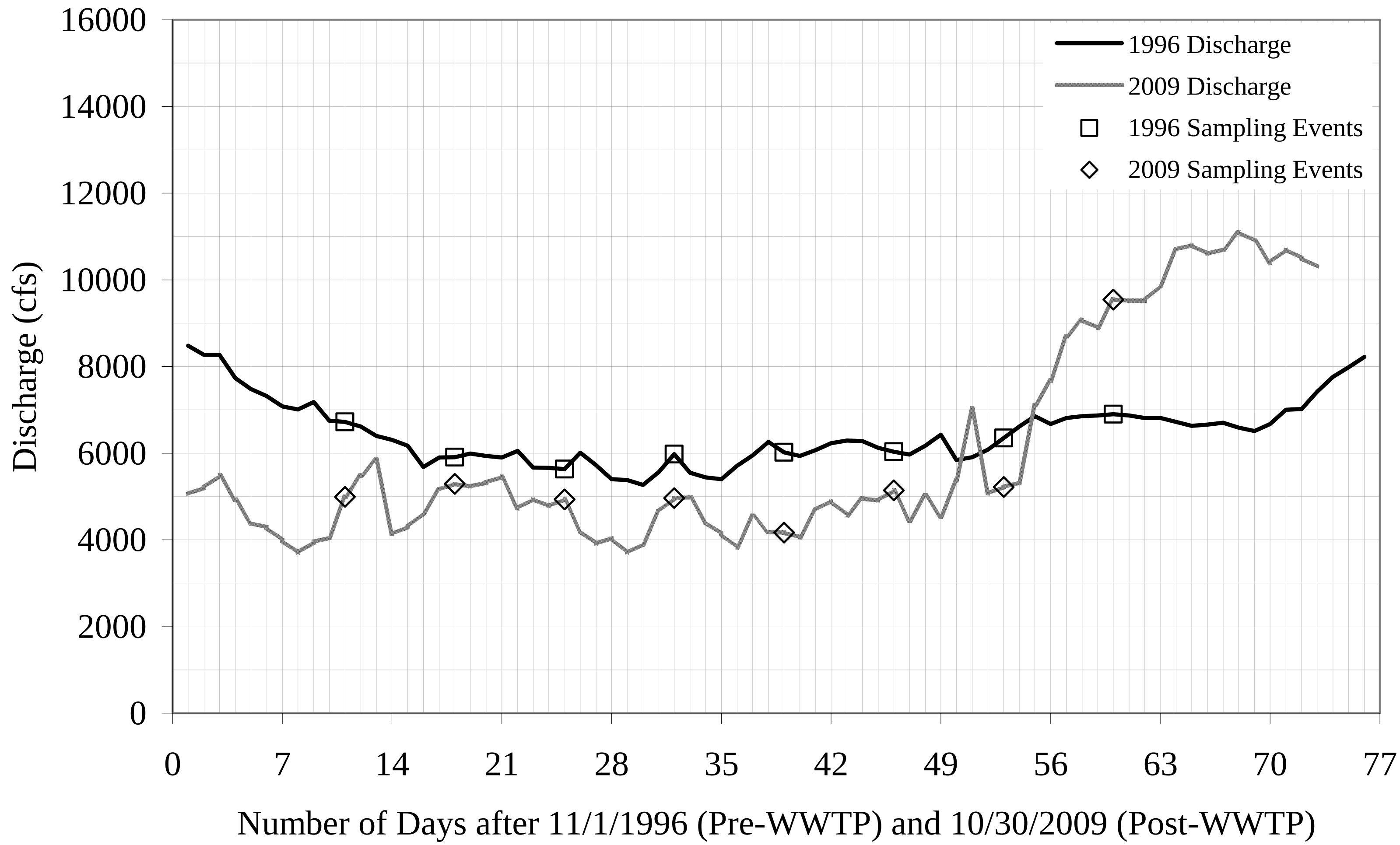

Figure 2. River discharges and sampling events during the November-December of 1996 and 2009

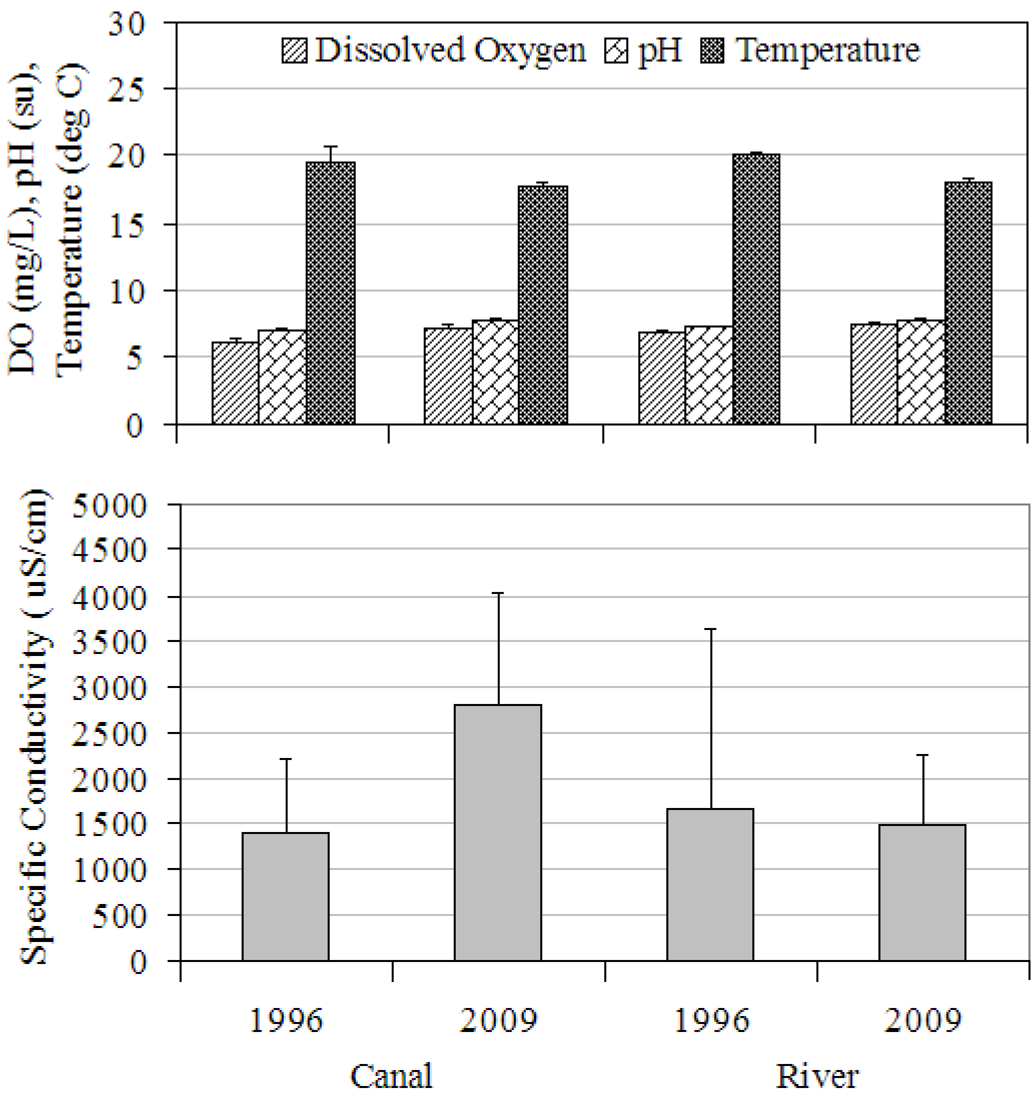

Figure 3. Comparison of ambient water quality in river and canals observed in 1996 and 2009 sampling periods. Also shown are standard deviations.

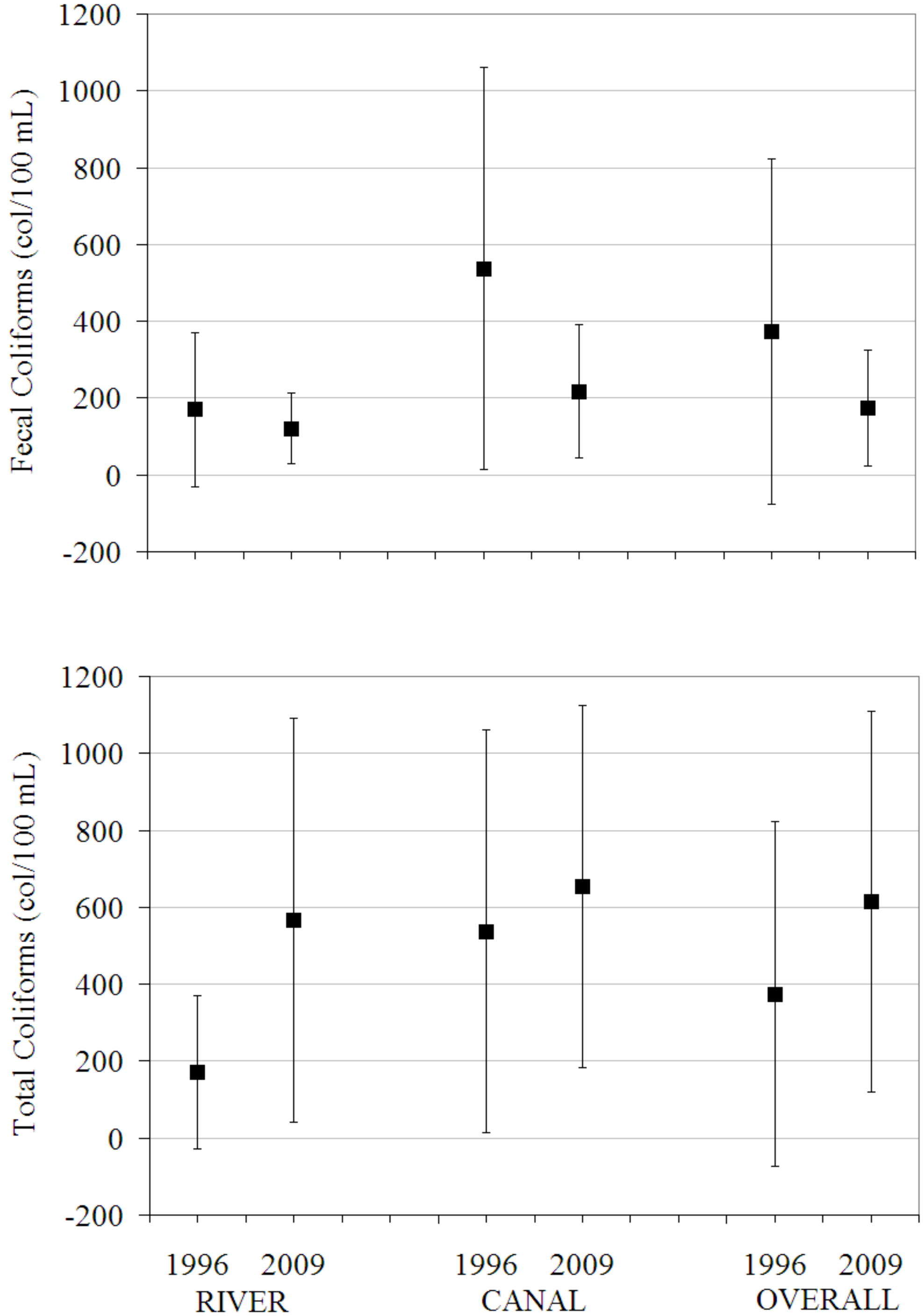

Figure 4. Comparison of fecal and total coliforms in river and canal observed in 1996 and 2009 sampling periods. Average values are shown with ± standard deviation. Overall values are the combination of river and canal station value.

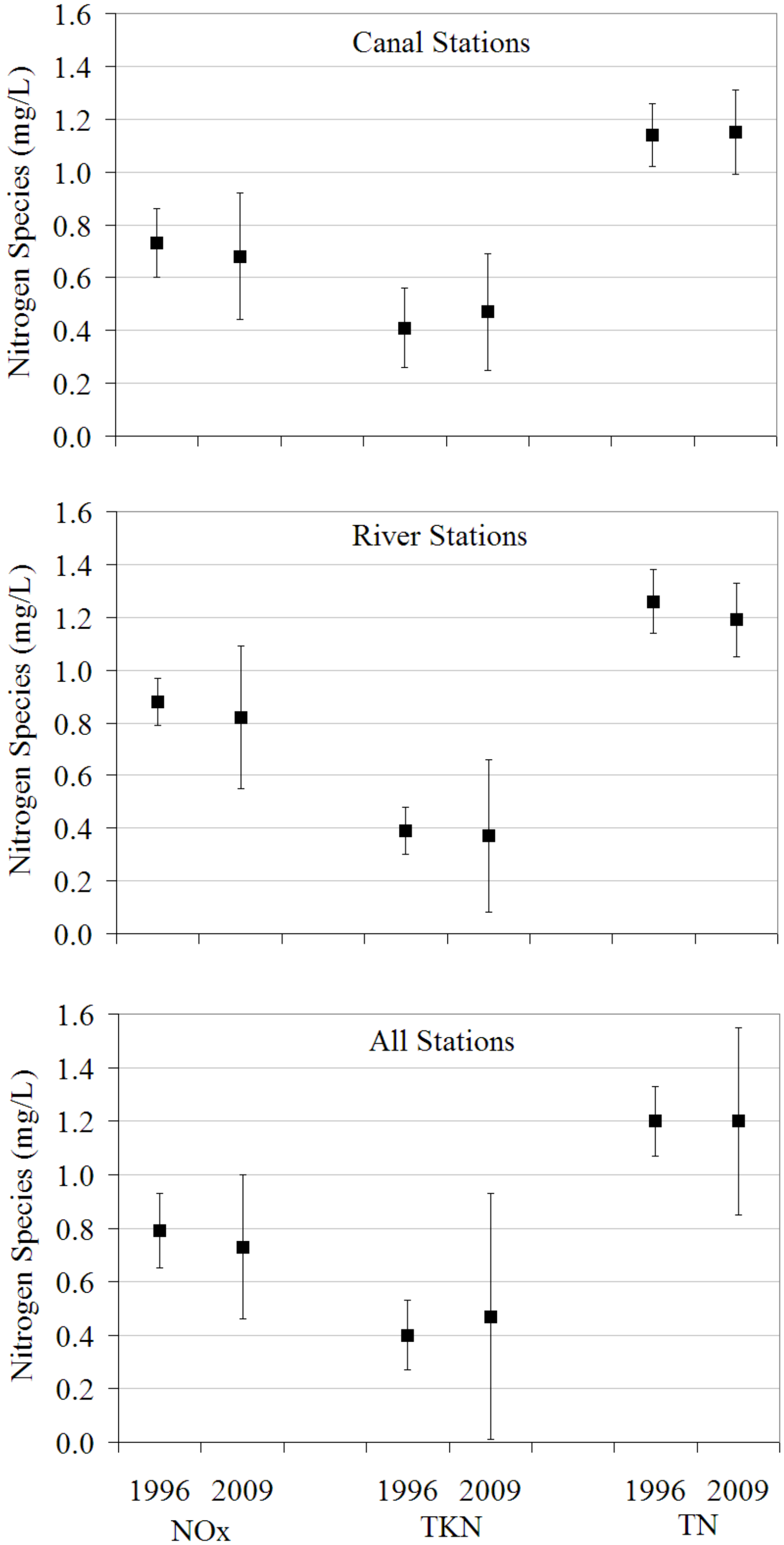

Figure 5. Comparison of NOx, TKN, and Total N (TN) in river and canal observed in 1996 and 2009 sampling periods. Average values are shown with ± standard deviation.

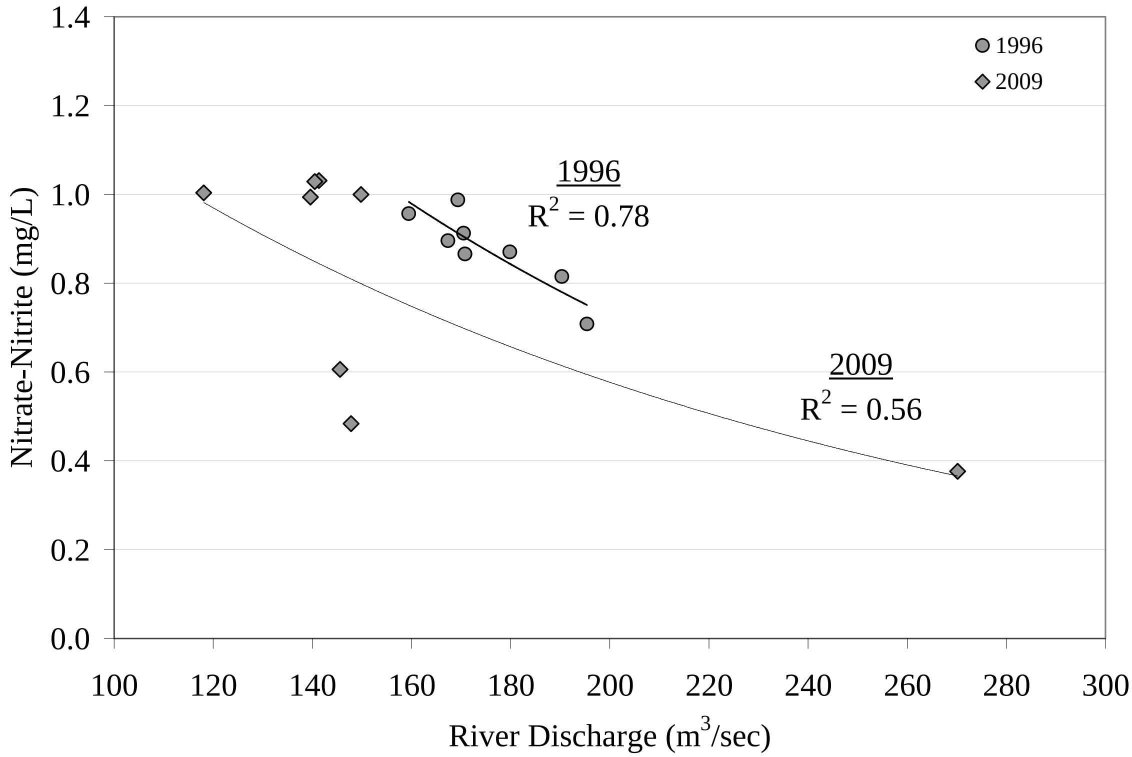

Figure 6. NOx and discharge relationship in river stations in 1996 and 2009 sampling periods