Statistical Evaluation of BMP Effectiveness in Reducing Fecal Coliform Impairment in Mermentau River Basin

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Abstract

This paper presents a statistical method for determining pathogen sources and for evaluating the effectiveness of conventional Best Management Practices (BMPs) in reducing fecal coliform bacterial impairment using water quality data monitored from 1980 – 2006 in the Mermentau River Basin. The statistical method mainly involves (1) determination of seasonal variations in the mean of flow and fecal coliform count in order to identify critical months of pathogen pollution, (2) establishment of multiple correlations between fecal coliform count and rainfall and other solid or sediment-related water quality parameters, (3) detection of temporal variation trends in the median of fecal coliform count in different watersheds within the basin, and (4) evaluation of the effectiveness of BMPs in reducing fecal coliform bacterial impairment based on the trend analysis and water quality criteria. Results of the statistical evaluation show that (1) February – May are the critical months of the highest fecal coliform count; (2) The main pollution in February – March is caused by wet weather runoff; (3) The severe pollution in April and May is related to the releases of muddy rice_field water; (4) Since the implementation of BMPs in 1990, water quality in most watersheds in the Mermentau River Basin has shown an improving trend in terms of fecal coliform count while it was worsening from 1980 – 1990. In terms of pathogen impairment the most polluted areas in the basin are the two watersheds Bayou Queue de Tortue and Bayou Plaquemine Brule, followed by the Bayou Nezpique watershed; and (5) BMPs need to be enhanced in the basin to meet water quality standards.

Introduction

The Mermentau River Basin is located in southwestern Louisiana, and encompasses the prairie region of the state and a section of the coastal zone, draining an area of approximately 12,400 square kilometers. The Mermentau River Basin is bounded on the north and east by the Vermilion-Teche River Basin, on the west by the Calcasieu River Basin and the south by the Gulf of Mexico. The Mermentau River and its five major tributaries divide the basin into 20 water quality management sub-segments, which has been defined as watersheds, as shown in Figure 1. Louisiana's 2006 Water Quality Integrated Report (http://www.deq.louisiana.gov/portal/tabid/2692/Default. aspx) indicated that 15 of the 20 water body subsegments within the basin were either not meeting or are only partially meeting their three

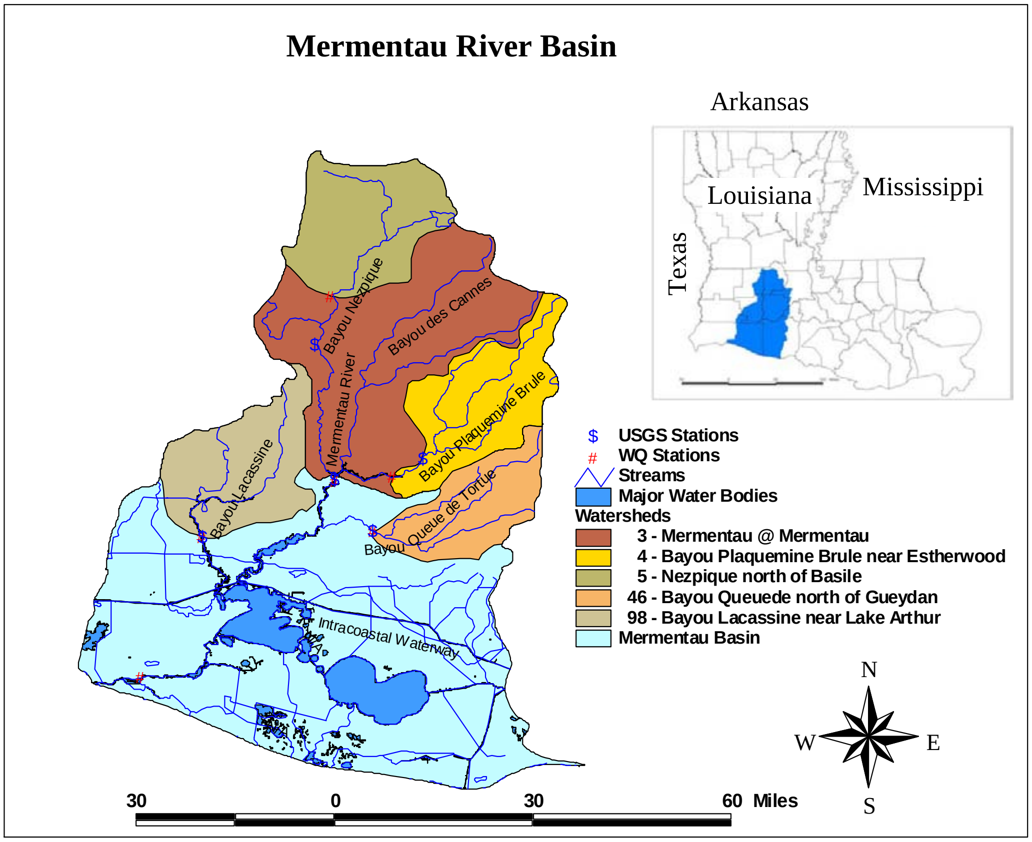

Figure 1. Map of the Mermentau River Basin

primary designated uses (US EPA 2001). Pathogen indicators (fecal coliforms) were the second most frequently cited suspected cause of waterbody impairment in the basin. Although agricultural sources, municipal point source, failing septic tanks are the most cited contributors to pathogen indicator problems, very little is known about the sources of fecal coliforms in the Mermentau River Basin. Since 1990, a variety of BMPs, including water planting in previous crop residue; retention of flood water in a closed levee system for a specified period during and after soil-disturbing activities (i.e. mudding-in); clear water planting into a prepared seedbed; and use of a vegetated filter area, has been implemented in the Mermentau River Basin through the cost-share assistance provided by various federal, state, and local agencies (LDEQ 1999). However, the effectiveness of the BMPs in improving water quality has not yet been fully assessed due to the lack of an efficient methodology and significant spatio-temporal variability in hydrological and hydrometeorological parameters controlling water quality.

The overall goal of this study is to evaluate the effectiveness of BMPs in improving water quality within the Mermentau River basin in terms of fecal coliform impairment. To that end a statistical approach is employed due to the temporal and spatial variability of controlling water quality and hydrometeorological parameters and the uncertainty involved in pollution sources. The specific objectives are therefore (1) to determine seasonal variations in the mean of flow and in the median of fecal coliform bacteria in order to identify critical months and main sources of fecal coliform impairment, (2) to detect variation trends of water quality in different watersheds in terms of the median of fecal coliform count, and (3) to evaluate the effectiveness of BMPs in improving fecal coliform impairment and to provide suggestions for achieving water quality standards.

Seasonal Variation and Main Sources of Fecal Coliform Impairment

In order to understand seasonal variation in water quality parameters it is important to determine the seasonal variation in flow because most pollutants enter water bodies through flow.

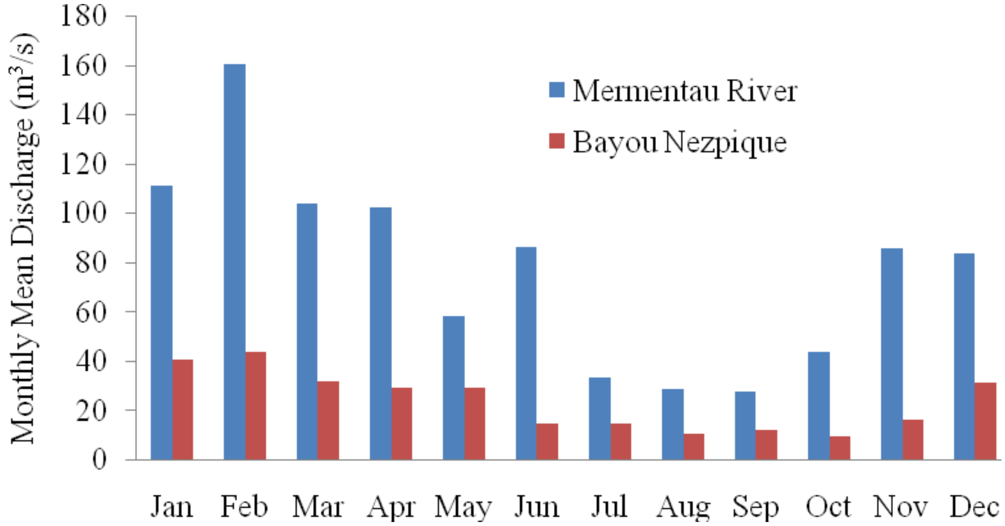

Figure 2. Mean discharge by month in the Mermentau River and Bayou Nezpique watersheds

Figure 2 shows means of monthly discharges from October 1989 – September 2005 for the station Mermentau River at Mermentau and from October 1938 – September 2005 for the station Bayou Nezpique near Basile, respectively. The figure indicates that the highest flow in both stations occurs in February, which may induce high sediment erosion and severe waterbody impairment due to the high loading of diverse pollutants, such as fecal coliform bacteria, absorbed onto eroded sediment particles. During periods of high precipitation, fecal material deposited during dry weather washes into water bodies, causing high fecal coliform count in February. It can be seen from Figure 3 that the fecal coliform count reaches the peak in February in the watersheds Bayou Nezpique, Mermentau River, and Bayou Lacassine. In the Bayou Plaquemine Brule watershed, both the highest TSS and the highest turbidity occur in February (Deng et al. 2007), coinciding with the high fecal coliform count in February although the peak fecal coliform count occurs in March. A reasonable explanation for the delayed peak is that bacteria may experience significantly growth after a wet period and then reach the peak in March, as shown in Figure 3. A multiple linear regression analysis further confirms the correlation between the fecal coliform bacteria and rainfall as well as rainfall-induced high TSS, TDS, and turbidity. Using the stepwise selection method the following regression equation has been established for describing the variation of fecal coliform count (FC) count with rainfall (f) and associated sediments in the Bayou Nezpique:

$$Log(FC) = 1.9136 + 0.0097 \times TSS + 0.2602 \times f \qquad (R^2 = 0.6416) \qquad (1)$$

where f = rainfall in inches in day 1 and day 2. The root mean square (R^2) value of 0.6416 indicates a significant correlation between FC and rainfall and TSS. A similar regression equation is also presented for the Bayou Queue de Tortue:

$$Log(FC) = 2.0199 \times f - 0.0116 \times TSS + 0.0130 \times TDS - 0.3226 \qquad (R^2 = 0.6974) \quad (2)$$

Partial R^2 values for TDS, rainfall *f*, and TSS are 0.2682, 0.2528, and 0.1764, respectively, implying that TDS and rainfall *f* are the two factors controlling the variation of FC although TSS also affects FC. It appears that the sources causing bacterial water quality impairment in the watershed Bayou Queue de Tortue is different from that in other watersheds where rainfall and associated TSS and TDS are the primary vector of bacteria. Figure 3 shows that the high fecal coliform count occurs in both March and May in the Bayou Queue de Tortue. The high fecal coliform count in March is obviously related to the high precipitation in February.

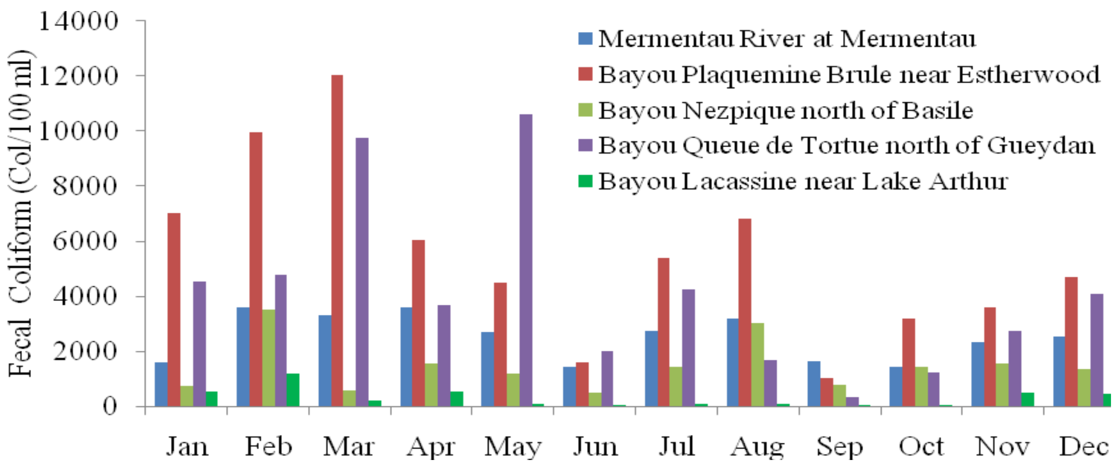

Figure 3. Mean fecal coliform by month in the Mermentau River Basin

Figure 4 illustrates that TDS reaches the peak in April in the Bayou Queue de Tortue due to releases of muddy rice_field water. Therefore, the peak bacterial count in May is attributed to the high TDS and TSS caused by the releases of muddy rice_field water. It means that the main source causing the high fecal coliform count in April and May is the discharges of tailwater from rice fields, although rainfall-induced sediment erosion may also contribute significantly to the high bacterial count. The main source causing the high bacterial count in February and March is rainfall-induced nonpoint source. The Bayou Plaquemine Brule watershed is the most polluted area in terms of monthly mean fecal coliform count, followed by the Bayou Queue de Tortue watershed.

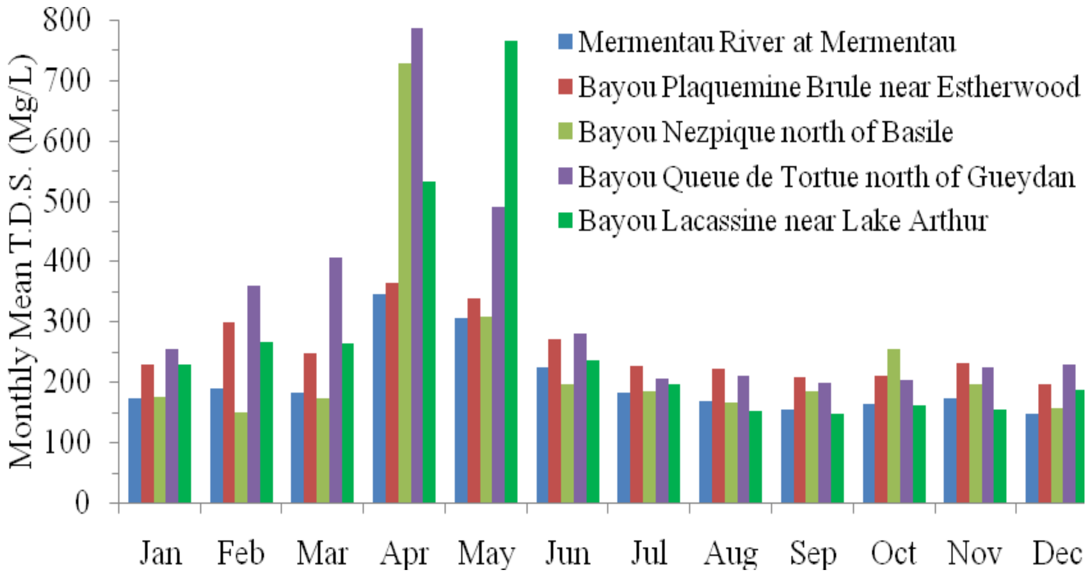

Figure 4. Mean total dissolved solid by month in the Mermentau River Basin

It is clear from figures 2 – 4 that the highest bacterial count in February and March is produced by the highest rainfall, while the high bacterial count in April and May is caused by the combined effect of turbid wet weather runoff and muddy tailwater releases. Therefore, the months of February – May are the critical period of the worst water quality in a year in terms of fecal coliform impairment. In order to reduce bacterial impairment in February stormwater treatment BMPs should be implemented at the watershed scale and particularly in the watersheds Bayou Plaquemine Brule and Bayou Queue de Tortue. In order to reduce bacterial impairment in April and May the tailwater discharges from rice-fields should be further reduced in the watersheds Bayou Queue de Tortue, Bayou Plaquemine Brule, and Bayou Nezpique, and Bayou Lacassine. Trend analysis of water quality will thus focus on the period of the February – May.

Variation Trends in Water Quality and Effectiveness of BMPs

To detect temporal variation trends, monthly means of fecal coliform count for the months of February – May for the periods of 1980 – 1990 and 1991 – 2006 are calculated and compared in figures 5 – 8.

Figure 5 demonstrates that the fecal coliform count in both March and May has decreased markedly in the Bayou Queue de Tortue watershed after 1990 due to the implementation of BMPs. The extreme high values in March have disappeared. It means that the BMPs are effective in reducing stormwater pollution. More implementation efforts are needed in the Bayou Queue de Tortue watershed to reduce the tailwater discharges from rice fields and thus to meet water quality standards.

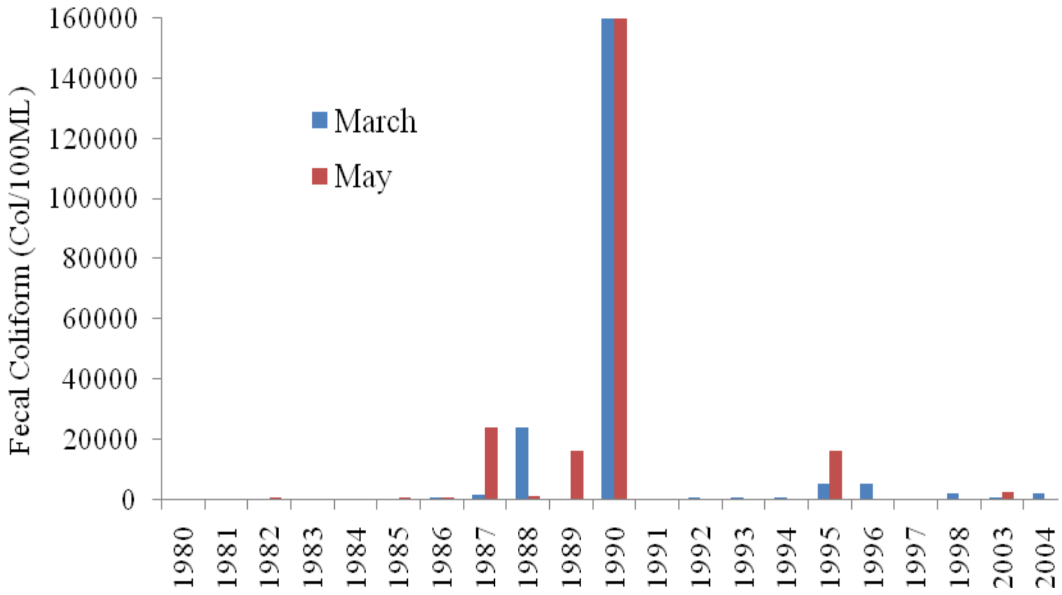

Figure 5. March and May fecal coliform count by year at the Bayou Queue de Tortue north of Gueydan

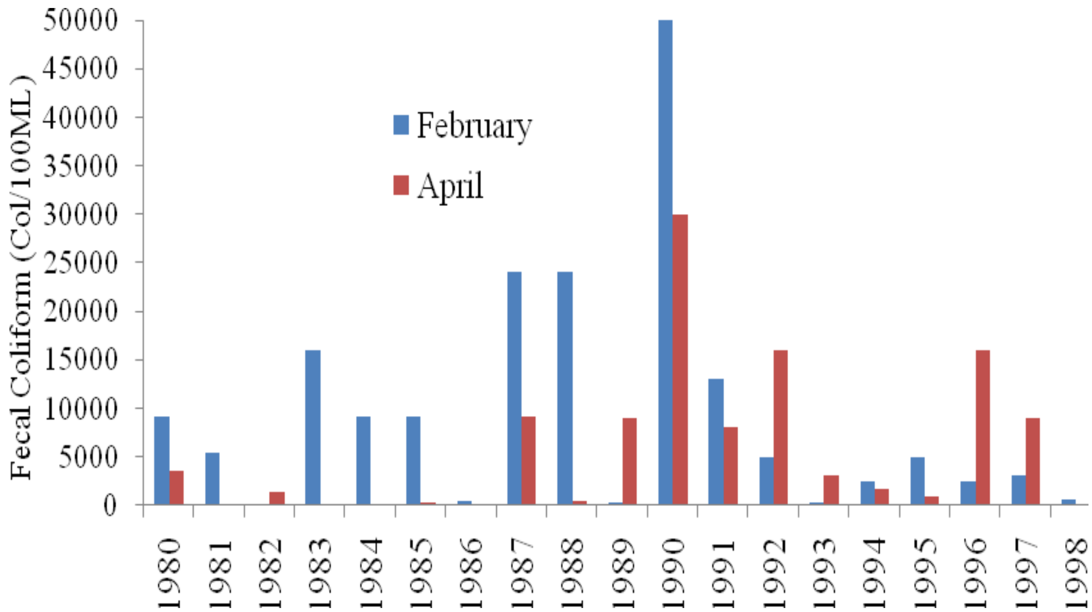

Figure 6. February and April fecal coliform count by year at the Bayou Plaquemine Brule near Estherwood

Figure 6 clearly shows two opposite variation trends in fecal coliform count in the Bayou Plaquemine Brule watershed. The fecal coliform count increased significantly from 1980 – 1990 and reached the peak in both February and April 1990. Then, the fecal coliform count shows a declining trend particularly in February. The median of February bacterial count for the periods of 1980 – 1990 and 1991 – 1998 are 9200 col/100 ml and 1400 col/100 ml, respectively. There was no significant change in the median of April bacterial count for the periods of 1980 – 1990 and 1991 – 1998 although peak bacterial count decreased after the implementation of BMPs in 1990. More implementation efforts are thus needed in the Bayou Plaquemine Brule watershed to reduce the bacterial impairment caused by turbid rice field releases.

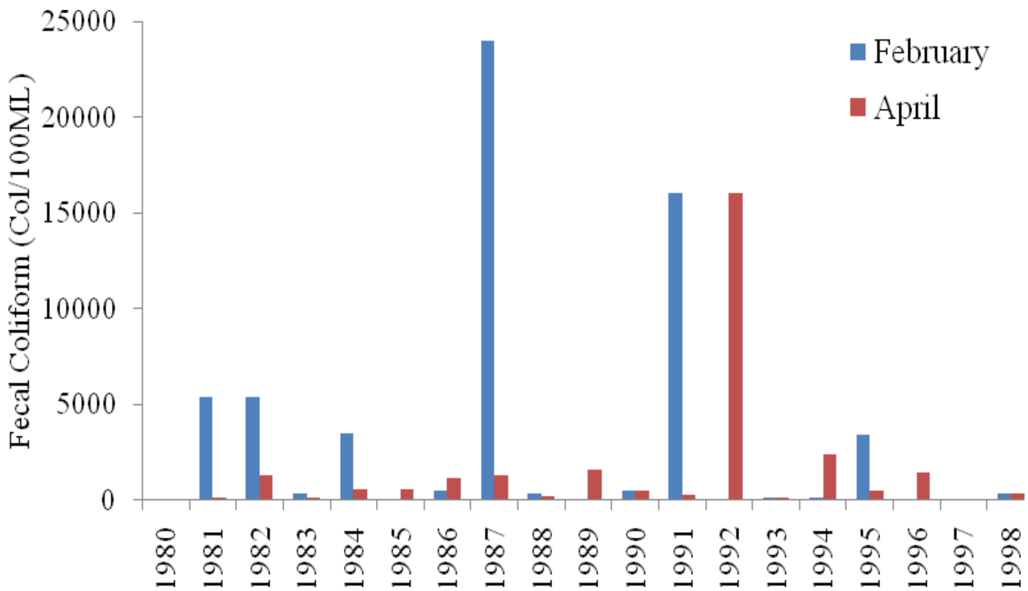

Figure 7. February and April Fecal Coliform by year at the Bayou Nezpique north of Basile

Figure 7 shows the two months of the highest bacterial count in the Bayou Nezpique watershed. The median of February bacterial count for the periods of 1980 – 1990 and 1991 – 1998 are 500 col/100 ml and 80 col/100 ml, respectively. The median of April bacterial count for the periods of 1980 – 1990 and 1991 – 1998 are 540 col/100 ml and 500 col/100 ml, respectively. Despite the slight decrease in the April bacterial count due to the implementation of BMPs. The April bacterial count is still higher than the water quality standard of 200 col/100 ml (LDEQ 1990). Consequently, the tailwater discharges from rice fields need to be further reduced by enhancing BMPs in order to meet water quality standard for fecal coliforms.

Figure 8 shows the two months of the highest bacterial count in the Bayou Lacassine watershed. The figure clearly demonstrates that the February bacterial count has reduced markedly and met water quality standard since the implementation of BMPs in 1991. The median of February bacterial count for the periods of 1980 – 1991 and 1992 – 1998 are 2400 col/100 ml and 170 col/100 ml, respectively. The median of April bacterial count for the periods of 1980 – 1991 and 1992 – 1998 are 70 col/100 ml and 500 col/100 ml, respectively, indicating a significant worsening trend in water quality. The opposite variation trend in April implies that BMPs are effective in reducing rainfall-induced bacterial impairment, but they are not effective enough to reduce the bacterial impairment caused by turbid tailwater releases.

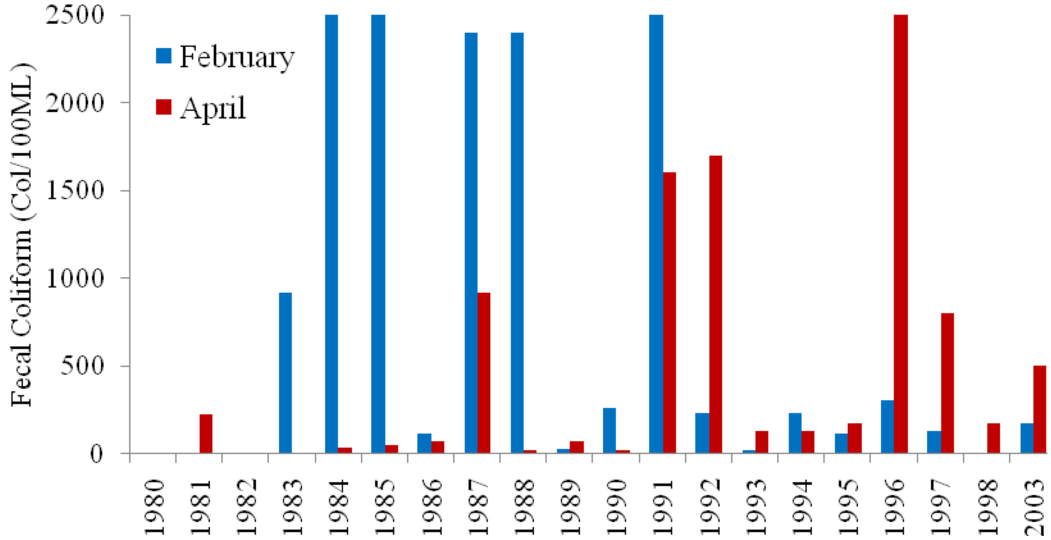

Figure 8. February and April Fecal Coliform by year at the Bayou Lacassine near Lake Arthur

Conclusions

Based on the results of this study the following conclusions can be drawn:

(1) February – May is the critical period of the worst water quality in terms of fecal coliform impairment.

(2) Water quality impairments in February and March are mainly caused by recent stormwater runoff and associated sediments/solids (TSS, TDS, Turbidity), and bacterial growth. The high bacterial count in April and May is primarily caused by the muddy tailwater releases.

(3) In order to reduce bacterial impairment in February and March stormwater treatment BMPs should be implemented at watershed scale and particularly in the watersheds Bayou Plaquemine Brule and Bayou Queue de Tortue. In order to reduce bacterial impairment in April and May the tailwater discharges from rice-fields should be further reduced in the watersheds Bayou Queue de Tortue, Bayou Plaquemine Brule, Bayou Nezpique, and Bayou Lacassine.

(4) The fecal coliform count depends to a large extent on recent precipitation and subsequent transport of sediments (TSS, TDS, and Turbidity). Sediments are the primary vector of fecal coliform bacteria while stormwater runoff is the main driver of the sediments and associated contaminants (TSS, TDS, Turbidity) and nutrients (TKN) in water bodies.

(5) Since the implementation of BMPs, most watersheds in the Mermentau River Basin have shown significant improvements in terms of the fecal coliform impairment particularly in February and March. However, most watersheds in the basin have not yet met water quality standard for fecal coliforms in April and May. The Bayou Lacassine watershed experienced a worsening trend in bacterial impairment in April. The most polluted areas in the basin are the two watersheds Bayou Queue de Tortue and Bayou Plaquemine Brule.

(6) BMPs in the basin need to be enhanced to meet water quality standards.

Acknowledgments

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References

Deng, Z.-Q., Morel, S., and Chowdhary, H. (2007). "Statistical Evaluation of BMP Effectiveness in Reducing Sediment Impairment in Mermentau River Basin." The 2007 EWRI World Water and Environmental Resources Congress, May 15-19, 2007, Tampa, Florida.

Louisiana Department of Environmental Quality (LDEQ). (1990). *State of Louisiana Water Quality Management Plan*, Volume 6 Part A, NPS Pollution Assessment Report. Baton Rouge, LA.

Louisiana Department of Environmental Quality (LDEQ). (1999). *Louisiana NPS Management Program 1999 Annual Report*. Baton Rouge, LA.

US EPA. (2001). *Total Maximum Daily Load (TMDL) for TSS, Turbidity, and Siltation for the Mermentau River Basin*. US EPA Region 6.