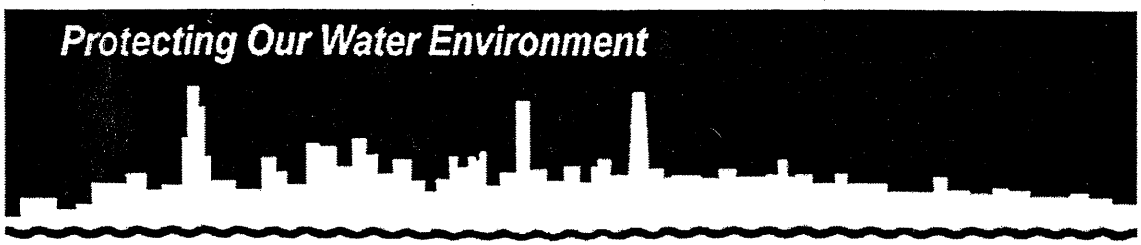

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 05-15

INTERIM REPORT

FECAL COLIFORM DENSITIES IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER

2004

October 2005

Metropolitan Water Reclamation District of Greater Chicago
100 East Erie Street Chicago, Illinois 60611-2803 312-751-5600

INTERIM REPORT

FECAL COLIFORM DENSITIES IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER

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ACKNOWLEDGEMENT

Thanks are extended to the Industrial Waste Division for collecting water samples for this study and to the Analytical Microbiology and Biomonitoring Section of the Environmental Monitoring and Research Division for analyzing the samples for fecal coliform bacteria.

Special thanks to Ms. Joan Scrima, Principal Office Support Specialist, for her assistance in formatting and organizing this report.

DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

In 2004 the Metropolitan Water Reclamation District of Greater Chicago (District) undertook a two-year study to predict the die off of fecal coliform (FC) in the receiving streams downstream of the North Side and Calumet Water Reclamation Plants (WRPs). These streams included the North Shore Channel and the North Branch of the Chicago River (North area), and the Little Calumet River and Calumet-Sag Channel (South area), respectively. Currently the effluents of these WRPs are not disinfected. Fecal coliform densities upstream and downstream of the North Side and the Calumet WRPs were measured during dry and wet weather.

The purpose of this study was to predict from the collected data whether disinfection of the effluents from these WRPs would significantly reduce the FC load in the receiving streams and result in compliance with the Illinois Pollution Control Board (IPCB) General Use stream standard of less than 200 cfu/100 mL.

Fecal coliform densities downstream of these WRPs were shown to die off at an exponential rate, and FC densities at specific locations downstream of these WRPs were predicted using the equation $FC_m = FC_0 \times e^{-km}$ where FC_m = FC concentration m miles downstream of the WRP outfall, FC_0 = FC concentration 0 miles downstream at the WRP outfall, m is miles downstream of the WRP outfall and k is the decay rate constant. The FC decay equations derived from the data are shown below:

North Side Receiving Stream in Dry Weather

$FC = 13{,}560 \times e^{-0.2018m}$, $R^2 = 0.9975$

North Side Receiving Stream in Wet Weather

$FC = 45{,}172 \times e^{-0.1932m}$, $R^2 = 0.9427$

Calumet Receiving Stream in Dry Weather

$FC = 3{,}072 \times e^{-0.2061m}$, $R^2 = 0.9930$

Calumet Receiving Stream in Wet Weather

$FC = 5{,}180 \times e^{-0.0881m}$, $R^2 = 0.9803$

Predicted dry weather FC values were subtracted from the predicted wet weather FC values to estimate FC densities that might occur in the waterways during wet weather if disinfection eliminated the FC burden in the WRP outfalls.

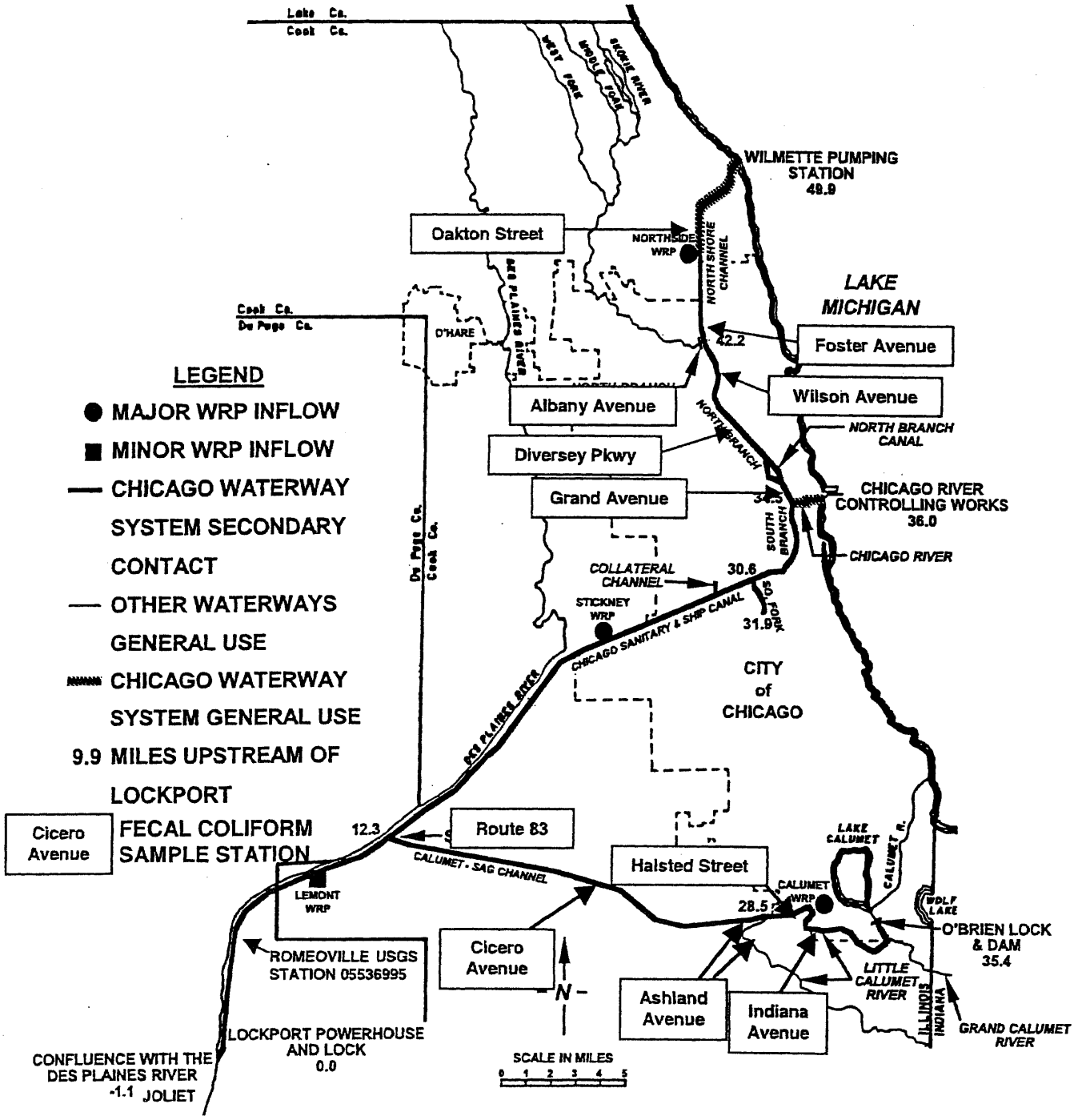
Analysis of the collected data indicated that FC densities less than the IPCB General Use stream standard were predicted to occur at North area stations 21 miles downstream of the North Side WRP during dry weather and 29 miles downstream during wet weather. The analysis predicted that disinfection of the North Side WRP effluent would only marginally improve the microbiological water quality downstream of the North Side WRP in that the IPCB standard could be met at 27 miles downstream of the WRP during wet weather. Fecal coliform densities less than the IPCB General Use stream standard were predicted to occur at South area stations 14 miles downstream of the Calumet WRP during dry weather and 37 miles downstream during wet weather. The analysis predicted that disinfection would not improve the microbiological water quality downstream of the Calumet WRP in that the IPCB standard could be met at 37 miles downstream of the WRP during wet weather, the same distance downstream predicted without disinfection.

The results of this study indicate that disinfection of the North Side and Calumet WRP effluents during wet weather would not improve the microbiological water quality downstream of these WRPs in terms of compliance with the IPCB General Use standard. The results of this study are consistent with a previous study (Haas et al., 1988) which suggested that beyond a certain zone, disinfection of an effluent may not improve microbiological water quality.

INTRODUCTION

This study was initiated in 2004 to determine the distribution and die-off of fecal coliform bacteria in District waterways relative to issues raised by the Chicago Area Waterways Use Attainability Analysis (CDM, 2004). The FC was measured at each of twelve locations in two segments of the Chicago Waterway System, including the North Area waterways (North Shore Channel and North Branch Chicago River) and South Area waterways (Little Calumet River and Calumet-Sag Channel). Sample stations are shown in Figure 1. While this study is still ongoing in 2005, this interim report presents the results of all of the sampling that was conducted in 2004.

FIGURE 1: CHICAGO WATERWAY SYSTEM SAMPLE STATIONS FOR FECAL COLIFORM DENSITY STUDY



MATERIALS AND METHODS

Water samples were collected twice a month between April 1 and December 31, 2004. The Industrial Waste Division (IWD) collected water samples for FC at the North Area stations on the first Tuesday and second Monday of each month and at the South Area stations on the third Tuesday and fourth Monday of each month. IWD also collected water samples for FC each day, for a maximum of three days, following any rain event sufficient to cause an overflow at the North Side Pumping Station (for North Area stations) or at the 122nd Street, 125th Street, or 95th Street Pumping Stations (for South Area stations). No samples were collected on weekends or holidays. FC data from routine bridge run samples collected during January through March 2004 at the North and South area stations were also included as dry weather data in this study.

Water samples were analyzed for FC by the Analytical Microbiology Section of the Environmental Monitoring and Research Division using the FC membrane filter procedure (SM 9222 D, SM 18th ed. [APHA, 1992]).

Equations for fecal coliform die-off curves, and corresponding R^2 values, were formulated using the exponential curve fitting function of the computer program Microsoft Excel®.

RESULTS AND DISCUSSION

Results of dry and wet weather FC are shown for each station in the Appendix and summarized in Table 1. FC data are expressed as colony forming units (cfu) per 100 mL. For the 12 sampling stations, dry weather FC ranged from 9 to 220,000 cfu/100 mL. During wet weather, FC ranged from 80 to 470,000 cfu/100 mL. Geometric mean dry weather FC ranged from 70 to 7,400 cfu/100 mL. Geometric mean wet weather FC ranged from 240 to 26,000 cfu/100 mL.

Downstream from the North Side WRP effluent outfall, dry weather geometric mean FC decreased from 7,400 cfu/100 mL at Foster Avenue on the North Shore Channel to 1,600 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River. Wet weather geometric mean FC decreased from 21,000 cfu/100 mL at Foster Avenue on the North Shore Channel to 5,700 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River

Downstream from the Calumet WRP effluent outfall, dry weather geometric mean FC decreased from 2,700 cfu/100 mL at Halsted Street on the Little Calumet River to 100 cfu/100 mL at Route 83 on the Calumet-Sag Channel. Wet weather geometric mean FC decreased from 4,600 cfu/100 mL at Halsted Street on the Little Calumet River to 1,200 cfu/100 mL at Route 83 on the Calumet-Sag Channel.

Comparisons of geometric means of fecal coliform bacteria, with calculated die-off density estimates for wet and dry weather, are shown in Figure 2 (North Area) and Figure 3 (South Area). The estimated die-off curves fit the sample geometric means well, with R^2 values all greater than 0.94. The data for stations located upstream of the WRPs (Oakton Street on the North Shore Channel and Indiana Avenue on the Little Calumet River) and for stations located in tributaries (i.e., Albany Avenue on the North Branch of the Chicago River and Ashland Avenue on the Little Calumet River) were plotted in Figures 2 and 3 but were not included in the die-off equation. It should be noted that the highest wet weather FC (470,000 cfu/100mL) during this study occurred upstream of the North Side WRP at Oakton Street on the North Shore Channel and the highest dry weather FC (220,000 cfu/100 mL) occurred at Ashland Avenue on the Little Calumet River. This highest dry weather FC result appears to be an anomaly, but it has not been excluded in the analysis of the data set.

In order to estimate waterway FC that might occur during wet weather conditions if there was complete disinfection of WRP effluent outfalls, dry weather FC were subtracted from wet weather FC and are shown in Figure 4 (North Area) and Figure 5 (South Area) with the calculated wet and dry weather FC. The calculated wet weather and calculated dry weather FC data displayed in Figures 4 and 5 were derived from the die-off equations determined from Figures 2 and 3. During wet weather, elimination of the fecal coliform contributions from the WRPs (dry weather FC) made little difference to the waterway FC in either area. Estimated wet weather FC, with or without disinfection, would not meet present General Use Water Quality Standards for at least a distance of 26 miles downstream of the WRPs. Densities of fecal coliform bacteria, with or without disinfection, would be equivalent at this distance downstream of the WRPs. WRP effluent disinfection is not effective for improving water quality during wet weather.

TABLE 1: FECAL COLIFORM DENSITY IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER JANUARY THROUGH DECEMBER 2004

Sample Station (Miles from WRP)	Dry Weather Fecal Coliform (cfu/100 mL) Number of Samples	Minimum	Maximum	Geometric Mean	Wet Weather Fecal Coliform (cfu/100 mL) Number of Samples	Minimum	Maximum	Geometric Mean
			North Shore Channel					
Oakton Street(0.6)[a]	18	40	19,000	670	12	700	470,000	7,800
Foster Avenue(3.1)[b]	18	1,800	25,000	7,400	12	4,600	130,000	21,000
			North Branch Chicago River					
Albany Avenue(3.3)[c]	17	200	2,000	710	12	990	130,000	10,000
Wilson Avenue(4.0)[b]	18	2,200	22,000	6,100	12	5,400	380,000	26,000
Diversey Parkway(6.6)[b]	18	1,200	8,800	3,400	12	4,500	67,000	12,000
Grand Avenue(10.7)[b]	18	550	24,000	1,600	12	1,100	110,000	5,700
			Little Calumet River					
Indiana Avenue(1.4)[a]	16	9	7,200	70	12	80	560	240
Halsted Street(1.0)[b]	19	270	15,000	2,700	12	2,200	54,000	4,600
Ashland Avenue(1.3)[c]	17	120	220,000	4,000	12	990	80,000	5,000
			Calumet-Sag Channel					
Ashland Avenue(2.1)[b]	19	250	12,000	2,100	12	2,000	36,000	4,800
Cicero Avenue(6.2)[b]	19	20	9,300	710	12	770	39,000	2,700
Route 83(16.9)[b]	17	20	510	100	12	210	31,000	1,200

[a]Upstream WRP effluent outfall.
[b]Downstream WRP effluent outfall.
[c]Tributary Downstream WRP effluent outfall.

FIGURE 2: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT NORTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)

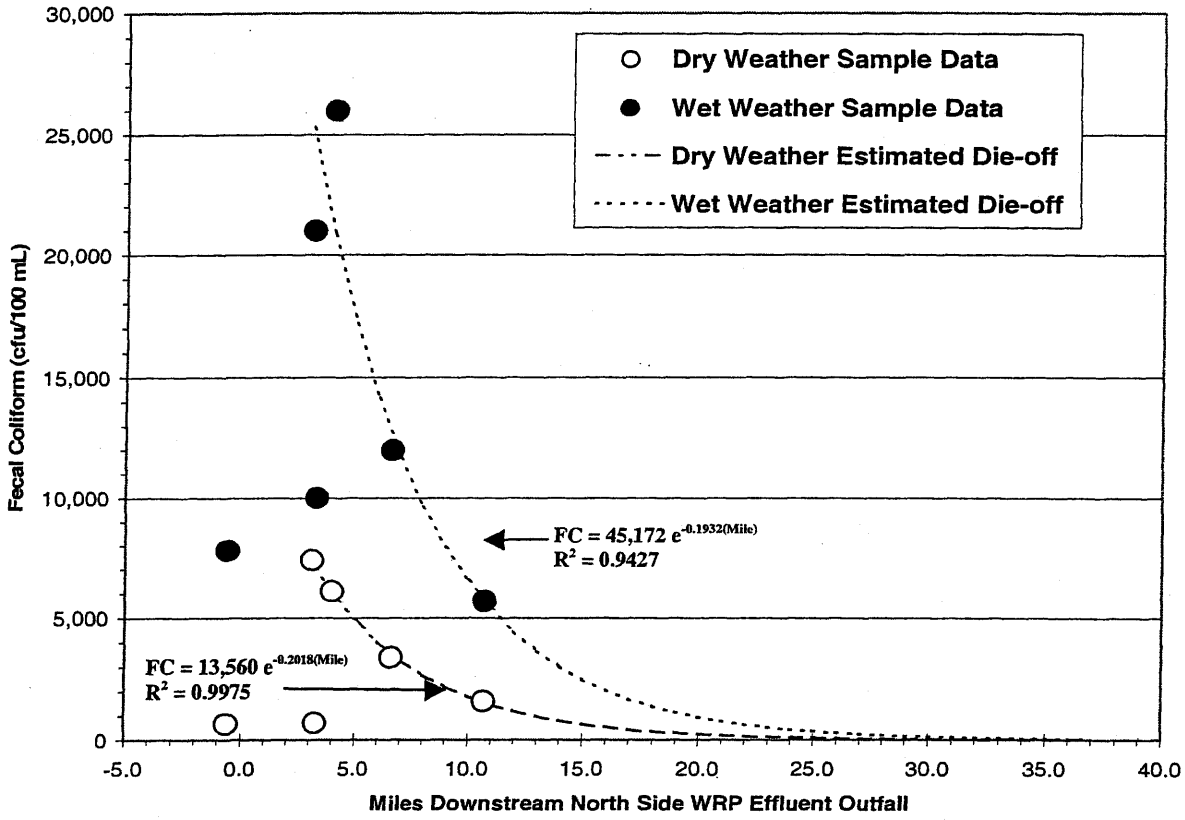


FIGURE 3: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT SOUTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)

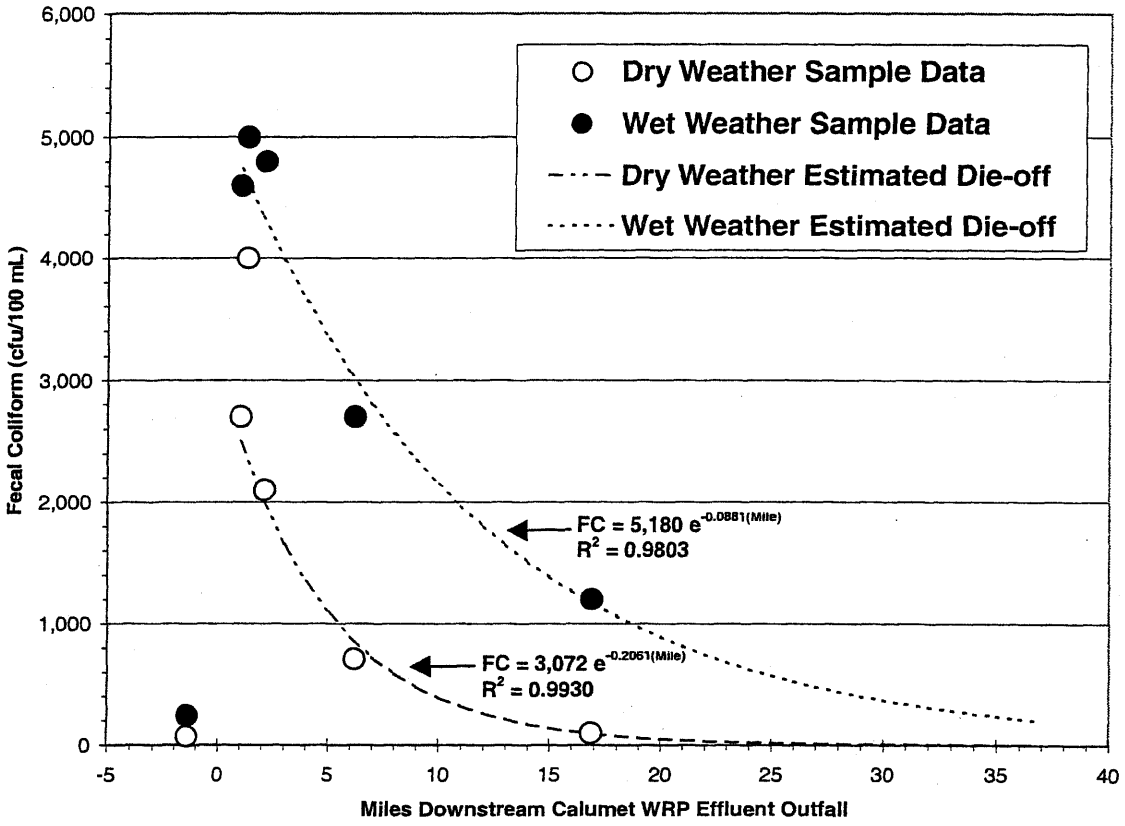


FIGURE 4: ESTIMATED FECAL COLIFORM BACTERIA DENSITIES DOWNSTREAM OF THE NORTH SIDE WATER RECLAMATION PLANT DURING WET AND DRY WEATHER, AND WHEN DRY WEATHER DENSITIES ARE SUBTRACTED FROM WET WEATHER DENSITIES

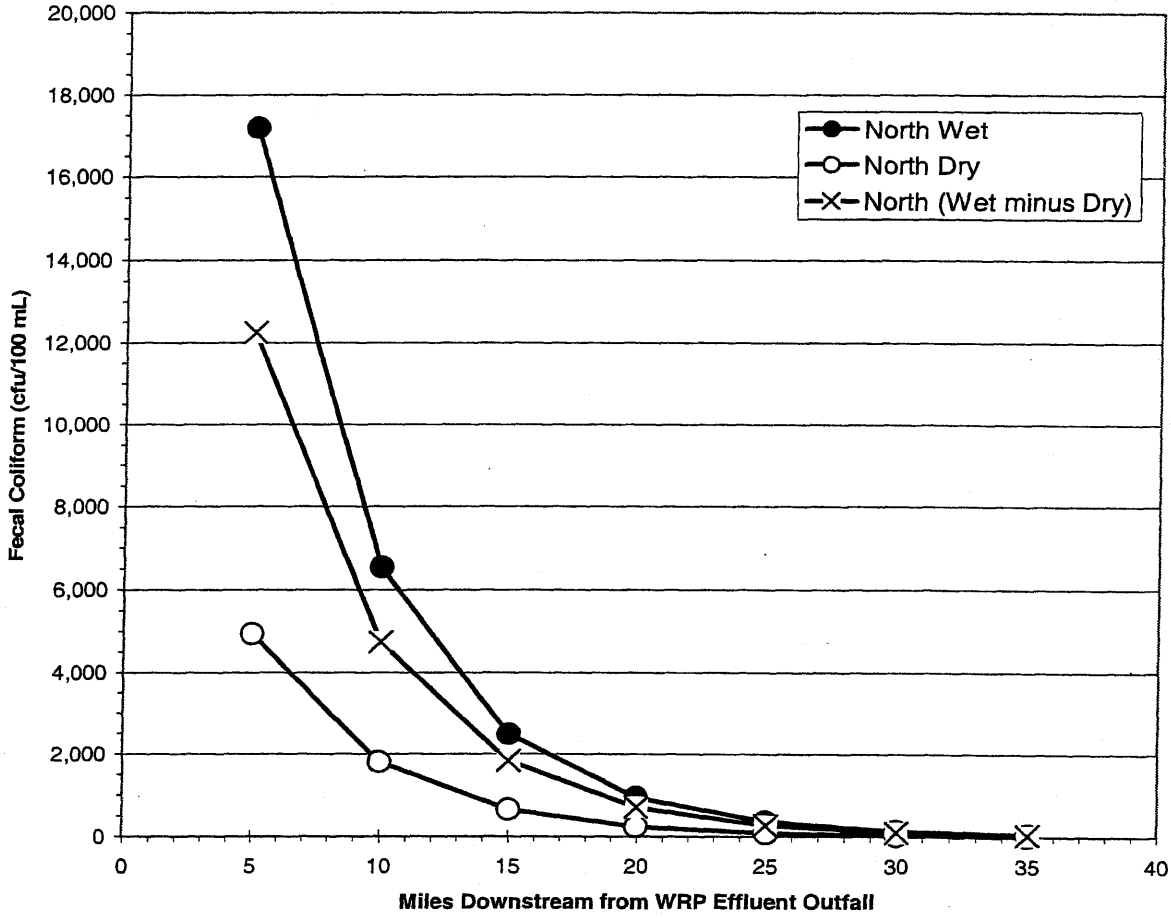


FIGURE 5: ESTIMATED FECAL COLIFORM BACTERIA DENSITIES DOWNSTREAM OF THE CALUMET WATER RECLAMATION PLANT DURING WET AND DRY WEATHER, AND WHEN DRY WEATHER DENSITIES ARE SUBTRACTED FROM WET WEATHER DENSITIES

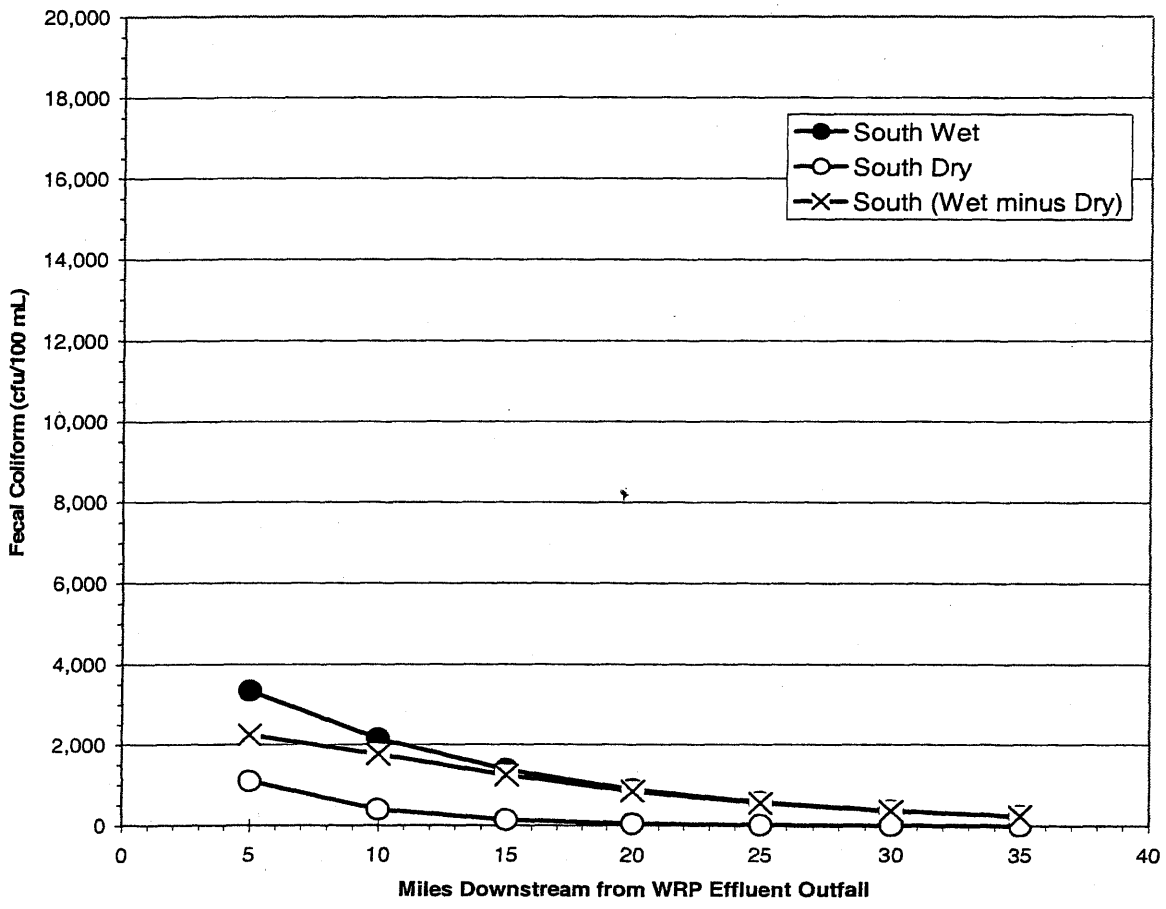


Table 2 shows estimated FC calculated from die-off equations at distances of 5 miles and at points downstream of WRP effluent outfalls at which General Use Water Quality Standards are first predicted to be met. FC less than the 200 cfu/100 mL IPCB General Use stream standard at North Area stations were predicted to occur 21 miles downstream of the North Side WRP during dry weather, 29 miles downstream during wet weather, and 27 miles downstream if disinfection eliminated FC from the North Side WRP effluent outfall during wet weather. FC less than the 200 cfu/100 mL IPCB General Use stream standard at South Area stations were predicted to occur 14 miles downstream of the Calumet WRP during dry weather and 37 miles downstream during wet weather, with or without disinfection having eliminated all FC from the Calumet WRP effluent outfall during wet weather.

Disinfection of WRP effluent during wet weather would not improve water quality below either the North Side or Calumet WRPs such that present General Use Water Quality Standards would be met.

It is expected that the Illinois Environmental Protection Agency may eventually replace FC limits in District National Pollution Discharge Elimination System (NPDES) permits and Water Quality Standards with limits for *Escherichia coli* densities (EC). In anticipation of this, Zmuda, Gore, and Abedin (2004) formulated ratios from which EC could be converted from FC for both the Chicago River and Calumet River Systems. Their best estimates for EC/FC ratios were 0.93 for the Calumet River System and 0.83 for the Chicago River System.

Given this relationship between FC and EC and the FC die-off equations developed for dry weather in this study, it is estimated that within 4.95 miles of the Calumet WRP and within 11.8 miles of the North Side WRP, the EC water quality standard of 1030 cfu/100 mL currently being considered for the new limited contact recreation use category would be met under dry weather conditions in their receiving streams.

TABLE 2: FECAL COLIFORM DENSITIES[1] CALCULATED FROM DIE-OFF EQUATIONS AT 5 MILES AND AT FIRST POINT OF COMPLIANCE WITH GENERAL USE WATER QUALITY STANDARD DOWNSTREAM OF WATER RECLAMATION PLANT EFFLUENT OUTFALLS

Weather Type	River Miles Below WRP Effluent Outfall					
	5	14	21	27	29	37
	cfu/100 mL					
North Area						
Wet	17,193	3,021	781	245	**167**	36
Dry	4,944	804	**196**	58	39	8
Wet minus Dry	12,249	2,217	585	**187**	128	28
South Area						
Wet	3,334	1,509	814	480	402	**199**
Dry	1,096	**171**	41	12	8	1
Wet minus Dry	2,238	1,338	773	468	394	**198**

[1]Values in bold type indicate first occurrence of a calculated fecal coliform density less than the 200 cfu/100 mL IPCB General Use stream standard.

REFERENCES

APHA (American Public Health Association), SM 9222D, Fecal Coliform Membrane Filter Procedure, Standard Methods for the Examination of Water and Wastewater, 18th Ed., A. E. Greenberg, L. S. Clesceri, and A. D. Eaton, Editors, American Public Health Association, Washington, DC, 1992.

CDM (Camp, Dresser & McKee, Inc.), "Chicago Area Waterway System Use Attainability Analysis," Draft Report, Available at www.chicagoareawaterways.org, Prepared for the Illinois Environmental Protection Agency, November 2004.

Haas, C. N., J. G. Sheerin, C. Lue-Hing, K. C. Rao, and P. O'Brien, "Effects of Discontinuing Disinfection on a Receiving Water," Journal of the Water Pollution Control Federation, Vol. 60, No. 5, pp. 667–673, 1988.

Zmuda, J. T., R. Gore, and Z. Abedin, "Estimation of the Escherichia coli to Fecal Coliform Ratio in Wastewater Effluents and Ambient Waters of the Metropolitan Water Reclamation District of Greater Chicago," Research and Development Department Report No. 04-10, Metropolitan Water Reclamation District of Greater Chicago, July 2004.

APPENDIX AI

FECAL COLIFORM BACTERIA DENSITIES AT EACH SAMPLING STATION IN THE NORTH AND SOUTH WATERWAY STUDY AREAS

FIGURE AI-1: FECAL COLIFORM BACTERIA IN THE NORTH SHORE CHANNEL AT OAKTON STREET IN DRY (O) AND WET (●) WEATHER

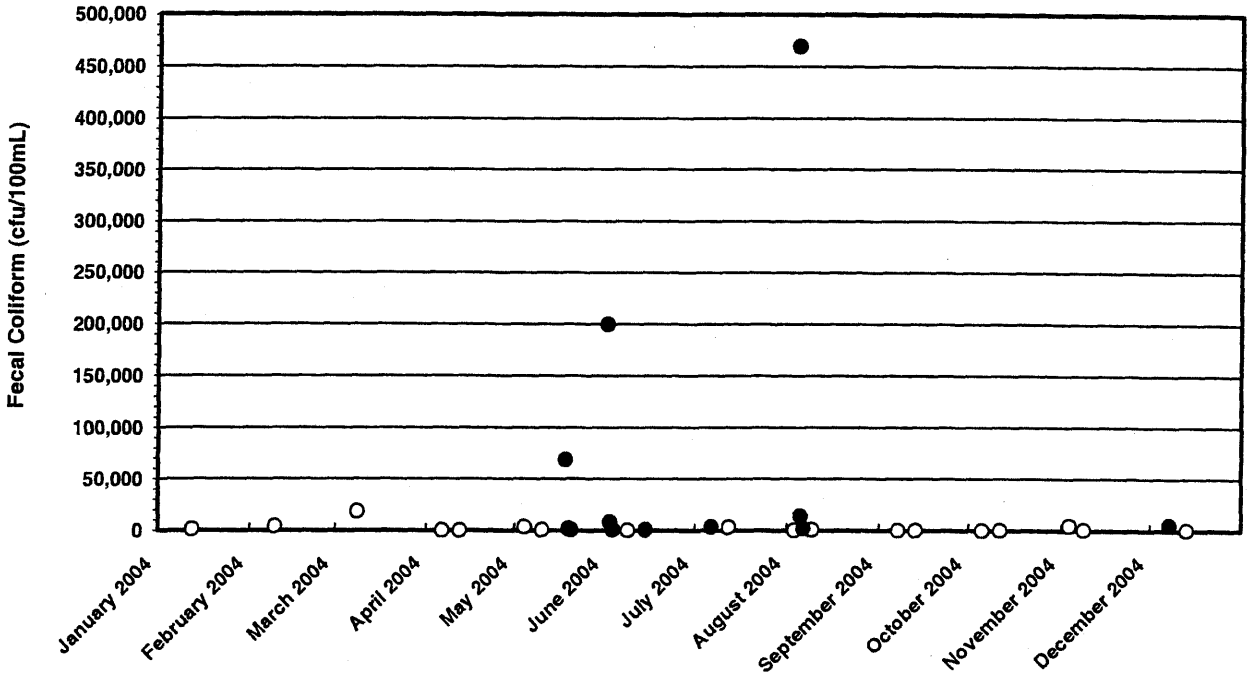


FIGURE AI-2: FECAL COLIFORM BACTERIA IN THE NORTH SHORE CHANNEL AT FOSTER AVENUE IN DRY (O) AND WET (●) WEATHER

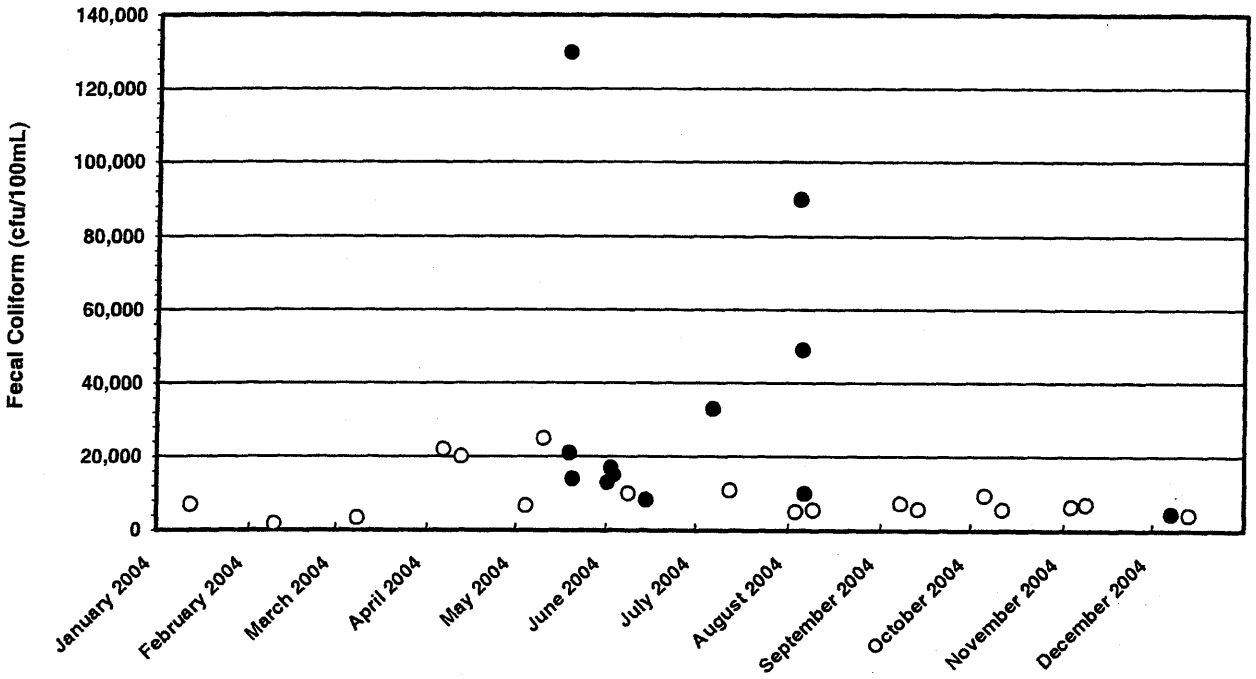


FIGURE AI-3: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT ALBANY AVENUE IN DRY (O) AND WET (●) WEATHER

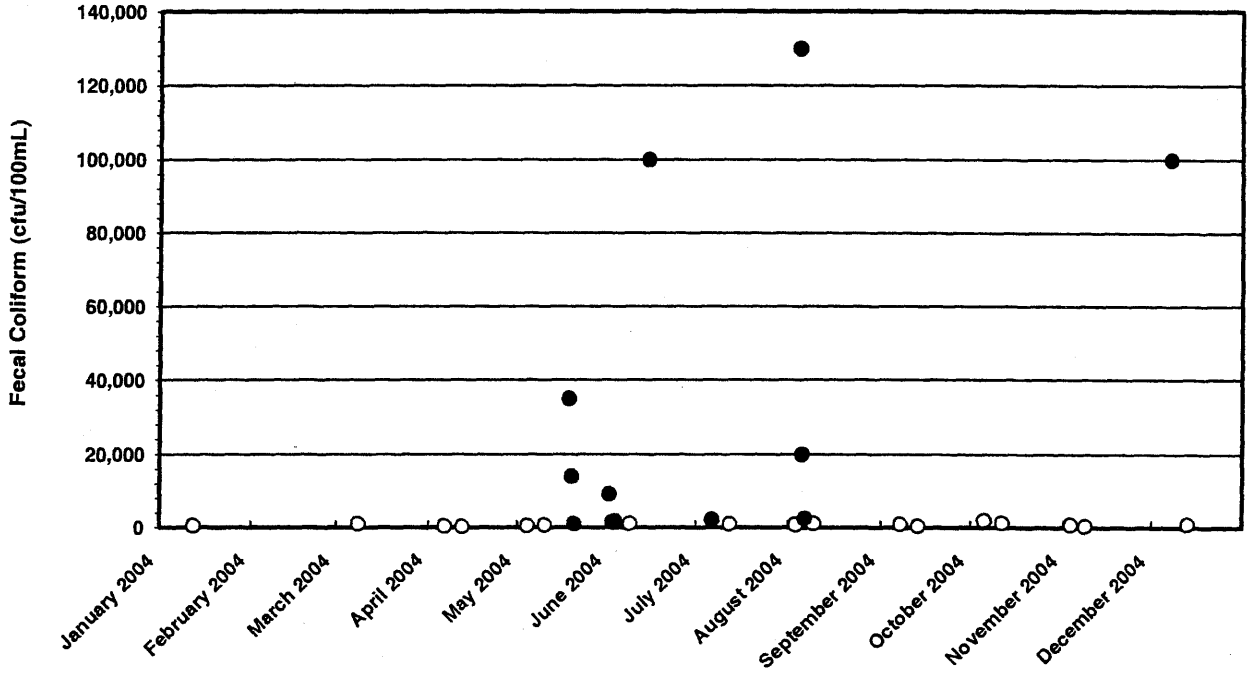


FIGURE AI-4: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT WILSON AVENUE IN DRY (O) AND WET (●) WEATHER

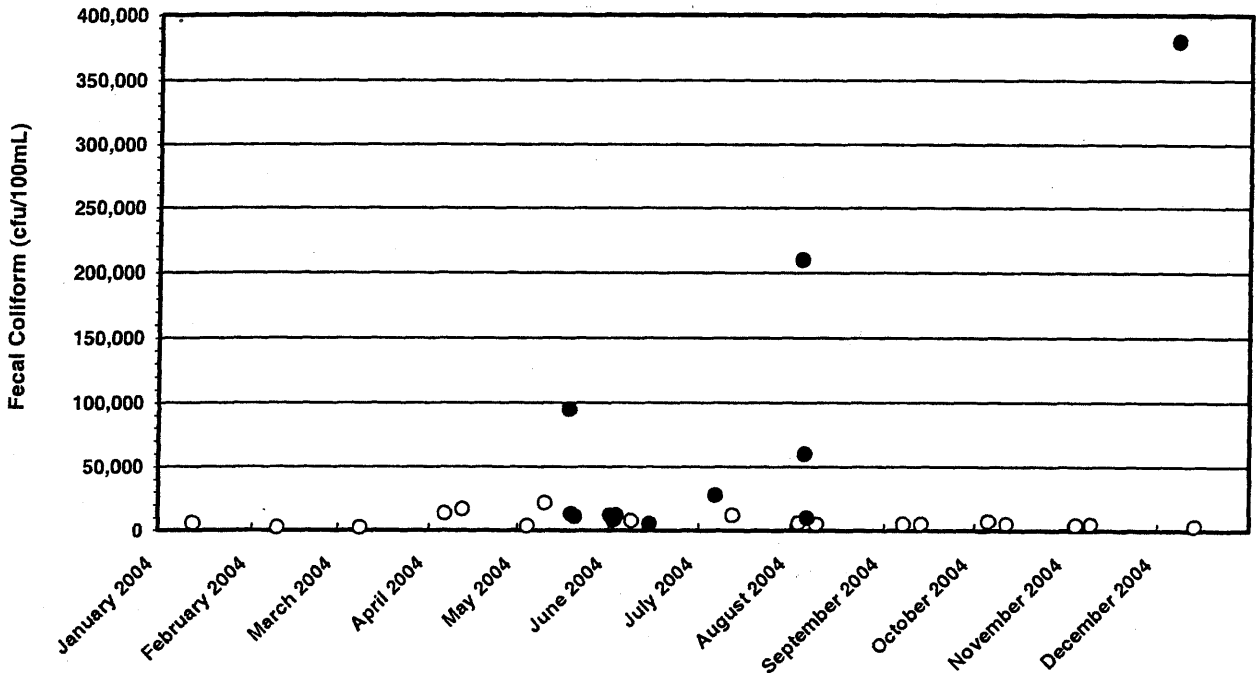


FIGURE AI-5: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT DIVERSEY PARKWAY IN DRY (O) AND WET (●) WEATHER

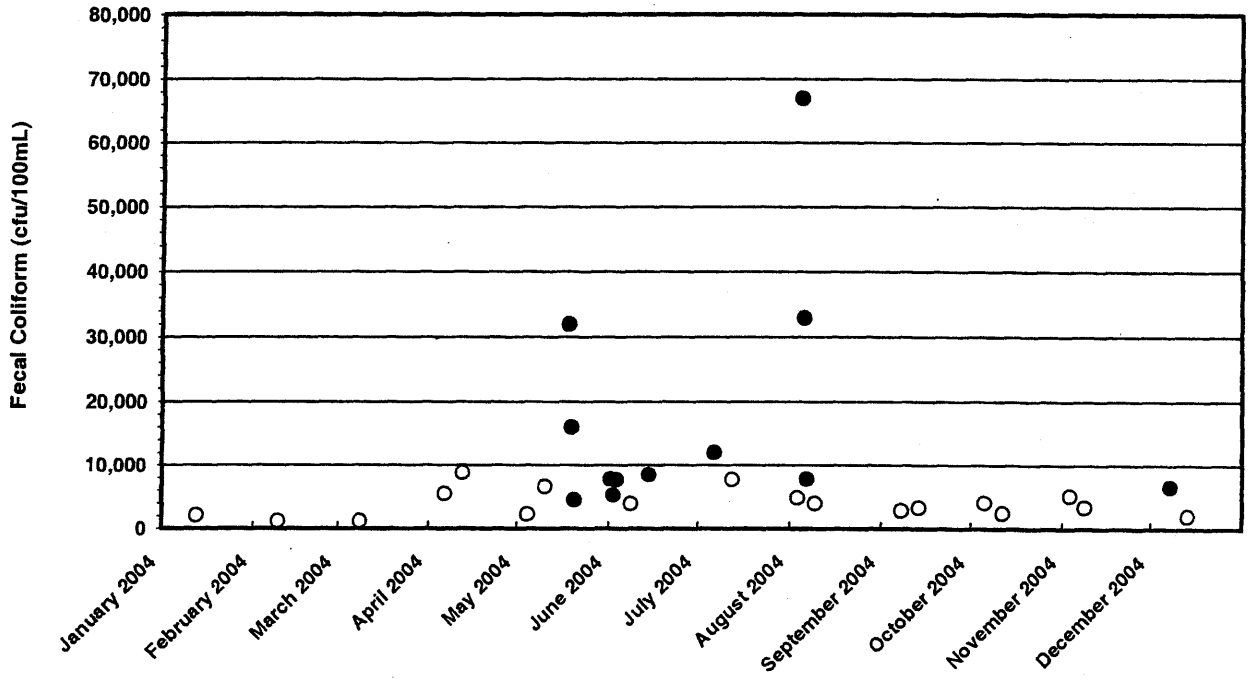


FIGURE AI-6: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT GRAND AVENUE IN DRY (O) AND WET (●) WEATHER

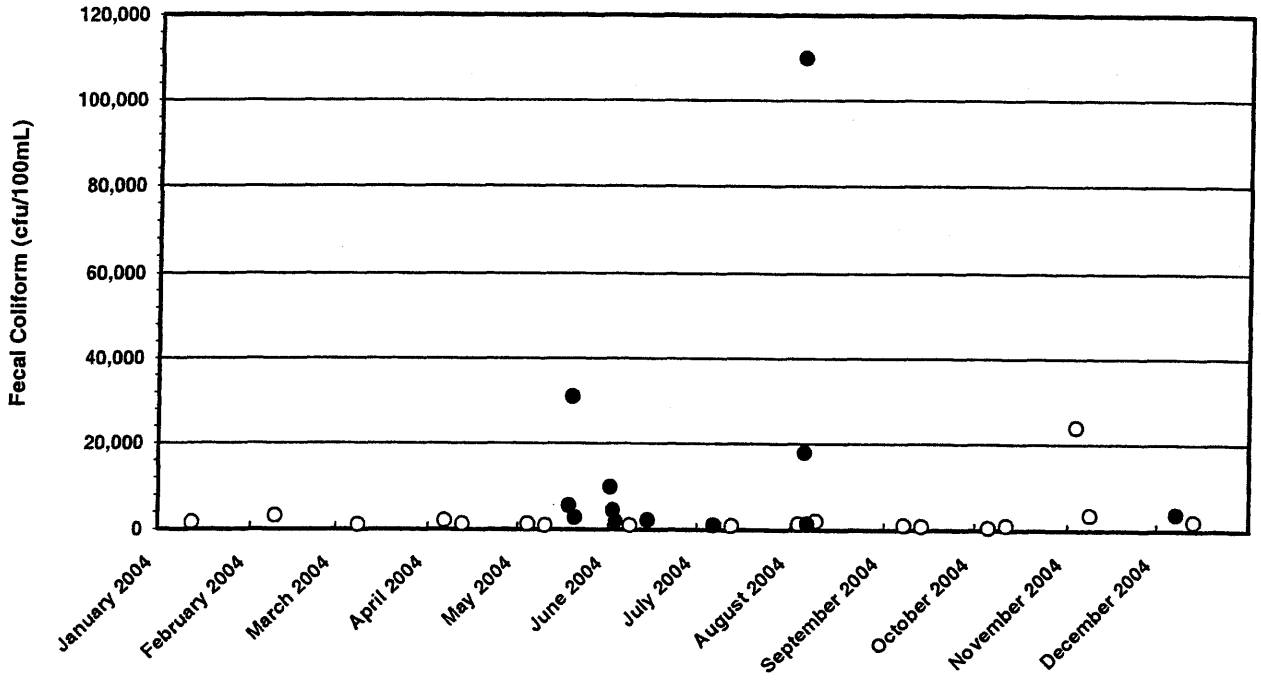


FIGURE AI-7: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT INDIANA AVENUE IN DRY (O) AND WET (●) WEATHER

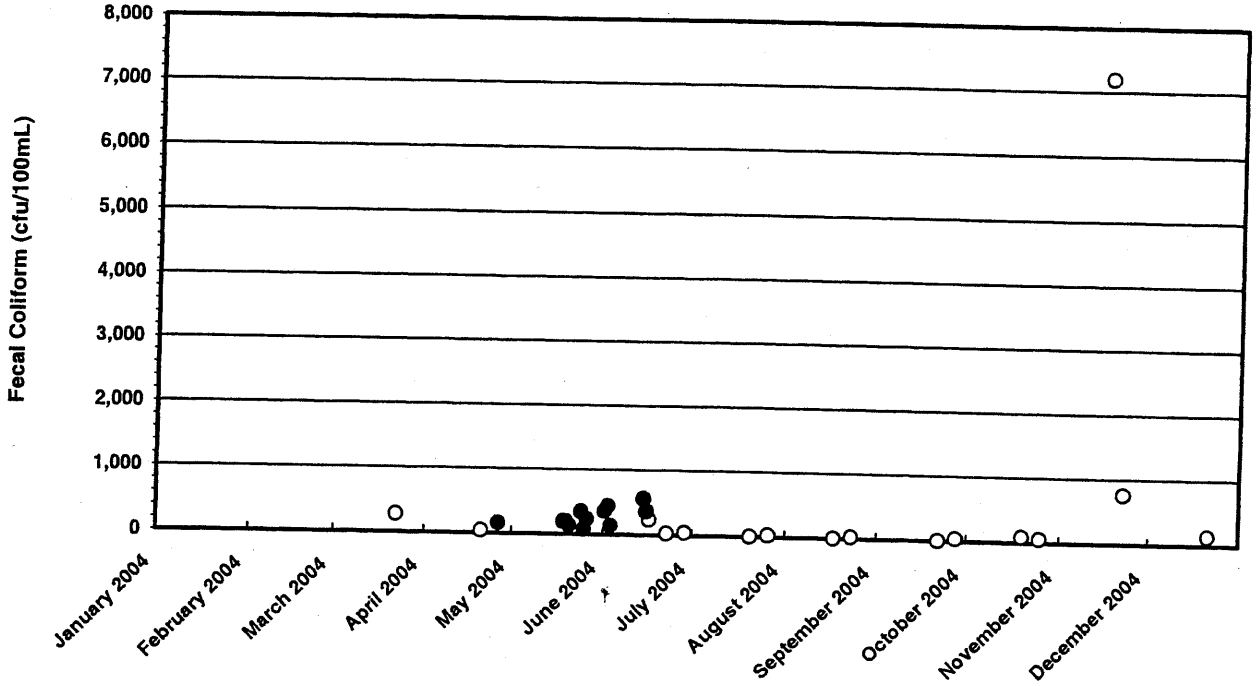


FIGURE AI-8: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT HALSTED STREET IN DRY (O) AND WET (●) WEATHER

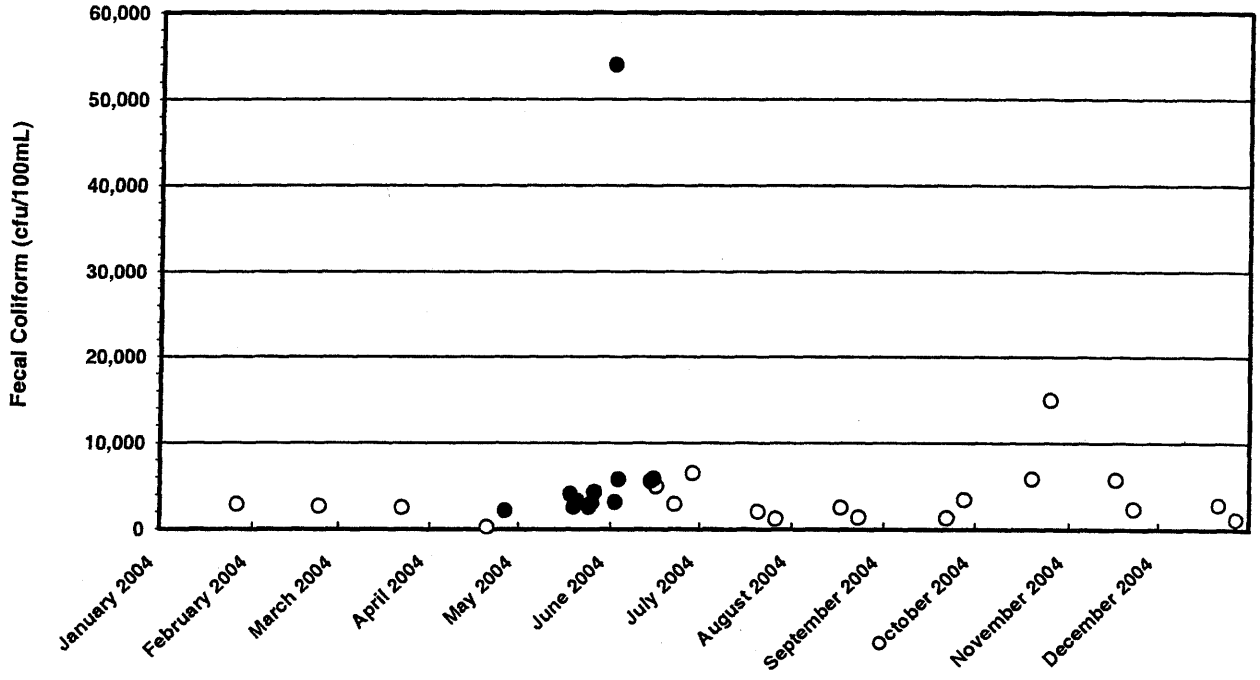


FIGURE AI-9: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT ASHLAND AVENUE IN DRY (O) AND WET (●) WEATHER

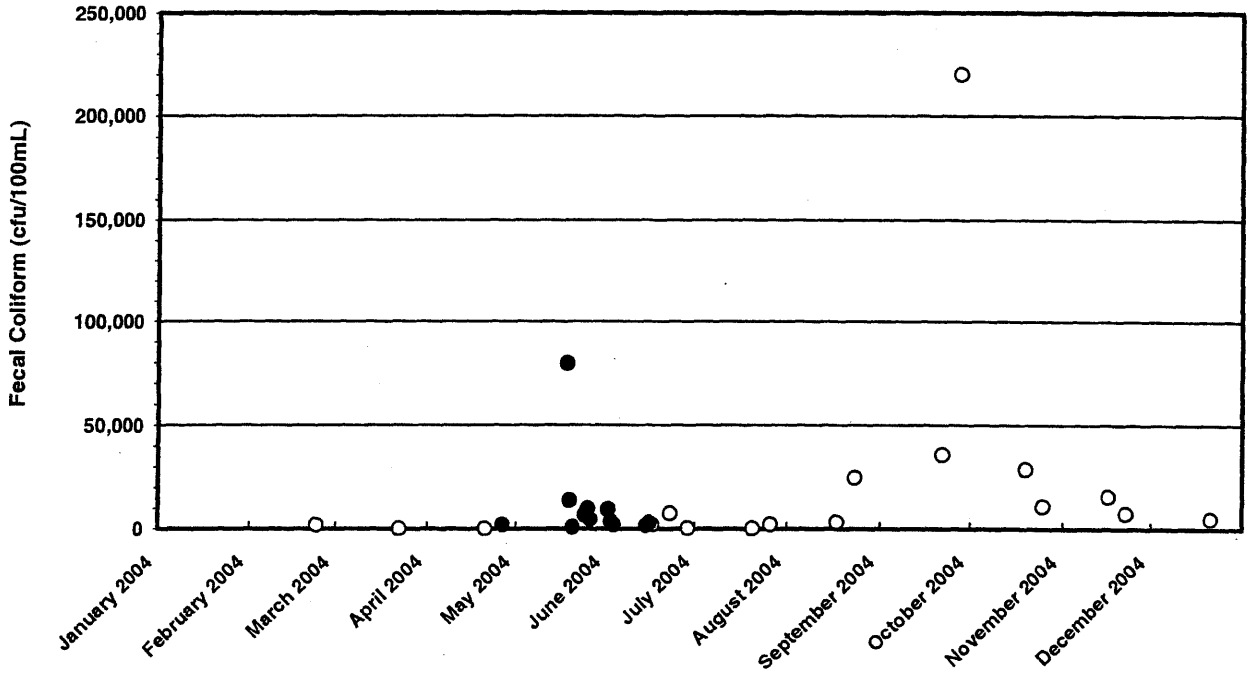


FIGURE AI-10: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT ASHLAND AVENUE IN DRY (O) AND WET (●) WEATHER

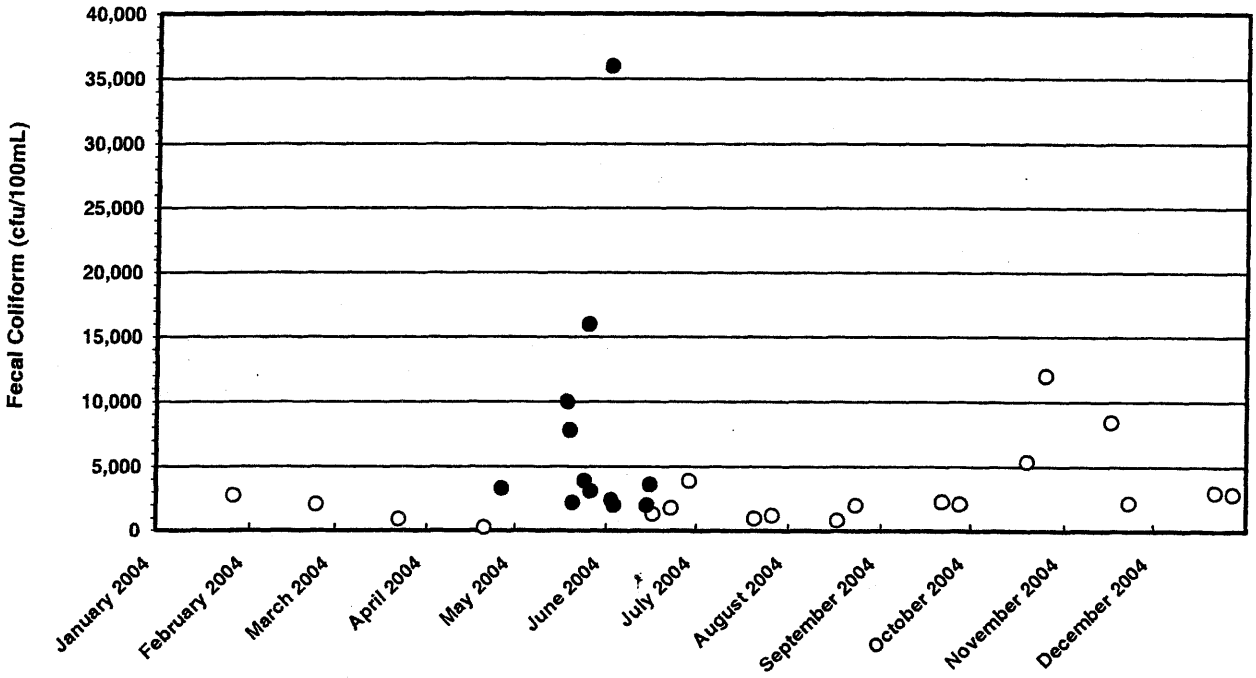


FIGURE AI-11: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT CICERO AVENUE IN DRY (O) AND WET (●) WEATHER

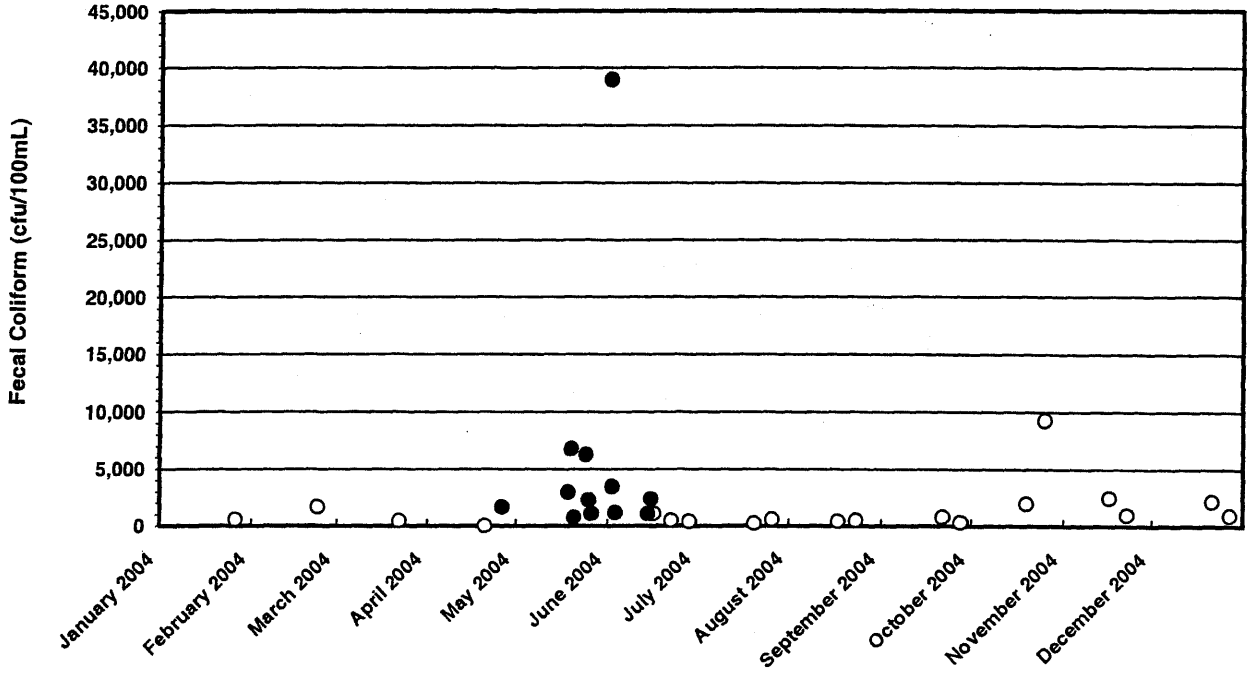


FIGURE AI-12: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT ROUTE 83 IN DRY (O) AND WET (●) WEATHER