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REPORT OF INVESTIGATION 93
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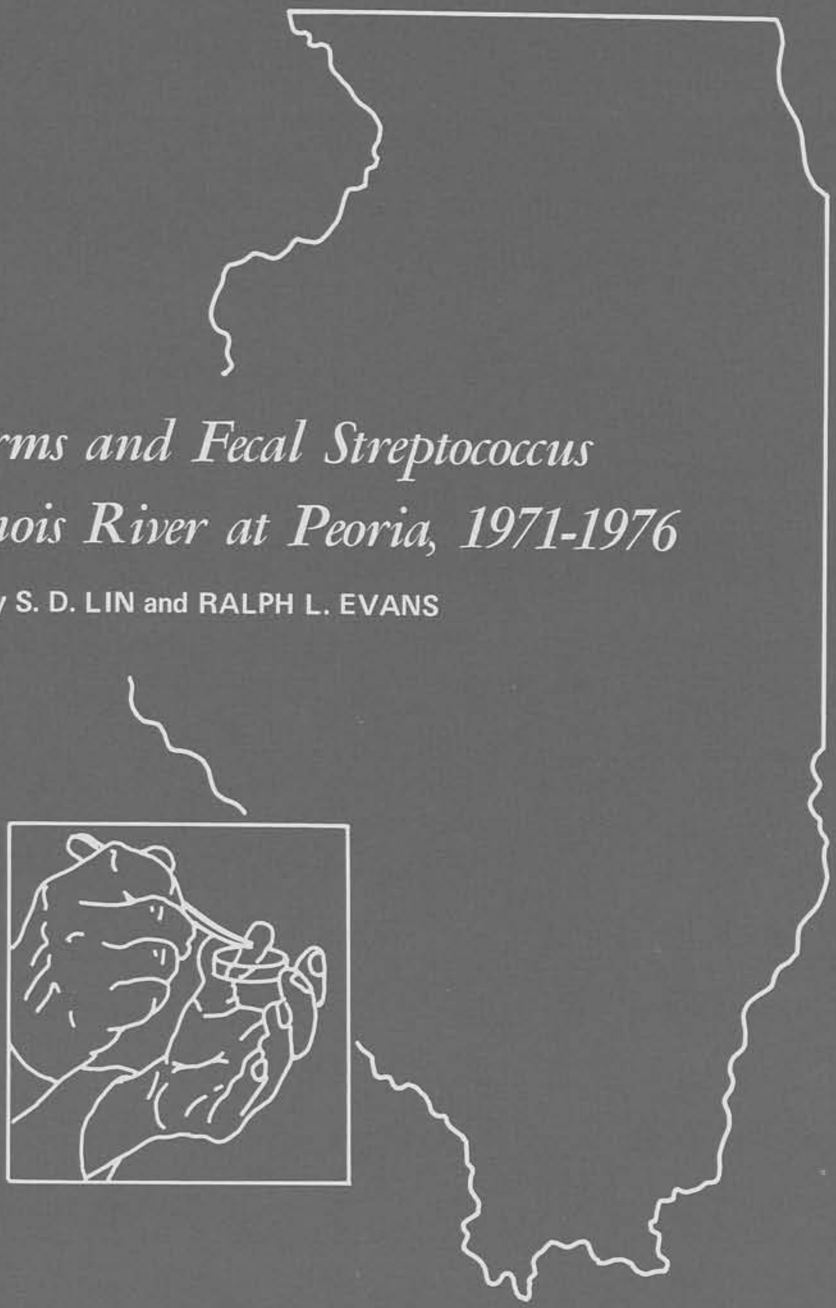

Coliforms and Fecal Streptococcus in the Illinois River at Peoria, 1971-1976

by S. D. LIN and RALPH L. EVANS

ILLINOIS STATE WATER SURVEY
URBANA
1980

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Abstract: Water samples from the Illinois River at Peoria were collected weekly and examined for total coliform (TC), fecal coliform (FC), fecal streptococcus (FS), and 17 chemical and physical parameters. The bacteria data obtained during June 1971 to May 1976 were compiled and evaluated monthly, seasonally, and yearly. Wide ranges of bacterial densities were observed. The densities of TC and FC were high during the winter and summer, respectively. The FS counts fluctuated less with time. About 44 percent of the time FC densities complied with the Illinois Pollution Control Board rule regarding 200 per ml. Compliance with the rule regarding 400 FC per 100 ml was found to be the limiting factor. Approximately 7.1 percent of the TC densities consisted of FC. The FC/TC values were low in the winter and spring months and high in the summer and fall. Based on FC/FS ratio values, fecal contamination derived from human sources occurred in 41 percent of the samples collected during June through August. An attempt to correlate the bacterial densities with the 17 parameters measured was not successful. A time series analysis was performed to show the trends, seasonal and cyclical indexes, and irregular factors for the bacterial densities.

Reference: Lin, S. D., and R. L. Evans. Coliforms and fecal streptococcus in the Illinois River at Peoria, 1971-1976. Illinois State Water Survey, Urbana, Report of Investigation 93, 1980.

Indexing Terms: Bacteria, fecal coliform, fecal streptococcus, Illinois River, time series analysis, total coliform, water pollution.

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Coliforms and Fecal Streptococcus in the Illinois River at Peoria, 1971-1976

by S. D. Lin and Ralph L. Evans

SUMMARY AND CONCLUSIONS

1. Bacterial samples for the Illinois River at Peoria were collected weekly during the 5-year period June 1971 to May 1976 and examined for total coliform and fecal coliform densities. Examination for fecal-streptococcus densities began in June 1972.
2. Samples for chemical analyses were collected and measurements for physical characteristics were performed weekly from December 3, 1973, to May 24, 1976.
3. Variations in bacterial densities were substantial during the 5-year period as shown from TC, FC, and FS data in figures 1, 2, and 3, respectively. The density (counts/100 ml) that is likely to occur 50 percent of the time was about 7900 for TC, 240 for FC, and 120 for FS.
4. The inspection of the bacterial density with precipitation in the Peoria area suggested that about 50 percent of the time increases in bacterial densities are associated with a precipitation event. The association is not sufficient to conclude that there is a clear-cut relationship between the two.
5. From a comparison of fecal coliform densities at Peoria with Rule 302(g) of regulations governing acceptable water quality in Illinois streams, it is concluded that compliance with the 200 per 100 ml stipulation is achieved about 44 percent of the time while compliance with the 400 per 100 ml stipulation is achieved about 25 percent of the time.
6. On the average about 7.1 percent of the total coliform densities consisted of fecal coliform. This compares with 8.8, 9.5, and 14 percent observed in the Upper Illinois River, Spoon River, and the Ohio River, respectively.
7. There is a considerable variation in FC/TC ratios. The lower ratios occur in the winter and spring because of increases in TC, while the higher ratios occur in the summer and fall because of increases in FC.
8. FC/FS values were used to determine the likely source of fecal bacteria. Grouping the bacterial density data on the basis of seasons indicates that fecal contamination is derived from human sources in 41 percent of the samples collected durihgvjune,. July, and August — the warm weather months.
9. Efforts to define relationships between bacterial densities and 17 chemical parameters observed at the point of sample collections were not successful.
10. A time series analysis suggests that total coliform densities will continue to increase with time in the river at Peoria. On the other hand, fecal coliform and fecal streptococcus densities will decline slightly.
11. In a situation where TC densities are expected to increase but FC and FS densities are to remain stable or decrease, bacteria of fecal origin are not the source of increasing TC densities.,The probable source is bacteria originating from the soil or *Aerobacter aerogenes* aftergrowths;
12. The fact that fecal coliform densities at Peoria exceed water quality standards most of the time is not surprising, since most Illinois streams do not meet bacterial standards. What is surprising is that the bacterial quality of the Illinois River at Peoria is as good if not better than that in one of its tributaries, the Spoon River, despite a sewered population upstream of the Peroia sampling station of about 10 times that of the Spoon River. This suggests that the assimilative capacity of stream waters and nonpoint sources are important factors in assessing the bacterial quality of streams.

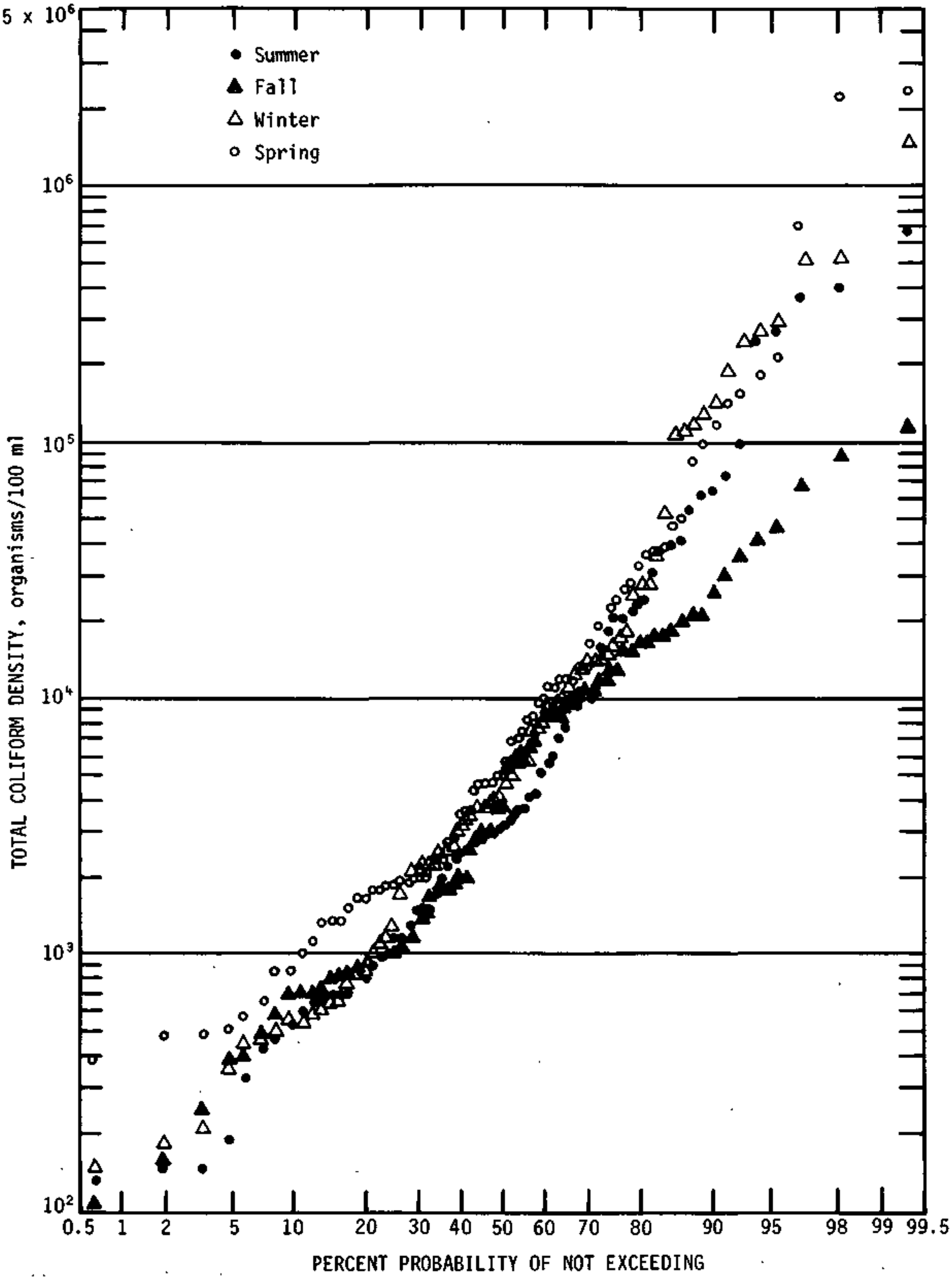

Figure 1. Logarithmic probability plots of total coliform densities for seasons during June 1971-May 1976

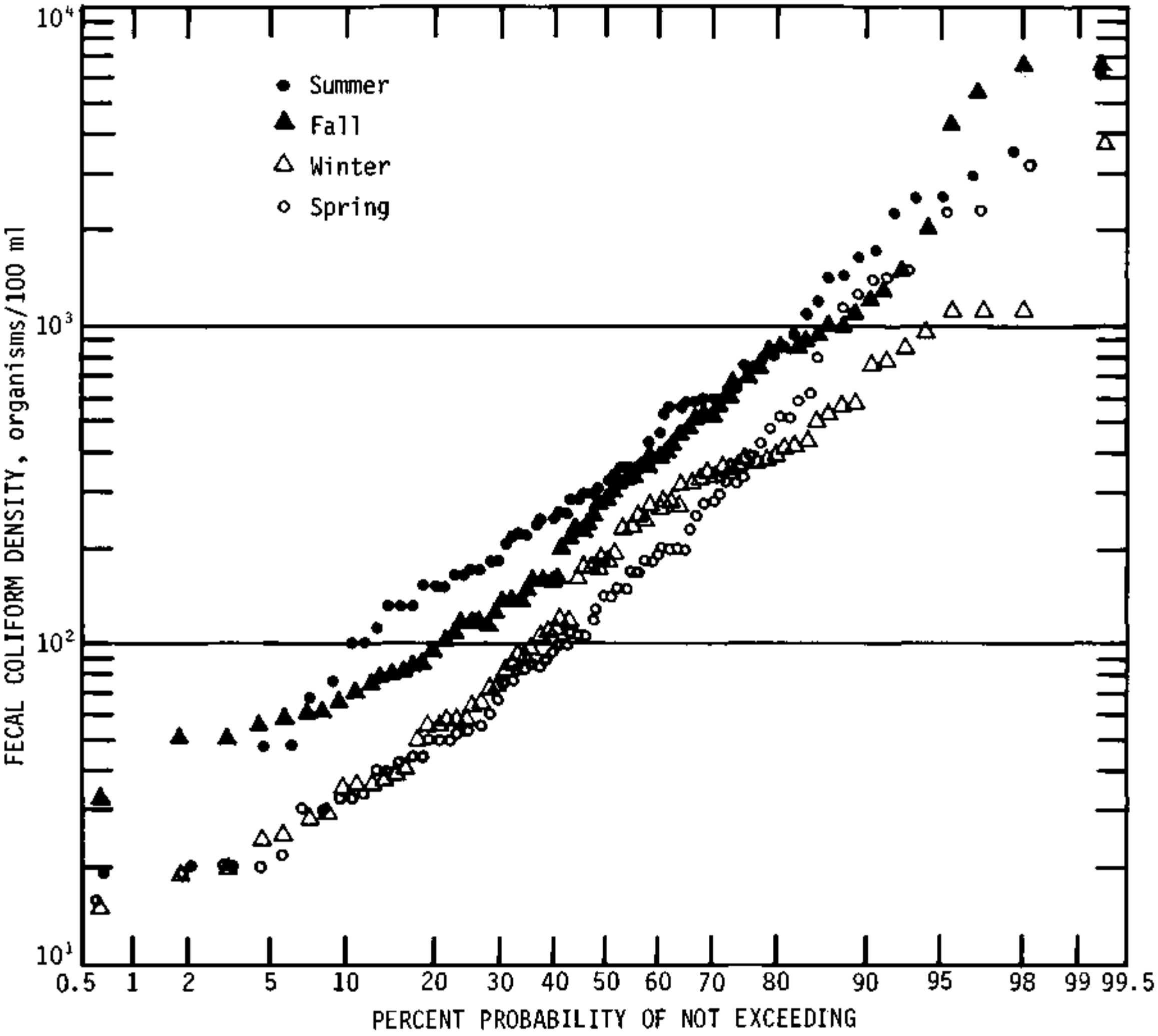

Figure 2. Logarithmic probability plots of fecal coliform densities for seasons during June 1971-May 1976

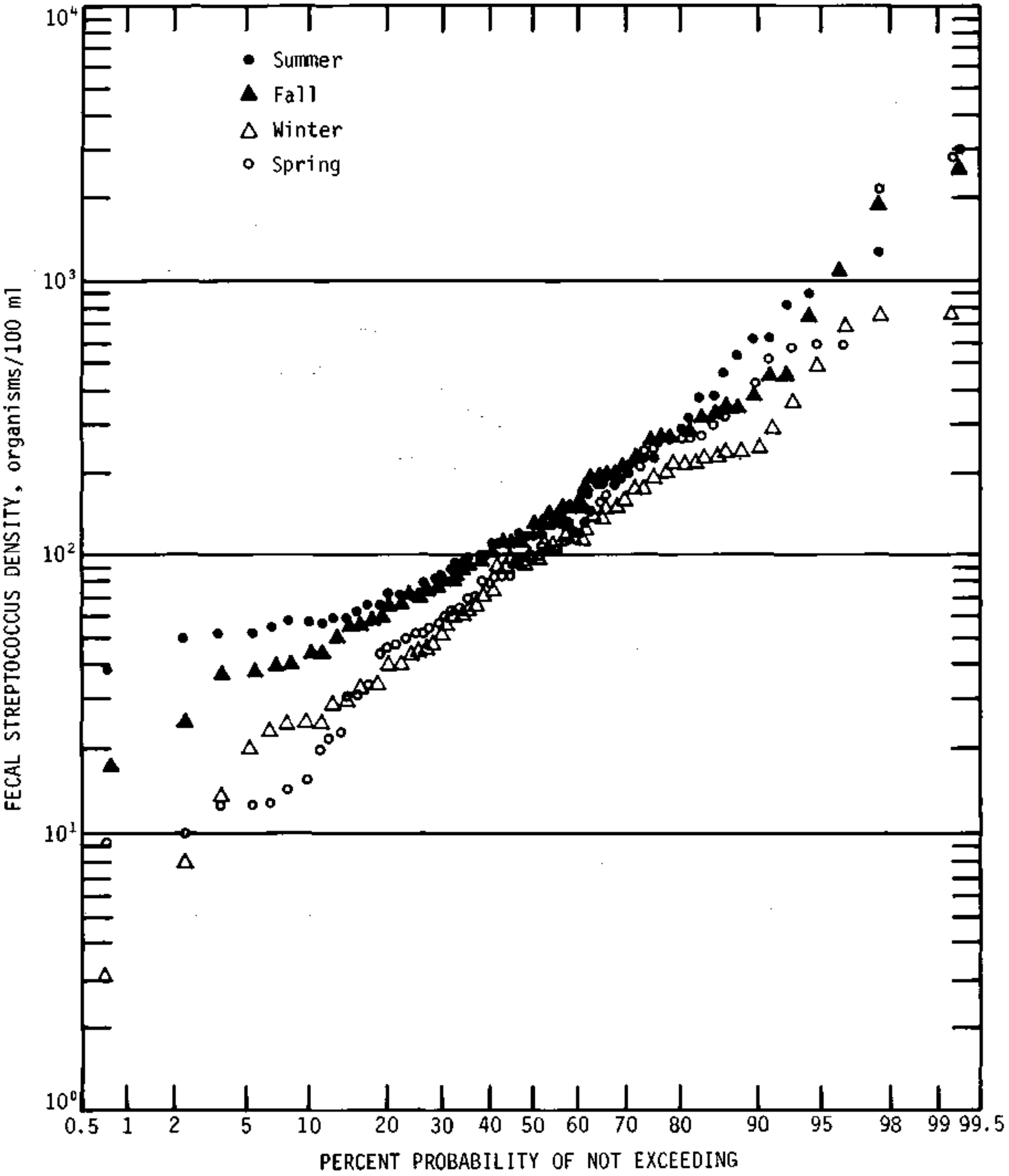

Figure 3. Logarithmic probability plots of fecal streptococcus densities for seasons during June 1972-May 1976

INTRODUCTION

Bacteria indicators, instead of pathogenic organisms, are used to determine the possible presence of disease-causing organisms derived from fecal pollution. Indicator bacteria such as total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) are used because of the laborious technique and expensive equipment required to isolate pathogenic organisms from water. The presence of coliform bacteria in a water is generally regarded as evidence of pollution by warm-blooded animals. The use of TC as a measure of the fecal contamination of lakes and streams has been in practice for almost six decades. The total coliform includes a group of heterotrophic bacteria, many of which have little in common with each other except that they are always present in the intestinal tract of humans and other warm-blooded animals. Thus, the occurrence and densities of the TC bacteria have been useful in assessing the sanitary conditions of water. The absence of TC is evidence of a bacteriologically safe water, not necessarily safe from virus.

Several strains of TC do not originate from fecal matter and are of soil origin. This confuses the use of TC as a water quality indicator. Several years ago, the fecal coliform, a subgroup of the total coliform bacteria, was introduced as an indicator of pollution from warm-blooded animal feces. This is a more precise bacteriological tool for assessing water quality. The Illinois Pollution Control Board[1] had adopted rules requiring adherence to certain limitations on bacterial quality in waters based on FC densities.

One of the drawbacks of using FC is the inability to distinguish between human and other warm-blooded animal sources. Geldreich et al.[2] first proposed the use of an FC to FS ratio as a more valuable tool for assessing pollution sources than the sole use of FC densities. Their findings[24] showed that FS densities were significantly higher than FC in all warm-blooded animal feces examined except that of humans. The application of these findings, within limits, permits the use of FS densities as a method for differentiating sources of bacterial pollution in surface waters.

FS tests are commonly used in the sanitary analysis of water supplies in European countries. In the United States, TC, FC, and FS have all been used as pollution indicators at various times.[5,6] Correlations between coliforms and pathogenic bacteria have been studied by many investigators. There is little evidence that enteroviral or other microbial diseases are transmitted frequently by the drinking water route in the absence of coliforms.[7] Unfortunately, bacterial indicators are generally not reliable indexes for viruses. The absence of indicators does not assure that viruses are also absent. Until a good alternative is discovered, the use of TC for water supplies and FC and FS for sewage and stream quality as indicators of enteric pollution is valid.

The bacterial population in a natural waterway is influenced by many factors including human activities and biological, physical, and chemical characteristics of the water. Recently the development of mathematical models for describing the various water quality parameters has been encouraged. Several models relating to coliform density in streams have been proposed.

About five decades ago, bacteriological studies on the Illinois River were made by Greenfield[8] for about 80 miles (130 km) from LaSalle to Kingston Mines and by Hoskins et al.[9] for approximately 300 miles (480 km), the whole length of the river. The State Water Survey performed weekly standard plate counts and some coliform tests on samples collected from the Illinois River at Peoria during a period from January 1959 to September 1962.

During the summer of 1971, an investigation to define the waste assimilative capacity of the Upper Illinois Waterway was undertaken by the State Water Survey. As a part of the study, about 150 water samples were examined for TC and FC in the waterway at 19 river stations from Lockport to Chillicothe, a distance of about 113 miles (182 km). The results have been reported elsewhere.[10,11]

Beginning on October 31, 1966, weekly samples of Illinois River water at Peoria were collected and analyzed for 17 physical and chemical parameters. Beginning in June 1971, bacterial examinations were made for TC and FC densities and in June 1972 for FS determination. The results of physical and chemical analyses for 1967-1972 have been summarized by Kothandaraman and Sinclair.[12] This study deals principally with bacterial data developed during the period June 1971 to May 1976. The sampling program is being continued.

Figure 4. Illinois River Basin showing the Illinois River and its tributaries

Table 1. Waste Discharge Point Sources to Upper Illinois Waterway

Source	*Mile point*	*Source*	*Mile point*
MSDGC Skokie	336.8	Morris	262.8
MSDGC Calumet	321.4	DuPont Corp.	254.4
MSDGC Stickney	315.8	National Phosphate	249.8
Grand Calumet River	325.7	Illinois Nitrogen	248.7
Lockport	290.9	Nabisco	246.8
Texaco	290.9	Marseilles	246.0
GAF Corp.	289.9	Marbon Corp.	244.3
U. S. Steel	288.9	Ottawa	239.3
Joliet	286.2	LOF Corp.	237.5
Olin-Blockson	284.5	Utica	229.6
Caterpillar	283.6	LaSalle	223.2
Amoco Chemicals	280.5	Peru	222.0
Stephen Chemicals	280.3	Spring Valley	218.0
Mobil Refinery	278.0	DePue	210.8
Rexene Chemical	277.7	Jones & Laughlin	208.2
Glidden Durkee	276.8	Hennepin	208.2
Reichhold Chemical	270.5	B. F. Goodrich	197.8
Northern Petroleum Co.	269.5	Lacon	188.8
Federal Paper	264.3	Chillicothe	179.0

The Illinois Waterway

The Illinois Waterway has three distinct sections. The uppermost portion includes the Chicago Sanitary and Ship Canal and its associated branches, which extend from Lake Michigan to the confluence of the Des Plaines River (MP 289.9). Approximately 17 miles of the Des Plaines River, between confluences with the Chicago Sanitary and Ship Canal and with the Kankakee River, is the middle section of the waterway. The lower and the major part of the waterway is the Illinois River.

The Illinois River is formed by the confluence of the Des Plaines and Kankakee Rivers (MP 273.0) southwest of Joliet. The river flows westward to DePue where it turns abruptly southwest and joins the Mississippi River at Grafton, above St. Louis (figure 4). The Illinois River is about 273 miles (439 km) long, whereas the entire waterway from Lake Michigan to Grafton is 327.2 miles (527 km). The total watershed area for the waterway is about 29,010 square miles (75,140 km^2). The watershed area for the waterway at Peoria, where the weekly samples are being taken, is 14,200 square miles (36,800 km^2). Besides the Des Plaines and Kankakee Rivers, other major tributaries above Peoria are the DuPage (MP 276.9), Fox (MP 239.7), and Vermilion (MP 226.3) Rivers.

The Illinois Waterway is a series of eight navigation pools created by locks and dams to maintain water depths needed for commercial barge navigation. The wastewaters from the Chicago area are frequently diluted with Lake Michigan water diverted through control structures maintained and operated by the Metropolitan Sanitary District of Greater Chicago (MSDGC). Diversion for dilution purposes by the MSDGC is limited to an annual average rate not exceeding 1500 cubic feet per second (cfs) (42.5 m^3/s). The average flow as measured at Kingston Mines, 16 miles (26 km) downstream from Peoria, is about 14,425 cfs (408.2 m^3/s). The recorded minimum and maximum flows are 1810 cfs (51.2 m^3/s) and 83,100 cfs (2350 m^3/s), respectively. The velocity of streamflow is less than 1 mile per hour (1.6 km/h) at normal river stages. The very small hydraulic gradient, an average of 0.267 feet per mile (5.06 cm/km), partially accounts for the low flow velocity in the river.

Wastewater Sources

There are 16 waste treatment facilities owned and operated by municipalities or sanitary districts which discharge effluents directly into the Illinois Waterway upstream of Peoria. In addition the waterway receives discharges from industries such as petroleum refining, metal finishing and plating, steel, fermentation and distillation, food, meat packing, paper and pulp, fertilizer and others.

Table 1 lists the wastewater sources upstream of the sampling station at Peoria. The three plants operated by the MSDGC contribute about 98 percent of the total municipal flow. This flow makes up over 93 percent of the total wastewater flows directly discharging into the Upper Illinois Waterway. The average flows of the MSDGC, other municipalities, and industries are 1466, 33.2, and 71.9 mgd (5.55×10^6, 0.126×10^6, and 0.272×10^6 m^3 *Id)*, respectively.

Objectives and Report Plan

Evaluating the quality of the Illinois Waterway at Peoria is a continuing process. The data subject to evaluation here were obtained from June 1971 through May 1976. The objectives of this report are:

1) To compile bacterial density data and compare them to existing rules and regulations governing bacterial quality in Illinois streams
2) To evaluate the significance of the FC/TC and FC/FS ratios
3) To determine the influence, if any, on bacterial densities and types by stream flow, seasons, and the chemical quality of water
4) To develop information from the data that would suggest predictive trends for bacterial densities at Peoria

This report describes the procedures used for bacteria enumeration. It also includes data on the type of bacteria examined, FC standards, bacterial type ratios, and statistical and time series analyses. The tabulations of observed data for TC, FC, and FS are given in appendix A.

Acknowledgments

The study was conducted under the general supervision of Dr. William C. Ackermann, former Chief of the Illinois State Water Survey. Many Water Survey personnel assisted in the study. Davis Beuscher, Dorothy L. Richey, Meri Phillips, and Pamella A. Martin performed bacterial determinations. Chemical determinations were performed by the Chemistry Laboratory. John R. Crooks and Robert A. Sinclair assisted data handling. J. Loreena Ivens and Tony Fitzpatrick edited the final report; Marilyn Innes prepared the camera-ready copy; Linda Johnson typed the original manuscript; and the Graphic Arts group, under the supervision of John W. Brother, Jr., made the illustrations.

METHODS

Beginning in June 1971, samples were collected weekly from the Illinois River (MP 161.6) at Peoria for chemical and bacteriological analyses. The location is 1.4 miles (2.2 km) upstream of the effluent from the Greater Peoria Sanitary District's facilities. During times of ice cover on the river, the samples were taken from the nearby Franklin Street Bridge about 0.5 mile upstream.

Besides bacteria enumerations, 17 other parameters were determined: water temperature, pH, dissolved oxygen, alkalinity, ammonia, nitrate, calcium, chloride, fluoride, hardness, iron, magnesium, silica, sodium, sulfate, total dissolved minerals, and turbidity. The procedures for chemical analyses are listed in table 2. The units are expressed as milligrams per liter (mg/1) except pH (unitless), temperature, and turbidity; temperature is in degrees Celsius, and turbidity in Nephelometric turbidity units (Ntu). Streamflows were estimated by subtracting flows of the Mackinaw River, Kickapoo Creek, and the Peoria Sanitary District effluent from the flow at Kingston Mines.

Bacteria enumerations for TC and FC began in June 1971, and tests for FS started in June 1972. Bacteria samples were collected 1 foot (30 cm) below the surface of the water and refrigerated immediately. Bacterial determinations were performed within 4 hours after collection.

Membrane filter techniques for TC, FC, and FS were performed in accordance with *Standard Methods.*[13] Previous studies[14,15] suggest that the membrane filter procedures are comparable to the multiple-tube methods for TC, FC, and FS determinations in river waters. TC counts were performed with the M-Endo agar LES two-step method. M-FC agar was used for the FC test. For the FS determinations, M-Enterococcus agar was employed during June 1971 through May 1975; since June 1975, KF-Streptococcus agar has been used. Three duplications for each sample were filtered through 0.45 Mm membrane filters for each test.

Table 2. Analytical Procedures

Determination	*Analytical procedure*
Iron (total on unfiltered sample)	Ortho-phenanthrohne (colorimetric)
Fluoride	Scott-Sanchis (colorimetric)
Silica	Molybdate (colorimetric)
Chloride	Mohr (volumetric)
Sulfate	Barium sulfate (gravimetric)
Nitrate	Reduction, distillation and nesslerization (colorimetric)
Determination	*Analvtical procedure*
Ammonium	Distillation and nesslerization (colorimetric)
Calcium	EDTA titration (volumetric)
Magnesium	Calculated
Sodium	Calculated
Alkalinity (as $CaCO_3$)	Methyl orange titration (volumetric)
Hardness (as $CaCO_3$)	EDTA titration (columetric)
Total dissolved minerals	Residue on filtration and evaporation

RESULTS AND DISCUSSION

Bacteria Density

Bacteria counts made for TC, FC, and FS on all dates are tabulated in appendix A. Bacteria densities varied from sample to sample. The intra-station variations observed were also apparent in other studies.[8-10,15,19] From June 1971 through May 1976, total coliform varied randomly from a minimum of 150/100 ml on July 16, 1973, to a maximum of 2,300,000/100 ml on March 17, 1975. A high TC count (2,200,000/100 ml) was also observed in the sample collected a week later. Generally, high TC counts were detected for samples collected during the fourth year of study, i.e., June 1974-May 1975.

Fecal coliform densities ranged from 16/100 ml on April 5, 1976, to 12,000/100 ml on May 28, 1974. Fecal streptococcus counts reached a minimum of 3/100 ml on January 5, 1975, and a maximum of 7700/100 ml on February 16, 1976.

Previous studies[10,18] suggest that the central tendencies and dispersion of bacteria data can best be expressed in geometric terms, i.e., geometric mean and geometric standard deviation. The yearly ranges, geometric means, and geometric standard deviations of the bacteria counts observed are summarized in table 3. During the 1974-1975 period, the mean densities for TC were significantly higher than recorded for other periods. This was not the case for FC and FS densities. Monthly geometric means of TC and FS bacteria densities are depicted in figure 5. In contrast to the TC densities, the pattern of monthly fluctuations of FS densities did not vary much from year to year. As shown in table 4, the highest geometric mean for TC, FC, and FS occurs in March, July, and June, respectively, during the period of study.

Figures 1, 2, and 3 depict the logarithmic probability plots of TC, FC, and FS, respectively, for each season. The geometric mean TC densities were high in the spring and winter, and were low in the fall and summer (figure 1). The difference between the high and the low was statistically significant. In contrast (compare figures 1 and 2), fecal coliform bacteria were significantly lower during the spring and winter months than during the summer and fall. There was no apparent seasonal trend in fecal streptococcus counts (figure 3), i.e., none of the seasonal geometric means were significantly different from each other for FS.

Several studies[15,19-22] indicated that peaks in the number of bacteria in water are associated with precipitation. Bennett[15] reported that increases in counts of TC, total plate count, FC, and FS at Toronto Harbour (Canada) occurred within 24 to 48 hours after rainfall. Gray[19] found peaks of *Escherichia coli* associated with precipitation during the previous 12 hours on three occasions, but a decrease on two occasions. Goyal et al.[20] observed that peaks of TC densities in water and sediment samples collected from canals along the Texas coast at polluted sites were always associated with precipitation within 48 hours of sampling. However, this is not the case for fecal coliform. A similar situation was observed in Biscayne Bay, Florida, by

Table 3. Statistical Data of Bacteria Counts per 100 ml

	Total coliform			*Fecal coliform*			*Fecal streptococcus*		
Study period	*Range*	*Mg**	og†	*Range*	*Mg*	*og*	*Range*	*Mg*	*og*
6/1971-5/1972	190-38,000	2,100	3.01	19-2,200	150	2.90			
6/1972-5/1973	420-1,500,000	8,200	4.13	20-5,300	300	3.58	8-900	120	2.84
6/1973-5/1974	150-180,000	5,000	4.22	48-12,000	330	3.52	12-2600	120	3.05
6/1974-5/1975	2400-2,300,000	67,000	4.99	20-8,300	290	3.78	3-1000	100	2.81
6/1975-5/1976	500-110,000	5,800	3.40	16-3,700	200	3.60	10-7700	140	3.24
6/1971-5/1976	150-2,300,000	7,900	5.91	16-12,000	240	3.50	3-7700	120	2.98

* *Geometric mean*
† *Geometric standard deviation*

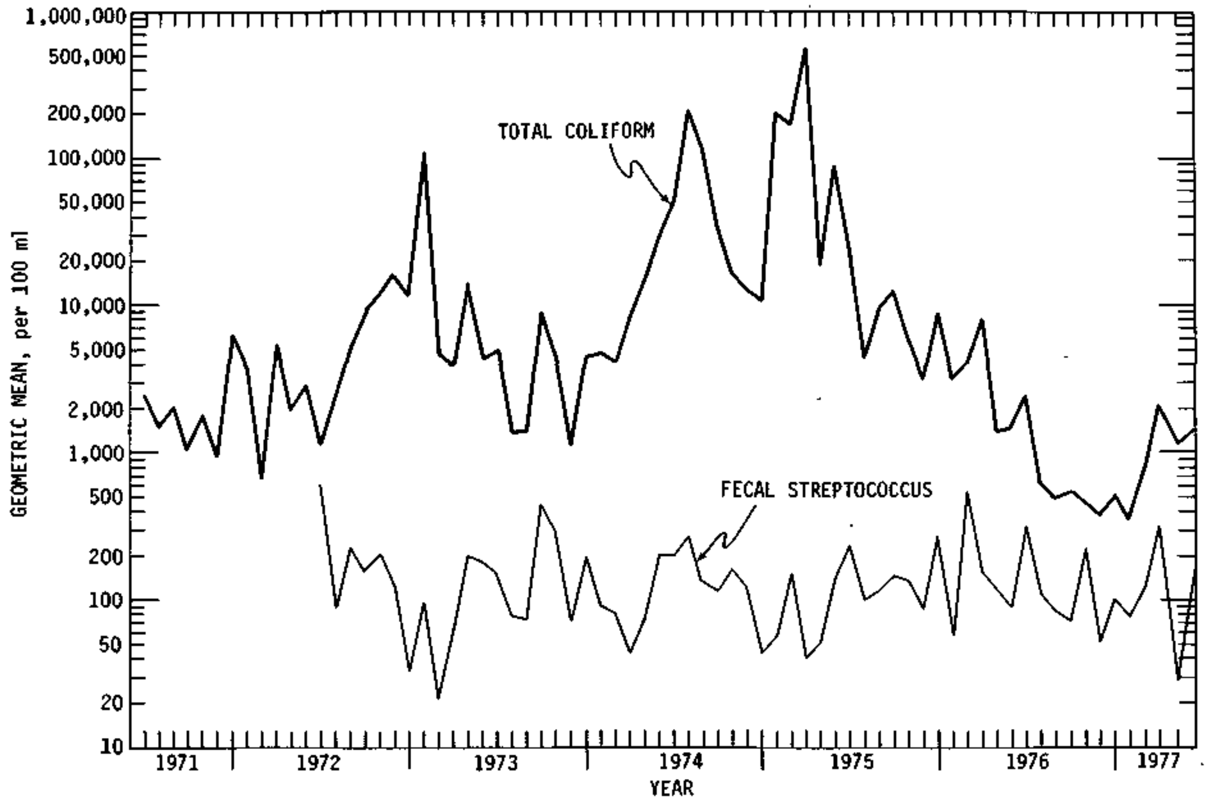

Figure 5. Monthly geometric means of total coliform and fecal streptococcus in the Illinois River at Peoria

Gerba and Schaiberger.[21] Feachem[22] reported that fecal streptococcus concentrations in streams of the New Guinea Highlands peaked rapidly following stormwater runoffs mainly because of animal (pigs) fecal pollution. Rises and falls of FC densities had no association with rainfall.

Daily precipitation data for 1971-1976 observed at the Greater Peoria Airport are listed in appendix B. Inspection of the observed bacteria counts (appendix A) and the rainfall data (appendix B) shows that about 50 percent of the time the increase in bacteria counts at Peoria was associated with rainfall at Peoria. Whether or not correlation existed was determined by comparing bacteria densities with the previous sample at times when significant precipitation (>0.3 inch) occurred three days before the sampling date. The rises in FC are generally associated with the peaks in the number of TC (appendix A). It is concluded that there is no clear-cut relationship between rainfall at Peoria and coliforms (TC and FC) in the Illinois River at Peoria, nor were sporadic increases in FS related to precipitation.

Table 4. Comparison of Bacteria Data on a Monthly Basis

	Total coliform 6/1971-5/1976			*Fecal coliform 6/1971-5/1976*			*Fecal streptococcus 6/1972-5/1976*		
Month	*N*	*Mg*	*og*	*N*	*Mg*	*og*	*N*	*Mg*	*og*
January	23	16,000	8.05	23	200	2.77	18	74	3.21
February	20	6,900	8.25	20	130	3.85	16	110	4.63
March	22	17,000	9.38	22	140	3.05	18	67	3.18
April	22	7,000	4.29	22	150	4.21	18	99	4.07
May	20	7,000	6.44	21	190	5.04	16	150	2.56
June	20	6,900	4.98	20	460	2.23	16	240	2.63
July	23	5,800	9.91	22	480	3.44	19	120	2.20
August	20	6,500	5.96	21	290	2.99	16	130	1.92
September	22	8,900	3.71	22	420	2.91	18	180	2.24
October	22	6,500	3.29	22	380	3.12	18	190	2.26
November	20	3,300	4.06	21	190	3.26	16	99	2.56
December	22	8,400	3.61	21	240	2.81	18	94	3.19

Note. N ts number of samples for each month during 5-year period

Comparison with FC Standards

The Illinois Pollution Control Board[1] has adopted two rules regarding bacteria quality applicable to the Upper Illinois Waterway. One (203g) is a general standard for most Illinois waters and the other (205 d) is for "Restricted Use Water" — certain designated waters which are not protected for aquatic life. The uppermost reaches of the Upper Illinois Waterway (above MP 278.0) are designated as restricted water by IPCB. The rules are:

203(g) Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 400 per 100 ml.

205(d) Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms shall not exceed a geometric mean of 1000 per 100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 2000 per 100 ml.

The FC data recorded for the Illinois River at Peoria from June 1971 to May 1976 were evaluated in terms of Rule 203(g) using a programmable Wang 720 calculator. The 30-day moving geometric mean and daily flow data are depicted in figure 6. There were some 30-day periods for which five samples were not available for evaluation, and these omissions are indicated on the abscissa of the figure.

The FC limit promulgated by the IPCB, i.e., the geometric mean of 200 per 100 ml that must not be exceeded, is shown in figure 6. Acceptable bacterial quality, as measured by geometric means during the study period, occurred during the following time intervals:

- In 1971, the first half of August, October through the first half of November, and the last half of December
- In 1972, January through May except February 28, December 29
- In 1973, January to the middle of March, April 23, July 9 and 31, latter part of October to the middle of November, and last half of December
- In 1974, March, September, and November to the middle of December
- In 1975, February through April, August 4, last half of September to the middle of November
- In 1976, January through the first part of February, latter part of February through May

From this information it is most difficult to draw a specific conclusion. Generally acceptable bacterial quality can be achieved in winter and spring, occasionally in the fall, and very rarely in summer. Table 5 shows that about 44 percent of the time there was compliance with the rule as measured by the geometric mean. During the second and third years of the study, compliance was achieved about 25 percent of the time. There is no relationship between streamflow and FC densities.

Nevertheless, the bacterial quality of the Illinois River at Peoria in terms of fecal coliform densities is better than that observed along the 161-mile (260 km) course of the Spoon River. From June

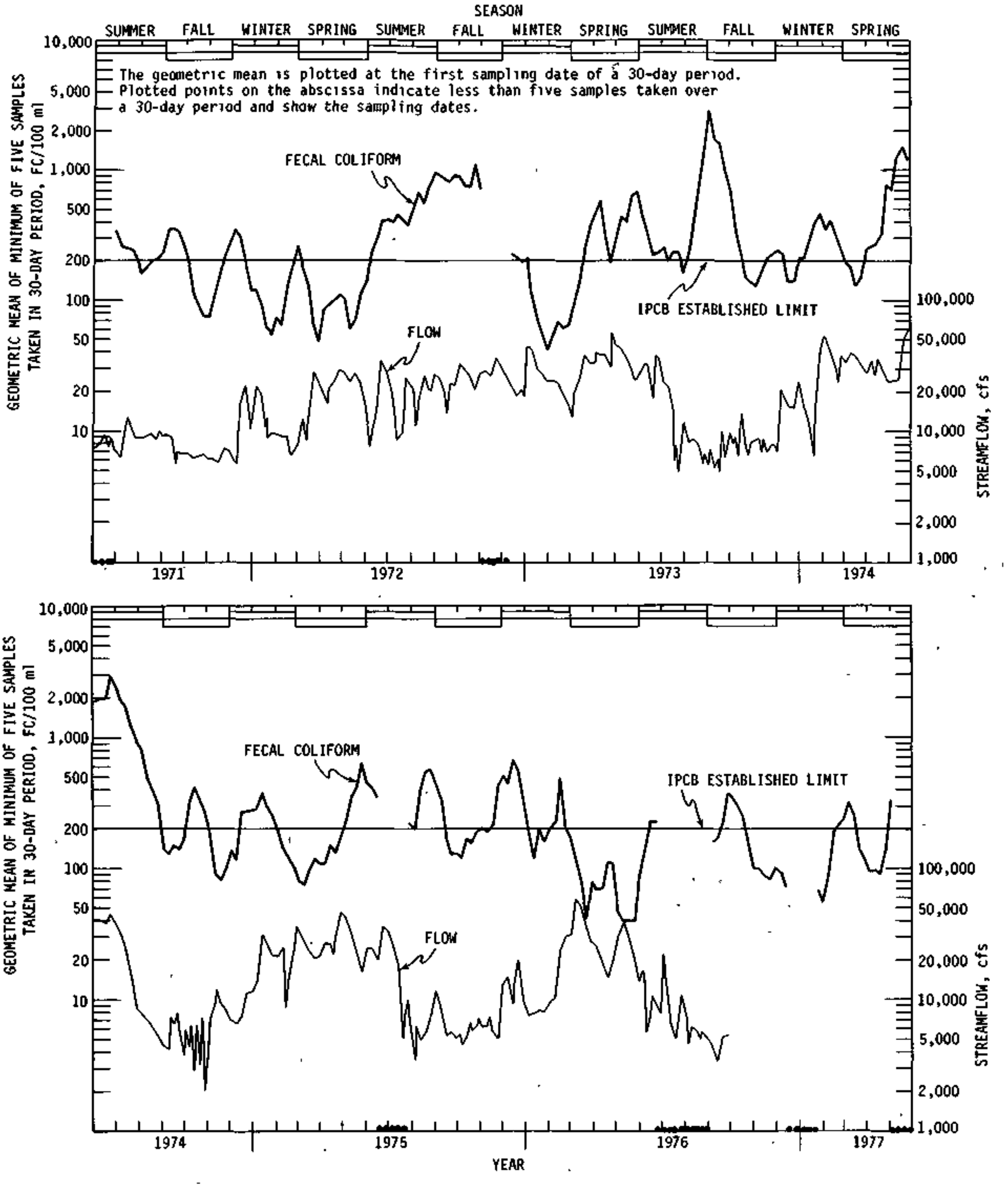

Figure 6. Geometric means of fecal coliform densities and flow in the Illinois River at Peoria

Table 5. Evaluation of Fecal Coliform Densities during June 1971-May 1976 with IPCB Rule 203(g)

		Observed data				***Data** adjusted with omissions*		
		Compliance with geometric mean (≤200/100 ml)		*Compliance with 10% of samples during 30 days (≤400/100 ml)*			*Compliance with IPCB Rule 203(g)*	
Sampling period	*Total number of 30-day periods evaluated*	*Number of 30-day periods*	*Percentage of 30-day periods*	*Number of 30-day periods*	*Percentage of 30-day periods*	*Total number of 30-day periods evaluated*	*Number of 30-day periods*	*Percentage of 30-day periods*
6/1971-5/1972	49	33	67.3	22	44.9	53	22	41.5
6/1972-5/1973	47	12	25.5	9	19.1	52	10	19.2
6/1973-5/1974	52	12	23.1	7	13.5	52	7	13.5
6/1974-5/1975	52	24	46.2	17	32.7	52	17	32.7
6/1975-5/1976	47	28	59.6	4	8.5	52	4	7.7
Five-year	247	109	44.1	59	23.9	261	60	23.0

1971 through May 1973, compliance was achieved along the Spoon River only about 20 percent of the time.[18] Since the sewered population of the drainage area at Peoria is about 10 times that of the Spoon River basin, nonpoint sources and the assimilative capacity of stream waters are important factors to be considered in assessing bacterial quality.

A comparison of the observed FC counts with the last part of Rule 203(g) shows that compliance was achieved about 25 percent of the time. On the basis of the results shown in table 5, it is apparent that this last part of the rule, whereby no more than 10 percent of the samples during any 30-day period shall exceed 400 FC/100 ml, is the limiting factor in assessing bacterial quality. The part of the rule regarding the geometric mean is not the limiting factor. A similar conclusion was reported for the Spoon River.[18]

FC/TC Values

The historical record of bacteria tests in the Illinois River as well as other surface waters is composed mainly of total coliform densities. It seems worthwhile, therefore; to determine the FC/TC ratio values. On the basis of these values, FC densities can be estimated from the historical TC data.

The arithmetic mean and standard deviation were used for evaluating the FC/TC ratios. The ratios are summarized for yearly and monthly intervals in tables 6 and 7. The overall ratios varied considerably, ranging from 0.0000 to 0.5333 with a 5-year average of 0.0711; in other words, about 7.1 percent of the total coliform consisted of fecal coliform. The overall average FC/TC ratio for the Illinois River at Peoria was found to be lower than that for the Upper Illinois Waterway (8.8 percent),[10] the Spoon River (9.5 percent),[18] and the Ohio River (14 percent).[23] The range of the ratios for the Illinois River at Peoria (0.000-0.53) was greater than that of the Upper Illinois Waterway (0.002-0.38) and the Ohio River (0.004-0.45), and was comparable to that of the Spoon River (0.003-0.57).

The yearly average FC/TC ratios varied widely; the high and low ones differ 10-fold (table 6). The highest yearly average was observed during the first study year (June 1971-May 1972), and the smallest ratio occurred during the fourth study year. To produce low ratios, either the FC densities must decrease or the TC counts must increase. From inspection of table 4, it can be concluded that the lower FC/TC ratios in the winter and spring are due to the increases in TC densities, and the higher ratios in summer and fall are due to the increases in FC counts.

Based on the 5-year data, the monthly average FC/TC ratios are modified by seasons. Table 7 shows that the ratios were low in winter and spring (December through May), while high ratios occurred in June, July, and September. The average ratio for August was about that for the 5-year average; the mean FC/TC values for October and November were above the 5-year average. Similar patterns were also observed in the Spoon River.[18] The monthly standard deviations followed the same pattern as the monthly average FC/TC ratios, i.e., the higher the monthly average, the higher the standard deviation.

Strobel[24] pointed out that the relationship between FC and TC varied with the source of pollution, level of wastewater treatment, characteristics

Table 6. Yearly Statistical Summary of FC/TC Values

Study period	*Number of samples*	*Range*	*Average*	*Standard deviation*
6/1971-5/1972	51	0.0081-0.5333	0.1181	0.1240
6/1972-5/1973	51	0.0007 -0.3095	0.0736	0.0690
6/1973-5/1974	52	0.0054-0.4483	0.1010	0.0870
6/1974-5/1975	50	0.0000-0.0523	0.0120	0.1534
6/1975-5/1976	49	0.0081-0.2235	0.0522	0.0462
Five-year	253	0.0000-0.5333	0.0711	0.0857

Table 7. Monthly Statistical Summary of FC/TC Values

Month, 6/1971-5/1976	*Number of samples*	*Range*	*Average*	*Standard deviation*
January	23	0.0002-0.1425	0.0353	0.0398
February	20	0.0006-0.1108	0.0537	0.0854
March	22	0.0000-0.1500	0.0290	0.0353
April	22	0.0054-0.1667	0.0338	0.0355
May	20	0.0009-0.1076	0.0428	0.0341
June	19	0.0081-0.5333	0.1166	0.1367
July	22	0.0008-0.5263	0.1466	0.1244
August	20	0.0007-0.1522	0.0695	0.0506
September	22	0.0013-0.4483	0.1140	0.1273
October	22	0.0100-0.2477	0.0880	0.0701
November	20	0.0133-0.2235	0.0785	0.0574
December	21	0.0007-0.1809	0.0487	0.0449

of the receiving waters, and precipitation on the watershed. Since so many factors may influence the FC/TC ratio value, it would seem unwise to rely on an overall average value based on a year or more of observation. In fact it would be preferable to limit judgment to only those ratio values obtained during stable streamflow conditions. Thus, on the basis of results shown in tables 6 and 7, the monthly average rather than the yearly average might be more useful in assessing the historical bacterial data.

The ORSANCO Water Users Committee[23] suggests that higher FC/TC ratio values might indicate the proximity of inefficient wastewater treatment operations or conditions where treatment facilities are being by-passed. Low ratios (<0.20) are most likely caused by aftergrowths of *Aero bacter aerogens* resulting in abnormally high TC counts.[23] In the Illinois Waterway at Peoria, 238 of 253 samples (94.1 percent) have FC/TC ratios less than 0.2. This is indicative of *A. aerogens* aftergrowths in the river in contrast to improper operation of waste treatment facilities.

FC/FS Values

The use of FS in conjunction with FC was first suggested by Geldreich et al.,[2] who felt the relationship of FC to FS density may be a more valuable informational tool for assessing pollution source(s) than sole reliance upon FC density. Estimated per capita contributions of FC/FS ratio values for animals are given in table 8. The data show that a ratio value greater than 4 is indicative of fecal bacteria derived principally from human waste such as domestic wastewaters. Values less than 0.7 are suggestive of fecal contamination derived principally from warm-blooded animals other than humans, i.e., livestock and poultry wastes, milk, and food processing wastes, or stormwater runoff (non-human source).

In applying the FC/FS technique to assess the source of waste, there are several precautions to be observed.[4,25] The best results are obtained if the sample is collected within a 24-hour streamflow time downstream of a pollution source because some species of fecal streptococci, such as *S. bovis* and *S. equinus*, have limited survival capabilities. Furthermore, the ratio values should not be used if FS densities are less than 100 per 100 ml. It is difficult to use ratios effectively when mixed pollution sources are present. Bacterial densities can be altered drastically if the pH of the water is above

9.0 or below 4.0. The FC/FS ratios have been of limited value in accurately defining major pollutional sources for marine waters, bays, estuaries, and irrigation returns.

During a 4-year period of this study, 120 water samples were collected in which FS densities were equal to or greater than 100 per 100 ml. A plot of FC densities versus FS densities for the period is shown in figure 7. About 62 percent of the samples had FC/FS values lying between 0.7 and 4.0; and 14 percent were less than 0.7 while 24 percent were greater than 4.0. On the whole, the source of fecal organisms at Peoria is not clear-cut, but there is a tendency for the human waste source to outweigh the non-human waste source, based on 4 years of record without regard to seasonal fluctuations.

For an evaluation of seasonal influences of FC/FS values, the data were divided into four seasons and two categories representing FC/FS >4.0 and FC/FS <0.7. The results are shown in table 9. During the summer and fall months, about 41 and 24 percent of the samples, respectively, were reflective of fecal contamination from wastes derived from human sources; whereas during the cold (winter) months, 27 percent of the samples reflected the fecal contamination from non-human sources, presumably from surface runoff. The spring period about equally divided those >4.0 and those <0.7, the majority (50-68 percent) of the samples having FC/FS values between 0.7 and 4.0.

From studies of the relationship of indicator and pathogenic bacteria in the Saline and Huron Rivers, Michigan, Smith et al.[26,27] reported that reaches of either river flowing through suburban areas of relatively low human population density might be expected to yield samples with no *Salmonella* but high FC/FS values. Conversely, samples from rural areas might yield salmonellae but exhibit low FC/FS ratios. High FC densities can occur in conjunction with low *Salmonella* counts and conversely.

Statistical Analyses

Mathematical models have been used for predicting changes in river water quality. There are two types of models, deterministic and statistical. A deterministic model describes an exact mathematical relationship among water quality parameters based upon continuity considerations and assumptions about the future behavior of the parameters in the model. A statistical model presents a probabilistic relationship among water quality parameters on a purely statistical basis. The statistical approach often includes probability relationships developed from time series analysis, multiple regression, age distribution, and probabilistic mass balance.[28] With any of these approaches, it is always necessary to assume some functional form whose usefulness can then be evaluated by comparison with given time series data.

Table 8. The FC/FS Ratio Values

Animal	*FC/FS*
Man	4.4
Duck	0.6
Sheep	0.4
Chicken	0.4
Pig	0.4
Cow	0.2
Turkey	0.1

The use of deterministic models for describing certain stream water quality parameters such as dissolved oxygen and biochemical oxygen demand has been successful to a certain degree. In contrast, the application of modeling techniques for indicator bacteria in natural waters has been limited because of the lack of definitive information on the relationship of bacteria densities to the environment.

An attempt to model coliforms in a stream by Dixon et al.[29] was not fruitful. Hendricks[30,31] and McFeters et al.[32] made efforts to describe growth and survival rates of coliforms in river waters. Brasfield[33] used multiple regression analysis to relate indicator bacteria to other water quality parameters, and Canale et al.[28] reported a consistent spatial pattern for total coliform in near-shore regions of Grand Traverse Bay, Michigan, with estimates of transient changes in TC density using statistical and deterministic models. First order kinetic formulations were developed for TC die-away relating reaction rate coefficients to water temperature. A negative linear correlation was observed between TC die-away rate and temperature.

Mahloch[34] made a comparative analysis of modeling for TC and FC in the Leaf River in Mississippi. He examined six different models, i.e., three each of the deterministic and the statistical types. A deterministic model $N_t = N_o e^{-\lambda t}$ was

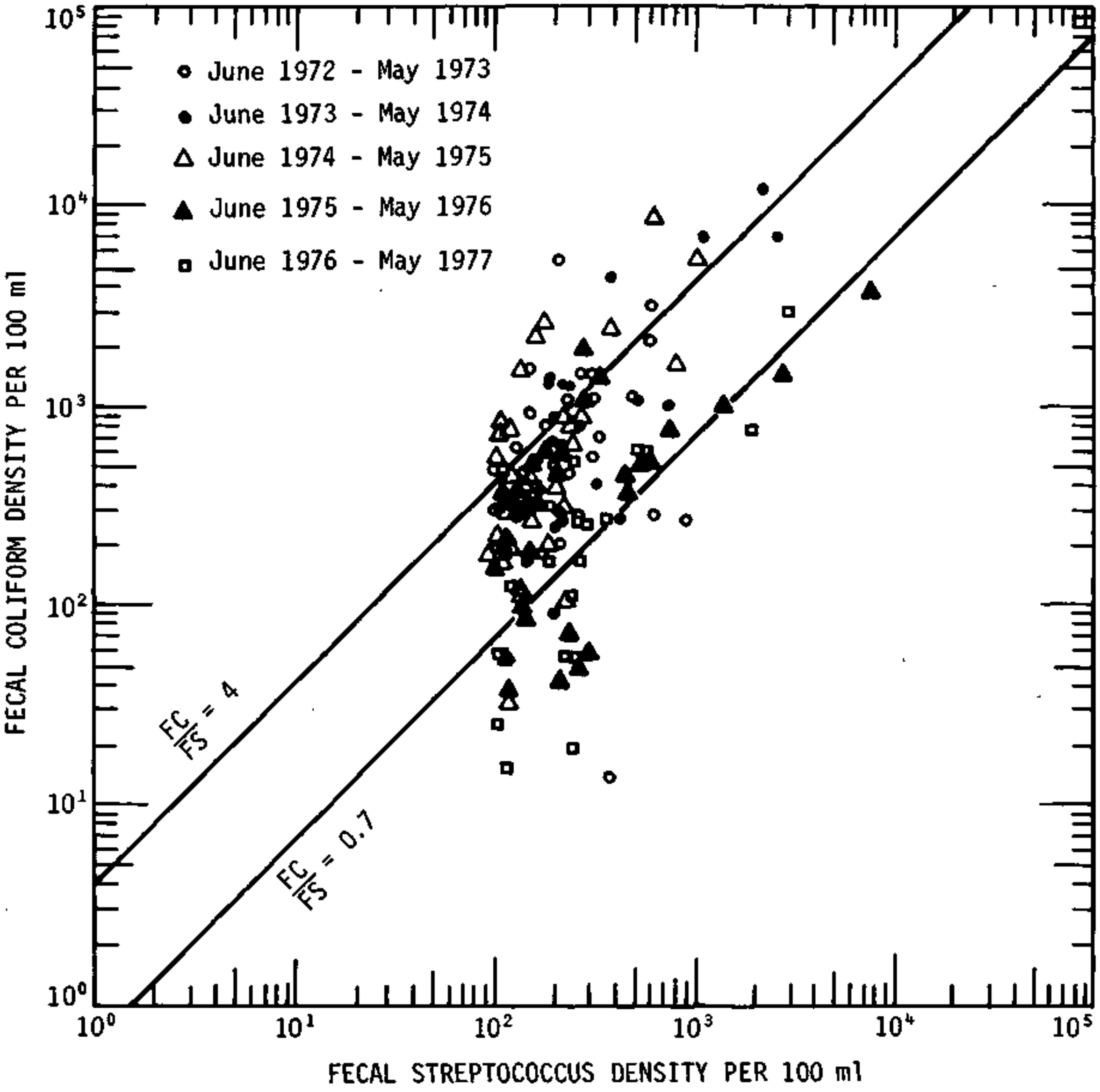

Figure 7. Relationship of fecal coliform and fecal streptococcus densities

Table 9. Seasonal Variation of FC/FS Values

Period (6/1972-5/1976)	Number of samples	FC/FS >4.0		FC/FS <0.7	
		Number of samples	Percentage	Number of samples	Percentage
Summer (Jun-Aug)	32	13	41	3	9
Fall (Sep-Nov)	37	9	24	3	8
Winter (Dec-Feb)	26	2	8	7	27
Spring (Mar-May)	25	5	20	4	16

found best suited for TC, where N_t = bacteria density at time t; N_o = initial bacteria density; X = net death rate; and t = time of travel in the stream (day). A statistical model, using canonical weights derived from the analysis to transform the original measurement variables, gave the best results for FC data.

Step-wise Regression

The data assembled as part of the weekly monitoring program at Peoria permitted the use of stepwise multiple regression techniques whereby 17 physical and chemical constituents of the waterway and its flow were correlated with the three types of bacterial densities. Means and ranges of these parameters, on a seasonal basis, are outlined in table 10. The corresponding constituents for each date of sampling with the bacterial densities observed on that date were subjected to regression techniques in the form:

$$y = a + a_1 X_1 + a_2 X_2 + \cdots + a_n X_n + e$$

where Y is the dependent variables is the intercept; a's are constants; X's are the independent variables; and e is the error term. A separate analysis was made of each season for each of the three dependent variables, i.e., log TC, log FC, and log FS. The 18 water quality characteristics included in table 10 were used as the independent variables. Any sample with incomplete data was deleted for analysis. The sample sizes were 35, 31, 17, and 27 for winter, spring, summer, and fall, respectively. Winter and spring samples cover a 3-year period, while summer and fall samples represent a 2-year period. The SOUPAC program and computer at the University of Illinois were used.

The results were interesting in terms of a statistical deliverance but completely inconsistent in terms of cause and effect. In one case (summer) about 75 percent of the variation of total coliform densities could be statistically explained by fluoride, silica, and alkalinity concentrations plus flow. In another case (fall) about 70 percent of the variation in total coliform densities could be explained by temperature, chloride, magnesium, and dissolved oxygen. Generally about 30 to 50 percent of the variation in fecal coliform and fecal streptococcus could be accounted for by a variety of water quality characteristics.

A similar approach was used by Brasfield[33] in analyzing data for the Gallinas River in New Mexico. Samples were collected twice weekly from March 12 to July 2, 1971, and eight independent variables were used for regression analysis. Phosphate, bicarbonate, and detergent were reported to be the significant variables for TC; phosphate, sulfate, and chloride were responsible for much of the variations in FC; and bicarbonate and chloride were the important factors for FS. However, the coefficients of determinations (R^2) were considerably less than those developed from the Peoria data. This suggests the evaluation applied to the Gallinas River produced results no more helpful in predicting bacterial densities from collateral data than experienced with the Illinois River at Peoria.

In general, where 50 percent or more of the variation in TC densities could be accounted for, about 12 different chemical constituents were involved in the interplay for the four seasons. In the case of FC and FS densities, most of the variations in the populations were unexplained.

Time Series Analysis

The weekly interval of sampling for bacterial densities produced data that can be classified as a time series. The analysis of a time series consists of an examination, generally mathematical, of the

Table 10. Statistical Summary of Water Quality for the Period of December 3, 1973, through May 24, 1976

	December-February		*March-May*	
Parameter, X*	*Range*	*Mean*	*Range*	*Mean*
1. Temperature, °C	0-9.8	2.4	2.9-22.8	11.3
2. Turbidity, Ntu	24-174	72	21-132	67
3. Iron	1.0-5.1	2.9	1.0-5.5	2.5
4. Fluoride	0.3-0.9	0.5	0.3-2.7	0.5
5. Silica	2.6-11.0	7.9	3.1-8.7	6.3
6. Chloride	33-116	64	29-70	43
7. Sulfate	67.5-131.6	103	65.0-104.9	88
8. Nitrate-N	11.1-31.5	20.9	17.0-32.2	24.0
9. Ammonia-N	0.5-3.6	1.7	0.2-1.9	0.8
10. Calcium	54.4-92.8	74.9	50.4-76.8	68.7
11. Magnesium	18.0-34.7	27.5	18.6-30.8	26.3
12. Sodium	18-82	47	17-46	28
13. Alkalinity	132-248	194	120-200	171
14. Hardness	220-372	301	202-316	279
15. Total dissolved minerals	345-636	477	315-490	410
16. pH	7.6-8.3		7.6-9.0	
17. Dissolved oxygen	10.2-17.1	11.9	4.0-12.7	9.5
18. Flow,cfs	6482-50,650	18,800	16,070-59,240	30,500
Total coliform	650-510,000	10,000t	500-2,300,000	19,000
Fecal coliform	20-3700	260t	16-1400	130
Fecal streptococcus	13-7700	130t	10-2900	75
Number of samples	35		31	

	June-August		*September-November*	
1. Temperature, C	20.0-28.8	25.3	4.4-24.5	14.4
2. Turbidity, Ntu	48-183	90	31-77	60
3. Iron	1.7-6.5	2.9	1.0-2.6	1.9
4. Fluoride	0.4-1.0	0.6	0.4-1.0	0.8
5. Silica	1.7-8.6	5.6	3.6-7.8	5.4
6. Chloride	22-61	43	44-76	63
7. Sulfate	60.5-109.2	87	82.5-123.4	105
8. Nitrate-N	11.1-29.1	20.1	11.7-21.9	17.2
9. Ammonia-N	0-0.3	0.2	0-1.5	0.5
10. Calcium	53.2-75.2	67.2	58.4-76.0	67.7
11. Magnesium	19.1-29.8	26.0	20.4-29.5	26.1
12. Sodium	16-54	33	25-69	53
13. Alkalinity	132-208	178	152-216	184
14. Hardness	214-310	274	248-310	276
15. Total dissolved minerals	299-488	413	401-518	462
16. pH	7.7-8.5		7.8-8.6	
17. Dissolved oxygen	4.2-7.1	5.6	4.1-11.6	8.4
18. Flow.cfs	3487-38,830	19,100	595-12,610	6300
Total coliform	1000-670,000	41,000	800-120,000	7600
Fecal coliform	75-8300	700	32-2000	230
Fecal streptococcus	60-1300	180	38-740	120
Number of samples	17		27	

* *Unit for bacteria ts organisms/100 ml, mg/l for others except as noted*
† *Geometric mean*

components responsible for the characteristics of the time series. The components are the trend (T), seasonal index (S), cyclical index (C) and irregular movements (I).[35,36] The mathematical relationship of the observed data (Y) to these components is in the form:

$$Y = T \times S \times C \times I = TSCI$$

The basic purpose of a time series analysis is to estimate the values of T, S, C, and I.

The trend can be estimated by 1) the method of least squares, 2) freehand method, 3) moving average method, 4) high-low midpoint method, and 5) the semi-average method. The seasonal index which permits an estimate of variations during a selected time interval within a year can be computed by 1) the average percentage method, 2) percentage trend (ratio of trend) method, 3) percentage moving average (ratio to moving average) method, and 4) the link relative method. The term CI is computed by dividing the observed data value, for a selected interval, by the product of the corresponding values determined for T and S, i.e., Y/TS. The cyclical index can be isolated from the CI term with an appropriate moving average method, thus smoothing out the irregular or random variations of CI values. The irregular movement (I) is then computed by the relationship Y/TSC.

The selected time interval for the time series analysis was monthly; and geometric means (Mg) for TC, FC, and FS for each month of the period of record, in log form, were used for Y. Trend values for each type of bacteria for each month were computed by the five methods previously mentioned. The least squares method in linear form produced the best results for the Illinois River data. The seasonal indexes were computed by the four methods previously noted. Three of the methods, i.e., the percentage trend, percentage moving average, and the link relative produced comparable results. Values derived from the percentage trend method are reported here. Cyclical indexes were developed from a three-month moving average, and they did not differ significantly from 100 percent, especially for FS. These methods suggest that the irregular factor (I) can approximately be determined by Y/TS. Nevertheless, I values presented here are calculated by Y/TSC.

The trends, seasonal indexes, cyclical indexes, and irregular movements for TC, FC, and FS are shown in table 11. The predicted bacterial density for any one month depicted in these tables is the product of the trend value for that month, the seasonal and cyclical indexes, and irregular movements, i.e., Y = TSCI. A review of table 11 shows a general trend of increasing total conform densities at Peoria, the highest seasonal index occurring in January. The trend for fecal conform densities is in a decreasing mode though at a very slow rate. The highest seasonal indexes occur during June, July, and September. The trend for fecal streptococcus densities is also in a decreasing pattern though hardly perceptible. The higher seasonal indexes occur during September and October.

Table 11. Estimated Trend Values, Seasonal Indexes, Cyclical Indexes, and Irregular Movements for Total Coliform, Fecal Coliform, and Fecal Streptococcus

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Total Coliform													
Trend,* T	1971						2,850	2,950	3,050	3,150	3,260	3,370	3,480
	1972	3,600	3,720	3,840	3,980	4,110	4,250	4,390	4,540	4,690	4,850	5,010	5,180
	1973	5,360	5,540	5,720	5,920	6,120	6,320	6,530	6,750	6,980	7,220	7,460	7,710
	1974	7,970	8,240	8,520	8,810	9,100	9,410	9,730	10,060	10,400	10,700	11,100	11,500
	1975	11,900	12,300	12,700	13,100	13,600	14,000	14,500	15,000	15,500	16,000	16,500	17,100
	1976	17,700	18,300	18,900	19,500	20,200							
Seasonal index (S%)		108.34	95.81	105.61	96.40	98.95	101.62	98.27	100.69	101.86	99.02	92.51	101.04
Cyclical index (C%)		100.24	100.47	100.63	100.70	104.59	103.14	99.40	99.54	99.65	99.78	99.77	99.99
Irregular movement, I	1971						.937	.938	.949	.854	.937	.915	1.061
	1972	.926	.823	.981	.944	.922	.806	.951	1.013	1.063	1.132	1.241	1.091
	1973	1.243	1.015	.899	1.142	.926	.927	.843	.820	1.014	.963	.853	.929
	1974	.867	.901	.942	1.086	1.091	1.132	1.371	1.265	1.107	1.061	1.100	.995
	1975	1.198	1.331	1.320	1.070	1.156	1.011	.897	.953	.965	.904	.897	.922
	1976	.760	.882	.859	.753	.728							
Fecal Coliform'													
Trend, * T	1971						249	249	249	249	248	248	248
	1972	248	248	248.	247	247	247	247	247	246	246	246	246
	1973	246	245	245	245	245	245	245	244	244	244	244	244
	1974	244	243	243	243	243	243	242	242	242	242	242	242
	1975	241	241	241	241	241	240	249	240	240	240	240	239
	1976	239	239	239	239	239							
Seasonal index (S%)		96.77	88.37	88.91	89.43	95.11	112.08	111.38	103.93	112.91	106.79	96.10	99.03
Cyclical index (C%)		99.47	99.48	99.63	99.63	102.91	102.45	99.31	99.34	99.36	99.40	99.44	99.46
Irregular movement, I	1971						.942	.935	.890	.894	.949	.819	1.095
	1972	.905	.852	1.063	.741	.865	.827	.983	1.134	1.087	1.163	1.245	.883
	1973	1.007	.723	.896	1.257	1.098	1.003	.904	.842	1.248	1.121	.937	.988
	1974	1.010	1.218	1.983	1.126	1.214	1.125	1.285	1.214	.805	1.062	1.062	.909
	1975	1.058	1.127	.902	1.010	.961	.968	.916	.936	.985	.838	.963	1.452
	1976	1.031	1.116	1.058	.893	.719							

Table 11. Concluded

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Fecal Streptococcus													
Trend,* T	1972						122	122	122	122	122	122	122
	1973	122	122	121	121	121	121	121	121	121	120	120	120
	1974	120	120	120	120	120	120	120	119	119	119	119	119
	1975	119	119	119	119	118	118	118	118	118	118	118	118
	1976	117	117	117	117	117							
Seasonal index (S%)		89.31	98.23	87.40	95.51	104.26	115.63	99.88	101.26	108.84	109.30	95.90	94.47
Cyclical index (C%)		100.01	99.98	99.98	99.97	100.51	100.00	99.99	100.00	99.99	99.99	100.00	100.00
Irregular movement, I	1972						1.149	.944	1.113	.967	1.014	1.048	.764
	1973	1.059	.656	.996	1.154	1.033	.905	.907	.884	1.168	1.080	.925	1.159
	1974	1.064	.937	.905	.936	1.066	.959	1.173	1.014	.907	.911	1.048	.838
	1975	.943	1.072	.886	.862	.979	.987	.976	.989	.957	.935	.979	1.238
	1976	.933	1.336	1.211	1.049	.902							

***** *Count per 100 ml***

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Appendix A. Bacteria Densities (per 100 ml) and River Flow (cfs) of Illinois River at Peoria

Date	*Total coliform*	*Fecal coliform*	*Fecal streptococcus*	*River flow*	*Associated wttb precipitation*
6/1/71	800	210		7,570	
6/7/71	23,000	220		7,770	No
6/14/71	Failed	Failed		9,020	
6/21/71	1,700	Failed		7,660	No
6/28/71	1,200	640		7,300	
7/6/71	190	100		6,360	
7/12/71	2,400	240		9,930	Yes
7/19/71	5,200	530		11,260	No
7/26/71	2,200	640		8,780	
8/2/71	7,700	150		8,860	Yes
8/9/71	800	110		9,100	
8/16/71	2,000	180		9,450.	Yes
8/23/71	2,500	230		8,770	No
8/30/71	1,200	150		9,370	
9/7/71	1,200	320		9,340	No
9/13/71	.400	160		8,910	No
9/20/71	1,400	230		7,000	Yes
9/27/71	2,000	350		6,726	Yes
10/4/71	6,400	1200		6,180	Yes
10/11/71	2,000	390		6,240	
10/18/71	1,000	120		6,443	
10/25/71	810	80		6,610	
11/1/71	700	73		6,150	
11/8/71	700	65		6,130	
11/15/71	1,000	120		5,850	
11/23/71	880	55		7,440	
11/29/71	1,800	76		7,030	
12/6/71	3,300	410		5,830	
12/13/71	2,100	380		15,900	
12/20/71	17,000	770		22,500	No
12/28/71	13,000	180		10,400	
1/3/72	7,600	230		19,900	
1/10/72	14,000	240		19,100	No
1/17/72	2,200	40		10,900	
1/24/72	1,900	72		9,640	
1/31/72	1,700	170		9,560	
2/7/72	530	57		9,090	
2/14/72	600	36		9,250	
2/21/72	650	19		6,730	
2/28/72	990	380		7,800	
3/6/72	1,600	88		12,400	
3/13/72	10,000	1500		12,100	Yes
3/20/72	13,000	180		25,800	
3/27/72	4,300	130		23,300	No
4/3/72	2,000	43		19,400	
4/10/72	2,700	22		20,900	No
4/17/72	1,500	52		23,900	No
4/24/72	1,900	43		29,400	
5/1/72	38,000	2200		28,400	Yes
5/8/72	2,300	60		23,800	
5/15/72	2,300	32		27,800	No
5/22/72	1,800	78		22,500	
5/30/72	480	40		15,000	
6/5/72	420	130	380	8,230	

(Continued on next page)

Appendix A. Continued

Date	*Total coliform*	*Fecal coliform*	*Fecal streptococcus*	*River flow*	*Associated with precipitation*
6/12/72	690	130	Failed	14,600	No
6/19/72	1,500	290	620	34,700	Yes
6/26/72	4,200	250	900	28,400	No
7/3/72	4,100	570	.63	19,300	
7/10/72	3,300	430	150	8,620	No
7/17/72	3,000	600	130	9,720	No
7/24/72	2,300	320	100	25,000	
7/30/72	900	220	59	20,600	
8/7/72	9,200	1100	470	17,100	Yes
8/14/72	2,700	300	220	26,500	No
8/21/72	3,100	340	88	21,200	
8/28/72	9,200	1400	280	27,400	Yes
9/5/72	9,100	840	260	26,030	
9/11/72	8,600	840	92	19,600	
9/18/72	6,900	820	180	22,900	
9/25/72	13,000	920	140	22,700	
10/2/72	21,000	1100	320	33,100	No
10/9/72	13,000	600	84	29,600	
10/16/72	11,000	700	330	26,200	
10/23/72	16,000	1500	160	20,600	Yes
10/30/72	8,600	810	260	27,400	
11/6/72	10,000	5.00	100	28,900	
11/13/72	11,000	560	310	26,600	No
11/20/72	6,7,000	5300	220	36,300	No
11/27/72	12,000	160	36	30,600	
12/4/72	4,100		4,6	26,900	
12/11/72	14,000	120	33	22,300	
12/18/72	35,000	170	29	18,300	No
12/26/72	12,000	90	24	20,500	
1/2/73	1,500,000	1100	230	43,600	Yes
1/8/73	280,000	3.1,0	190	41,200	
1/15/73	5^,000	.95	.64	29,100	
1/22/73	28,000	110	60	27,700	
1/29/73	24,000	110	43	23,800	
2/5/73	8,700	50	52	24,500	
2/12/73	5,000	34	8	23,700	
2/19/73	3,900	25	20	18,392	
2/26/73	2,500	28	29	15,800	
3/5/73	7,300	320	110	19,300	
3/12/73	11,000	200	210	24,700	No
3/19/73	1,800	20	15	38,500	
3/26/73	1,600	30	52	33,000	No
4/2/73	4,500	180	170	33,400	
4/9/73	32,000	2100	600	38,400	Yes
4/16/73	47,000	3200	660	38,900	Yes
4/23/73	7,100	200	100	30,900	No
4/30/73	17,000	100	50	45,500	Yes
5/7/73	6,900	430	230	43,000	No
5/14/73	1,300	110	93	36,500	
5/21/73	2,800	280	160	29,000	
5/29/73	13,000	1400	310	25,100	Yes
6/4/73	10,000	810	260	30,500	Yes
6/11/73	3,600	310	150	32,600	

(Continued on next page)

Appendix A. Continued

Date	*Total coliform*	*Fecal coliform*	*Fecal streptococcus*	*River flow*	*Associated with precipitation*
6/18/73	6,100	880	200	17,800	Yes
6/25/73	2,700	460	66	36,800	
7/2/73	1,500	170	55	23,700	
7/9/73	600	150	52	21,300	
7/16/73	150	48	51	14,100	
7/23/73	11,000	1200	220	5,747	Yes
7/30/73	3,400	600	82	11,700	
8/6/73	680	68	59	9,120	
8/13/73	3,700	280	94	8,360	Yes
8/20/73	480	48	72	7,700	
8/27/73	3,200	220	73	6,680	No
9/4/73	18,000	4200	390	7,350	Yes
9/10/73	2,900	1300	190	5,380	
9/17/73	35,000	6700	2600	6,702	Yes
9/24/73	3,700	650	200	6,370	
10/1/73	88,000	6800	1100	9,600	Yes
10/8/73	3,000	400	330	9,040	
10/15/73	5,300	1000	740	12,600	Yes
10/22/73	1,700	420	97	8,270	
10/29/73	950	140	73	8,150	No
11/5/73	1,500	160	66	8,710	
11/12/73	820	59	38	6,850	
11/19/73	800	140	76	6,870	
11/26/73	1,600	270	130	7,870	
12/3/73	1,300	88	200	7,000	
12/10/73	7,400	580	220	18,800	
12/17/73	11,000	240	210	15,200	Yes
12/26/73	3,700	160	140	14,900	
1/2/74	8,600	350	92	23,300	No
1/7/74	3,700	63	24	14,700	
1/14/74	1,200	63	32	10,600	
1/21/74	3,400	260	220	12,600	
1/28/74	18,000	1100	500	39,100	Yes
2/4/74	16,000	380	170	50,700	
2/11/74	5,600	270	40	40,100	
2/18/74	3,200	310	40	28,800	
2/25/74	9,600	520	170	37,100	
3/4/74	50,000	270	420	34,700	Yes
3/11/74	12,000	950	53	39,600	Yes
3/18/74	4,600	81	14	36,500	
3/25/74	2,000	100	12	31,700	
4/1/74	3,500	110	31	27,300	No
4/8/74	120,000	200	110	34,000	No
4/15/74	8,000	230	47	32,300	No
4/22/74	5,000	150	52	31,300	
4/29/74	37,000	1200	230	24,100	Yes
5/6/74	9,700	140	62	23,700	
5/13/74	12,000	250	71	24,500	
5/20/74	36,000	520	200	50,900	Yes
5/28/74	180,000	12,000	2200	58,800	Yes
6/3/74	41,000	800	110	41,800	
6/10/74	62,000	2200	170	40,700	Yes
6/17/74	54,000	750	110	38,800	
6/24/74	Failed	1600	810	45,500	Yes

(Continued on next page)

Appendix A. Continued

Date	*Total coliform*	*Fecal coliform*	*Fecal streptococcus*	*River flow*	*Associated with precipitation*
7/1/74	240,000	8300	620	38,600	
1/8/14	31,000	1400	130	32,100	
7/15/74	270,000	2500	180	24,400	Yes
7/22/74	370,000	5500	1000	14,500	Yes
7/29/74	670,000	560	100	8,660	Yes
8/5/74	400,000	2500	390	7,560	
8/12/74	100,000	750	120	7,000	
8/19/74	66,000	350	80	6,060	
8/26/74	75,000	1700	93	5,290	
9/3/74	20,000	330	120	4,410	
9/9/74	120,000	160	100	4,220	No
9/16/74	41,000	280	110	6,580	No
9/23/74	25,000	120	130	5,930	
9/30/74	15,000	32	110	3,800	No
10/7/74	17,000	220	110	4,390	
10/14/74	30,000	300	210	6,430	Yes
10/21/74	16,000	200	190	3,220	
10/28/74	9,800	330	150	2,040	
11/4/74	17,000	890	260	7,080	Yes
11/11/74	46,000	670	240	9,710	Yes
11/18/74	2,700	100	210	9,480	No
11/25/74	Failed	79	17	8,460	
12/2/74	2,600	58	24	6,950	
12/9/74	2,400	20	13	6,780	
12/16/74	5,800	420	140	7,680	
12/23/74	14,000	270	67	11,800	
12/30/74	510,000	350	60	11,500	No
1/6/75	190,000	39	3	13,800	
1/13/75	140,000	860	210	29,300	No
1/20/75	120,000	430	120	25,400	
1/27/75	510,000	350	130	22,000	
2/3/75	240,000	330	160	21,400	
2/10/75	260,000	170	110	25,600	
2/17/75	110,000	260	150	14,200	No
2/24/75	130,000	190	210	23,800	No
3/3/75	84,000	110	130	34,000	
3/10/75	210,000	50	65	28,400	
3/17/75	2,300,000	76	12	23,300	No
3/24/75	2,200,000	150	60	20,800	No
3/31/75	670,000	53	20	21,700	No
4/7/75	12,000	83	30	24,400	
4/14/75	19,000	200	33	26,800	
4/21/75	26,000	190	83	29,000	
4/28/75	22,000	120	80	35,500	
5/5/75	28,000	40	82	42,700	
5/12/75	150,000	400	200	33,600	No
5/19/75	100,000	80	83	23,300	
5/26/75	140,000	800	240	16,100	No
6/2/75	40,000	600	180	24,100	No
6/9/75	24,000	350	90	24,800	
6/16/75	21,000	930	1300	20,000	No
6/23/75	22,000	590	530	35,800	
6/30/75	21,000	170	60	33,400	No
7/7/75	18,000	360	110	25,200	No

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Appendix A. Concluded

Date	*Total coliform*	*Fecal coliform*	*Fecal streptococcus*	*River flow*	*Associated with precipitation*
7/14/75	1,000	160	72	17,700	
7/21/75	7,100	Failed	130	7,490	
7/28/75	3,000	300	120	6,590	-
8/4/75	5,700	75	66	3,490	Yes
8/11/75	10,000	100	120	4,890	Yes
8/18/75	15,000	370	120	5,630	Yes
8/25/75	Failed	580	210	7,610	
9/2/75	8,600	210	110	11,800	
9/8/75	21,000	2000	290	8,320	Yes
9/15/75	10,000	510	150	5,200	
9/22/75	15,000	470	200	5,610	Yes
9/27/75	12,000	140	65	5,140	
10/6/75	5,500	58	58	4,480	
10/13/75	3,700	83	140	5,300	
10/20/75	8300	140	80	5,800	
10/27/75	6,100	440	450	6,370	
11/3/75	3,200	85	60	6,200	
11/10/75	5,800	360	450	6,400	
11/17/75	3,000	50	40	5,650	
11/24/75	1,700	380	55	5,020	
12/1/75	5,700	500	700	13,000	Yes
12/8/75	2,200	80	90	14,500	
12/15/75	10,000	750	760	12,300	Yes
12/22/75	27,000	1100	290	20,500	No
12/29/75	15,000	960	95	9,520	Yes
1/5/76	7,900	270	44	7,480	No
1/12/76	3,000	330	23	7,800	
1/19/76	4,000	570	71	8,200	
1/26/76	1,100	55	110	8,040	
2/2/76	650	72	240	9,380	
2/9/76	870	35	110	10,300	
2/16/76	110,000	3700	7700	24,100	Yes
2/23/76	4,700	230	360	31,800	No
3/1/76	11,000	140	100	33,700	
3/8/76	21,000	170	150	59,200	
3/15/76	24,000	1300	320	51,200	Yes
3/22/76	3,400	50	270	35,900	No
3/29/76	1,700	90	70	27,300	
4/5/76	500	16	10	25,600	
4/12/76	1,000	30	22	20,000	
4/19/76	850	55	300	14,600	
4/26/76	8,400	1400	2900	20,700	Yes
5/3/76	1,100	42	210	31,600	
5/10/76	Failed	20	55	39,200	-
5/17/76	5,700	300	130	30,600	Yes
5/24/76	850	50	43	21,400	

Appendix B. Daily Precipitation Observed at the Greater Peoria Airport, 1971-1976

Date	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Year - 1971												
1			.01	.01		.28			.18		.18	
2			T					T		.10	T	
3	.50	.01	T					.07		.90		
4	.03	.85					.05		T			.02
5		.03	.12		.33			.02	.04		T	.05
6			.10		.29				.53		T	.23
7			T		.42		T					T
8					.27			T		.23	.07	T
9			.07				1.93			T	.04	.12
10			.03			T	1.11	.43	T			1.48
11	T	.05	.31		.12	.08			.30			
12	T	.01				.01	T					
13	.02	T		.03			.34			T		T
14		T	.22			T	T	1.44				.27
15			T			T			T			.83
16		T			T				.01			
17	.01	T		T	T		.03					T
18	T	.21	.08				.01		.46		.49	
19		.29	.15		T		T	.11	.32	.05		.13
20		T		.22	T			T			T	T
21	T	.02		T	T					.42		
22		.16	T		T	T		T		T		
23		T	T		.56		1.18 .	T		T	.02	-
24					.81	.29		.12	T	.01	.02	
25					T	.32		T	1.14			.02
26		.01					T		.09		.41	.01
27	.02			.45						T	T	.04
28	.01						.50				.14	-
29	T						.06				.06	1.25
30						T				T	T	.51
31												
Total	.59	1.64	1.09	.71	2.80	.98	5.21	2.19	3.07	1.71	1.43	4.96
Year - 1972												
1	.06	T	.08	.08	.09			T	T		.64	
2	T	.10	T	.01	T		.03	.01	.35		.11	
3	.09	.05		.04				.78		.06	.01	.01
4	.04		T							.03		.02
5			T		T	.86		T				.04
'6		.05		.50	.11			.78		.14	T	.01
7		T		.31	.01		.06	.02	.25		T	.05
8		.03	T		.05	.72		.21			T	.02
9		T				.44	.86					.07
10		.06					T		T	T	.20	T
11	.01	.12		.30				.01		.18		.03
12	T	T	.60	T	.02	.23	T	.59	.47	T	.12	1.42
13	.25	.02	.53		.68	.29			2.09		.79	
14	T	.04		.41	.21	*.69*	.42		.55		.14	
15		T	.16		T		.01			T		.02
16	T	T	.06	.23				T		T		
17		.10					1.10		T		T	
18		T					.30			.06		T
19	T			1.08		1.84	.46		.01		.20	T
20	.01					. T			.69	.05		T
21	T		.02	.50	-	T			.02	.57	. T	T

T = Trace

{Continued on next page)

Appendix: B. Continued

Date	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Year - 1972												
22	.01			T				.05	T	1.06	.02	T
23	.13	.14		T				1.73	.10	T		T
24	T	T			T		.02		T	T		T
25		.03						.08	.04		.23	.03
26			.54		.03		.28	T	.02		.07	T
27	.20		.01				T			.14	.02	
28	.01		T	.30	.02	.90			.60	.01		
29			.35	T	.07				.02	T		.44
30				.62	.01					T	.01	.32
31			.13				T			.20		T
Total	.81	.74	2.48	4.38	1.30	5.97	3.54	4.26	5.21	2.50	2.56	2.48
Year - 1973												
1		.31	.04	.35	.38		.02			1.04		
2		.05	T	.01	.02	.58	T		.06		T	
3	.97		T	T		.62			1.07	.39		T
4	T		.29	.09		.09	1.00	T	.63	.32		1.56
5	T	T	.12		T	.44						.05
6	T	T	1.64		.28					.02		T
7		.11	.24	T	1.40							
8	T			.13	.03			T	.78	T	.01	
9	T		.05	.93	.10			.01	.02			.05
10			.28	.01	T		.54					T
11			.01	.01	.01			.26		.09		
12		.01		T		.13		.33		1.52		.07
13		.35	.90		T			.10	.67	.45		.55
14		.09	.23		T			.03	T			.04
15		.03		.01		T			T		T	.06
16			.25	.48		.65			.15			
17		T	.02			.02			.84	T		
18	.25	T		.01	.01	1.65						.32
19	T	.04	.06	.04		.93	1.88	T	T			.60
20		T	T	.06			.31				.88	
21	.19			1.64	T		1.43	T	T		.08	
22	.19			.07	.61		T	T	.60			
23	T		T		T		.18	.11				T
24			.01		.25		T		.21		.05	.38
25		T	.80		T		.46		.26		.01	.05
26	T	T	.01		.40	1.07	T				.04	T
27	.02				.35	.28	.03		.02	.40	.25	.04
28	.14		.25	T	.10				1.12	T	.16	.12
29	T		.80	.26	.50		.18	T		.02		.04
30				.16	.07		.01	.06	1.15	.03		.13
31	T		.95				T			.90		.05
Total	1.76	.99	6.95	4.26	4.51	6.46	6.04	.90	7.58	5.18	1.48	4.11
Year - 1974												
1			T				T	.04	.03			.30
2	.01				.11	.07		.09	.11			T
3			T	.05	.05			.05			1.52	
4			.86	.15			.16	T		.10	.59	
5		T		.02		1.48				.02	T	.04
6	.02	.12				.70				.10	T	.22
7		T		T	.55	.30						T
8	.32	T	.15		.14	.43						
9	.07	T	.36	T		.11		.07			.01	
10	.13	.03		T	.24	.01	.75	.25	T		1.10	

(Continued on next page)

Appendix B. Continued

Date	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
11	T		.34	1.71	.16	.50	.27		.08	.17	.03	.20
12			.13	T	T				.40	T	T	T
13	T			.18	T					.97	.33	T
14		T		.49	.73	.97	.64			.02	T	.21
15			.31					.07				.04
16			T		.14			.03			.21	T
17	T				.32							.01
18	.01	.21	T	.16	.90		T	.13	*	.06	T	.16
19	.36	.07			.84	.71	T				T	
20	.77		.08	T	T	.05			T			.01
21	.16	.74	.01	.31	.82	1.95			T			T
22	.17	.45	T		.01	4.41	.58					
23			T		.02					.05	.06	.18
24		.03	T								T	.08
25				.02				T		.02		
26	1.02				.14							
27				T	T							T
28	.05		T	.38	.70		.23	.01	.83	.07		T
29			.34	.64	.22	T				.49	.06	.02
30			.11		.15			.04			.22	T
31					.02			.03		T		.46
Total	3.09	1.65	2.69	4.11	6.26	11.69	2.63	.81	1.45	2.07	4.13	1.93
Year-	*1975*											
1			T			.01		.13			.28	
2	.02		T	1.42		.01		.32				
3	.02			T	.02	T	T				.11	T
4		.05			T	.01	T		.16		T	
5		.21				.84	.55	.23	1.08			.16
6	.10	.01	.05		T	T	T					.10
7	.01		.17		T						T	
8	T	.20		.06	.81				.17	.32		.12
9	.22		.09	.06							.38	T
10	1.25	T	.11	T			.02					
11	T	.01	.07		.20		.36	.40	.01			
12	T		T		.10	T	T	T			.09	T
13	T	T				.23	.01	.31			T	.03
14	.03	.31		.05	.20	.80		1.62	T	1.93		1.14
15	.11	.42				.07			T			T
16	T	.28				T						
17	.03	.06				.89			.35			T
18	.02	T		1.28				1.31	.58			
19	.15			T	.50		.03		.22			T
20					T		T	.02			.12	T
21			T	T	.03						.03	
22	T	.51	T			.08	T					
23		.42	.25	.93	.23	.09	3.26					
24	.38	.34	T		.40	T	.01			1.32	.05	.02
25	.10	.03	.04		.89	.22		.36			.01	.01
26	T	T			1.02						.53	T
27			.76	.11								
28	.08		.19	.01	.01	.65		.16	T	.06		.01
29	.02		T		T			.61	.17		1.14	.44
30	.05		T	T	.78			.15			.01	.01
31	T											T
Total	2.59	2.85	1.73	3.92	5.19	3.90	4.26	5.62	2.74	3.63	2.75	2.04

(Concluded on next page)

Appendix B. Concluded

Date	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Year --1976												
1	.08	.01	.04		T							.03
2	T		.15		.02		T					.04
3	T		.53									
4		T	1.48							.01	.01	
5	T	.10	T		.44			.94		1.26		
6	T	T			1.31			.28				.31
7	.08						.01					
8									.05			T
9							.01		.08	.09		
10	.01		.25	T				T				T
11			.13					.93				
12			.30					.09				
13	.35		T		.60			..05				
14		T			T	T		T				
15	.05	.02	T		.37	T	.05	T				
16	T	1.13			.56							
17		T		.01	.07			.01				
18		.02		.01		.13				.14		
19	.04	T		.02						.16		T
20	T	.06	.40	1.07			.04		T			T
21	T	.73		.12			.24				T	
22				T		T	.88					T
23				2.00	T	.05			.02	.09		T
24				.30		.28			T	.01	T	
25	.12		T	1.33					1.06		T	
26	T		.75				.18	T	.57	T	.80	T
27			.12			.08	.56		T		T	
28					.10	2.24	.89					T
29		.49	.06		1.60	.14					T	T
30			T		.04	T	.12			.72	.02	T
31	.05		.04							T		
Total	.78	2.56	4.25	4.86	5.11	2.92	2.98	2.30	1.78	2.48	.83	.38