Paper No. 902028
AN ASAE MEETING PRESENTATION

IMPACT OF AGRICULTURAL PRACTICES ON TILE WATER QUALITY

by

R. J. Fleming
Research Engineer
Centralia College
Huron Park, Ontario

Written for presentation at the
1990 International Summer Meeting
sponsored by
The AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Hyatt Regency Columbus
at Ohio Center
Columbus, Ohio
June 24-27, 1990

SUMMARY:

Weekly samples were collected from 14 tile drains in the Parkhill Creek watershed of Southwestern Ontario for a 3 year period. Physical, chemical, and bacterial analysis of these samples was carried out. The relative impact of various farming practices is discussed.

KEYWORDS:

pollution, manure, nitrate, phosphorus

American Society of Agricultural Engineers

St. Joseph, MI 49085-9659 USA

IMPACT OF AGRICULTURAL PRACTICES ON TILE WATER QUALITY

INTRODUCTION

Water quality is a major concern of society today. Over the years we have learned that agricultural practices can have a detrimental effect on the quality of surface water and groundwater. Thornley and Bos (1985) found that the quality of water in a branch of the Thames River (in Southwestern Ontario) was very poor, mainly due to contamination from agricultural sources. They found that field tile drain effluent was also of poor quality, but the causes were not obvious. During the same period, the Ontario Ministry of the Environment (1984a) and Palmateer and Huber (1985) investigated causes of high bacteria levels in the water at several Southwestern Ontario beaches. These high levels resulted in the beaches being posted as unsafe for swimming. Livestock manure was singled out as the major contributor of this bacteria.

The study that is the subject of this report was initiated in an effort to gather information on tile water quality for a typical watershed in Southwestern Ontario. There were two objectives:

1) to determine the quality of water in subsurface drains in a small watershed, and

2) to identify the farm practices having the greatest negative impact on the quality of tile discharge water.

WATERSHED DESCRIPTION

The study was carried out in the Parkhill Creek watershed, located in the counties of Huron and Middlesex in Ontario. Water from Parkhill Creek eventually empties into Lake Huron at Grand Bend. Almost all of the 135 km^2 watershed consists of agricultural land. The watershed is about 29 km long and 4.8 km wide, with an average grade of 2.4%. Huron clay loam is the predominant soil type. There is a mixture of cash crop farms and livestock farms. The major crops grown are corn, soybeans, white beans, wheat, barley, alfalfa, and pasture. Livestock consists mainly of dairy, beef, and swine.

DESCRIPTION OF PROJECT

Water sampling was carried out at 14 tile outlets representing drainage water from a cross-section of farms in the subject watershed. Samples were collected from tile outlets at regular weekly intervals from June, 1986 to May, 1989. As well, 6 representative stream sites were sampled, in order to give a comparison between tile water and the water in the receiving stream. All water samples were refrigerated and delivered to the Ontario Ministry of the Environment lab in London, Ontario, where chemical and bacterial testing were done. Table 1 lists the parameters measured weekly at each sample site. Information on precipitation for the area was gathered at a weather station located close to the study area.

The farmers involved were each interviewed on different occasions to gather information relative to locations of tile drains, livestock type, crops grown, applications of fertilizer, pesticides, and manure, and other management information. The farmers did not modify any of their farming practices for this study, nor were they asked to. They simply ran their farms as they normally would.

Table 1. Water Quality Parameters Measured

Physical	Chemical	Bacterial
Temperature	pH	Fecal coliform
Flow Rate (tile)	Free Ammonia	Fecal Streptococci
	Nitrate - N	*Pseudomonas Aeruginosa*
	Nitrite - N	*E. coli*
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Soluble Phosphorus	
	Chloride	
	Total Solids	
	Suspended Solids	
	Dissolved Solids	

RESULTS AND DISCUSSION

Tile water samples were not available every week during the 3 years of the study. The main reasons were lack of flow during dry periods, inability to get samples during frozen conditions, and the fact that the tile outlets were often submerged during periods of maximum flow. In all, samples were collected for most tiles between 50 and 60% of the weeks in the study period.

Background information on the 14 tile sampling sites is summarized in Table 2. Most farms with livestock used bedded manure systems (using straw). In certain cases, the tiles drained cropland only, whereas in others, the tile system also drained water from around the farmstead. Typically, the farms with dairy or beef cattle had outside yards or feedlots and/or outside solid manure storages. None of the farms in the study had an effective way of containing any contaminated runoff from these areas. This, then, created a potential for contaminated runoff to enter tile drainage systems if drains existed near the farmstead.

Water Quality Standards

To make reporting the results easier, only 3 parameters will be discussed: nitrate-N, total phosphorus, and fecal coliform bacteria. These represent the 3 distinct types of water contamination often associated with agriculture (other than pesticides). In the case of the bacterial results, the trends exhibited for fecal coliform were also found for the other bacteria.

The Ministry of the Environment (1984b) has set water quality objectives, used in the interpretation of water sampling results. For nitrate-N, the maximum acceptable concentration in drinking water is 10 mg/L. For total phosphorus, there is no drinking water objective. However, excessive plant growth in streams will likely be eliminated if the total phosphorus concentration is less than 0.03 mg/L. Fecal coliform bacteria are of concern in drinking water and in bathing water. No fecal coliform bacteria are tolerated in drinking water. In bathing water, a potential health hazard exists if the geometric mean density for a series of water samples exceeds 100 per 100 mL.

Tile Water vs. Stream Water

In a simple comparison, tile water data for all 14 sites were compared to open drain water data for all 6 sites. The results are shown in Table 3. In the case of bacteria, geometric means were used throughout the data analysis. The data exhibited a distribution closer to "normal" when log-transformed.

Table 2. Background Information on the Tile Sampling Sites

Site No.	Outlet Tile Diam. (mm)	Drainage Area (ha)	Livestock Type	Tile Layout [a]	Manure Spread [b]	Also Drains Farmstead? (Yes/No)
1	250	20	Beef	Sy	O	No
2	250	20	Beef	Sy	O	Yes
3	300	12	Dairy	Ra	R	Yes
4	250	20	Beef/Hogs	Sy	R	No
5	200	8	Beef/Hogs	Sy	O	No
6	150	6	Dairy	Ra	R	Yes
7	150	8	Beef/Hogs	Sy	R	Yes
8	150	6	Beef	Ra	O	Yes
9	150	6	Beef	Ra	N	No
10	150	6	Beef	Sy	O	Yes
11	200	10	Beef	Sy	O	No
12	250	12	None	Sy	N	No
13	200	20	None	Sy	N	No
14	300	24	Dairy	Sy	O	No

[a] Sy = systematic , Ra = random

[b] N = no manure spread on subject field during study
O = manure spread occasionally i.e. on average, less than once per year
R = manure spread regularly i.e. at least once per year

Table 3. Comparison of Tile Water to Water in Open Drain

	Nitrate		Total Phosphorus		Fecal Coliform	
	Tile	Ditch	Tile	Ditch	Tile	Ditch
Mean (mg/L)	10.6	6.8	1.3	0.14	-	-
Geometric mean (#/100 mL)	-	-	-	-	78	217
Standard Deviation	8.0	5.7	5.8	0.13	-	-
Number of Samples	1110	538	1109	538	1123	526

The levels of nitrate and phosphorus are higher in the tile water than in the stream water (which would be comprised of tile water, surface runoff and groundwater). However, the fecal coliform levels were higher in the stream than in the tile. While not the case at every site, on average, the quality of tile and stream water in this study was not as good as had been hoped. The mean nitrate concentration exceeded the provincial drinking water standard. The mean concentration of phosphorus in the tile water and in the stream exceeded the guideline for streams. The geometric mean density of fecal coliform bacteria in the stream exceeded the bathing water standard. The higher bacteria loadings in the open drain may have been related to higher water temperatures, although no correlation between bacteria count and temperature could be found. The average temperatures of tile water and stream water were 8.9° and 11.5°C, respectively.

Tile Water Quality - Nitrates

Nitrate levels in the tile water were relatively high. Site # 6 had the lowest average (5.8 mg/L, n = 60) and Site # 5 had the highest (18.1 mg/L, n = 69). Only 5 of the 14 sites had mean nitrate levels below the drinking water standard of 10 mg/L. No significant relationship existed between nitrate levels and either: a) time of year, or b) number of weeks after spreading of manure.

Figure 1 shows a notched box-and-whisker plot representing all of the tile water nitrate concentrations during the three year period for each of the 14 sites. With this type of plot, the tops and bottoms of the boxes denote respectively the upper and lower quartiles, and the median appears as a horizontal line between the two. The notches about the median show statistically significant differences between sample populations. The vertical lines (whiskers) extend to the upper and lower values, and outlier values are shown as distinct points. Table 4 lists the mean values for the complete three years (nitrate, total phosphorus, and log of fecal coliform density) and shows the groupings of sample sites where the mean values are not significantly different (95% level, Scheffe method).

From Figure 1 and Table 4, it is obvious that Site # 5 has the highest levels of nitrate in the tile water. This drainage area does not include a farmstead. The only time

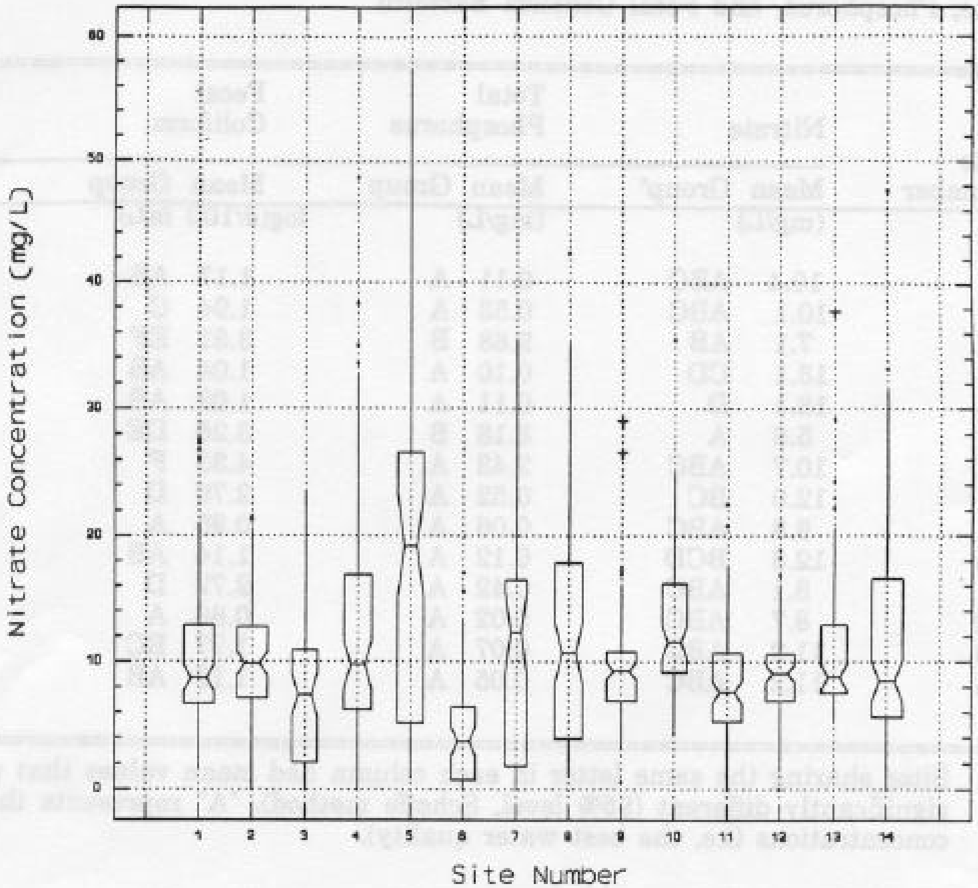

Figure 1 Notched box-and-whisker plot of nitrate concentrations in tile water for each sampling site (1986 to 1989)

manure was spread was early in 1986 on alfalfa. During 1986 and the first part of 1987, nitrate levels for this site were relatively low. The alfalfa was plowed down in 1987 and because the year was so dry no further crop was planted. When heavy rains started in the fall of 1987, quite high nitrate levels appeared in the tile water. This trend continued for the duration of the study, during which time white beans, then wheat, were the crops grown. Presumably, large reserves of nitrogen were present in the soil following plow-down of the alfalfa in 1987 and some of this nitrogen was leached from the root zone in the nitrate form once the heavy rains began.

The overall pattern for nitrate levels suggests that the cause of high concentrations is not related to manure spreading or drains carrying water from around farmsteads. Rather, it seems to be related to total levels of nitrogen in the soil, whether from fertilizer sources or from manure or a legume crop.

Table 4. Three-year Means and Groupings of Sites Having Similar Mean Concentrations of Nitrates, Phosphorus, and Fecal Coliform Bacteria

Site Number	Nitrate		Total Phosphorus		Fecal Coliform	
	Mean (mg/L)	Group[a]	Mean (mg/L)	Group	Mean log(#/100 mL)	Group
1	10.4	ABC	0.11	A	1.17	AB
2	10.1	ABC	0.53	A	1.94	C
3	7.1	AB	9.68	B	3.81	EF
4	13.1	CD	0.10	A	1.04	AB
5	18.1	D	0.11	A	1.09	AB
6	5.8	A	8.18	B	3.26	DE
7	10.7	ABC	2.43	A	4.33	F
8	12.0	BC	0.52	A	2.76	D
9	9.8	ABC	0.06	A	0.95	A
10	12.8	BCD	0.12	A	1.14	AB
11	8.1	ABC	0.42	A	2.72	D
12	8.7	ABC	0.02	A	0.86	A
13	11.2	ABC	0.07	A	1.77	BC
14	11.2	ABC	0.05	A	1.19	AB

[a] Sites sharing the same letter in each column had mean values that were not significantly different (95% level, Scheffe method). "A" represents the lowest concentrations (i.e. the best water quality).

Tile Water Quality - Total Phosphorus

Figure 2 shows a summary of the total phosphorus concentrations by site number. In general, levels of total phosphorus were high compared to the Ministry of the Environment (1984b) stream water recommended maximum of 0.03 mg/L. Only one tile (Site # 12) had a mean value less than this standard. The highest mean was for Site # 3 (9.7 mg/L, n = 67). Site # 6 also had a high mean (8.2 mg/L). In both cases, the high levels are believed to be related to direct connections of milkhouse wastewater systems to the field tile system. This is in keeping with the findings of Briggs (1988), who recorded high levels of phosphorus and bacteria in tile water where there were milkhouse drains connected to the tile drainage systems. Sites having tiles that drained areas around farmsteads had significantly higher mean concentrations of total phosphorus than those that drained only cropland (means of 3.2 mg/L and 0.12 mg/L, respectively). Also, the sites receiving regular applications of manure had significantly higher levels of phosphorus in the tile water than those receiving only occasional manure applications or none at all.

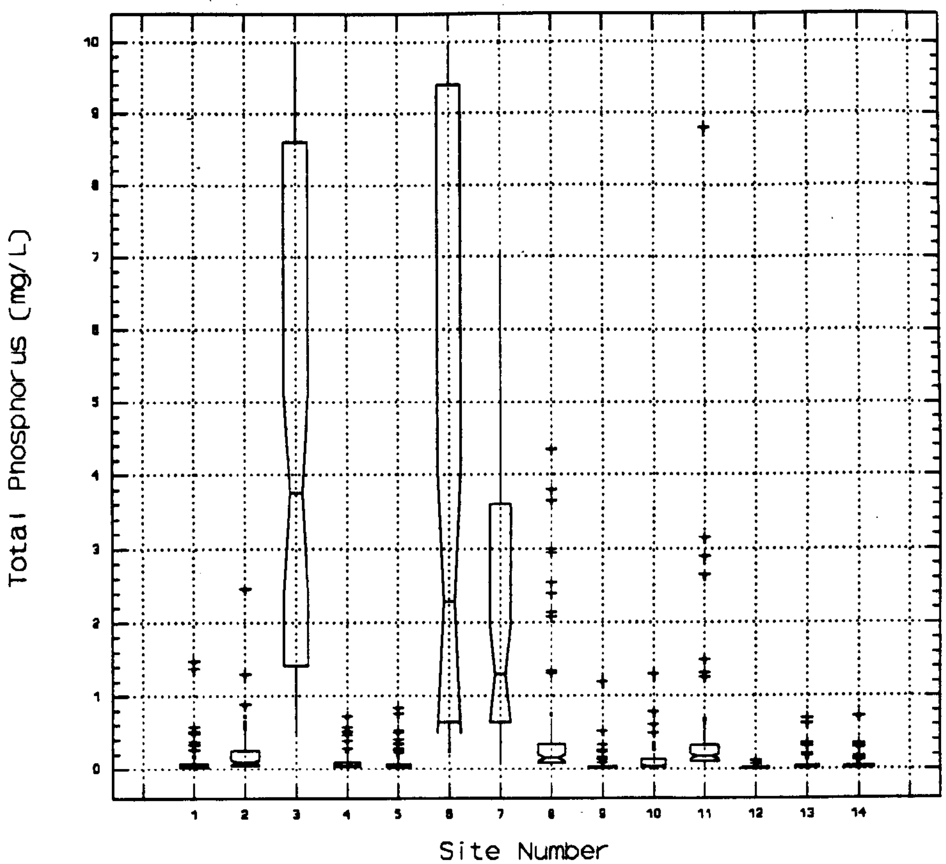

Figure 2 Notched box-and-whisker plot of total phosphorus concentrations in tile water for each sampling site (1986 to 1989)

Tile Water Quality - Fecal Coliform Bacteria

A summary of the fecal coliform densities is shown in Figure 3 (plotted on a log scale). 5 tile sites had geometric mean densities exceeding the bathing water limit of 100 per 100 mL. No significant correlation existed between levels of fecal coliform and any of the following: week of year, nitrate level, total solids level, water temperature, or manure spreading date. Sites where farmstead areas drained into the system had significantly higher levels than those where only cropland was drained. This is shown in Figure 4. Also, sites where manure was spread at least once a year had higher levels than those with occasional spreading or no manure spreading. Sites # 3 and # 6, believed to have milkhouse washwater contamination of tiles, had among the highest levels of fecal coliform bacteria.

It appears as though there is little risk of contamination of tile water with fecal coliform bacteria where the drainage area has no manure present. Practices that appear to cause

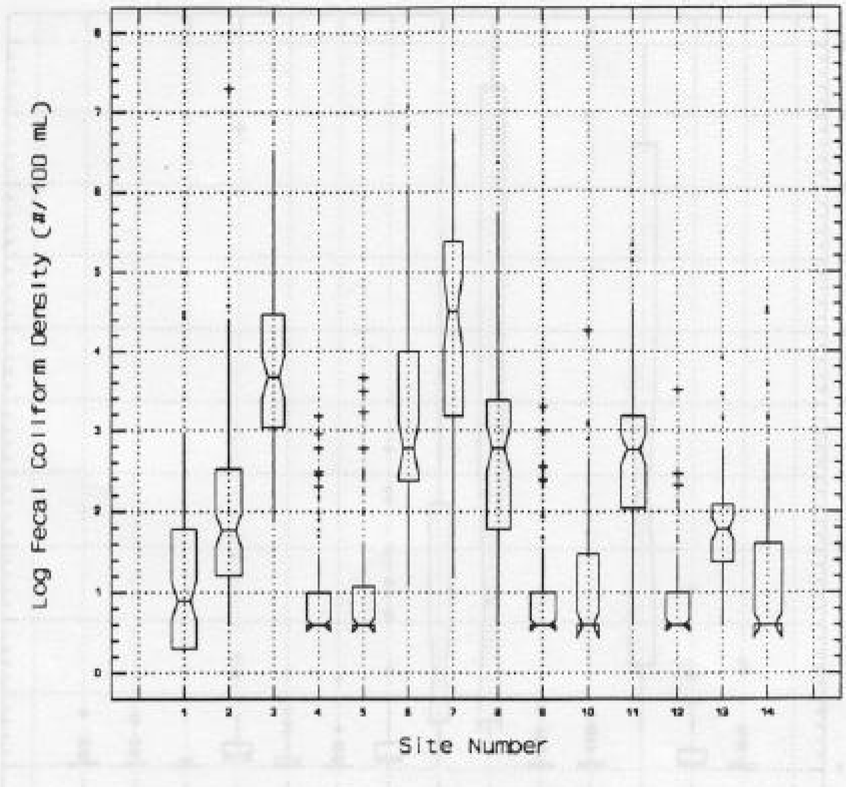

Figure 3 Notched box-and-whisker plot of log fecal coliform densities in tile water for each sampling site (1986 to 1989)

high bacteria levels in tiles include: spreading manure regularly onto a field, allowing contaminated runoff from a farmstead area to enter a tile drainage system, or allowing milkhouse washwater to enter a tile drainage system. Based on observations in this study, the latter 2 are likely the most important in terms of magnitude of impact.

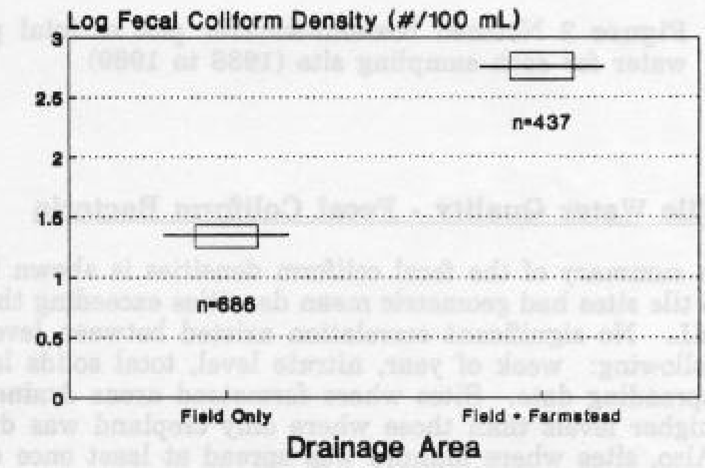

Figure 4 Mean and 95% confidence interval for mean values of log fecal coliform densities for two types of drainage area

SUMMARY AND CONCLUSIONS

Weekly samples were collected from 14 tile drains in the Parkhill Creek watershed of Southwestern Ontario for a 3 year period from 1986 to 1989. These samples were analyzed for several physical, chemical, and bacterial parameters. Comparisons were made between the tile sites and 6 nearby open-ditch sample sites. The following conclusions can be drawn.

1. The tile-drain sites had higher levels of most chemical parameters than the open-ditch sites, and lower levels of bacterial parameters.

2. The mean nitrate concentration for all tile water samples was 10.6 mg/L (S.D. = 8.0, n = 1110) which exceeds the Ontario drinking water standard of 10 mg/L.

3. Nitrate levels in tile water were not necessarily related to manure use, but appeared to be related to the total N applied to cropland, regardless of the source (i.e. fertilizer, manure, legume).

4. In every case but one, the mean concentration of total phosphorus exceeded the Ministry of the Environment standard for "total phosphorus in a stream". The most obvious culprit was the direct connection of milkhouse drains to the field tile system. Regular application of manure seemed to also lead to high values.

5. Fecal coliform levels in tile water varied widely from one farm to the next. Farms which had tiles draining areas around farmsteads and farms where manure was spread regularly onto the fields had the highest levels of fecal coliform bacteria in the tile water.

REFERENCES

Briggs, T. 1988. Pittock sub-basin #2 watershed - Milkhouse washwater discharge study. Report of the Upper Thames River Conservation Authority, London, Ont. 25pp.

Ontario Ministry of the Environment - Southwest Region. 1984a. Lake Huron beaches - factors affecting microbiological water quality in 1984 - summary report.

Ontario Ministry of the Environment. 1984b. Water management - goals, policies, objectives, and implementation procedures of the Ministry of the Environment. 70pp.

Palmateer, G., and Huber, D. 1985. Lake Huron beach study - a microbiological water quality evaluation of Grand Bend Beach and related pollution sources in 1985. Report of the Director - Southwestern Region, Ministry of the Environment, London, Ont. 31pp.

Thornley, S., and Bos, A. W. 1985. Effects of livestock wastes and agricultural drainage on water quality: An Ontario case study. J. Soil Water Conserv. 40(1):p. 173-175.