"Comparison of Liquid Manure Spreading Practices on Tile Drain Water Quality"

Final Report

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DISCLAIMER

This project report has been prepared for the Research Advisory Committee in fulfilment of their requirements. The views expressed are those of the author and do not necessarily reflect the views and policies of the Ontario Ministry of the Environment.

ABSTRACT

Five liquid manure spreading events have been monitored and compared for their relative bacterial and nutrient loading to the tile drain water on a Perth clay loam soil under conventional tillage. Two events involved the comparison of irrigated swine manure on cropland that had been recently tilled and on cropland that had not been tilled prior to the manure applications. The spreading events took place in May and November 1991. Two events involved the comparison of the irrigation and the injection methods of manure application. These spreading events took place in June and October 1991. The final spreading event involved the comparison of loading from a field tile drain with blocked flow for six days versus a field tile drain with unblocked flow at the time of the application. This spreading event took place in May 1992. Observation chambers and shallow sampling wells were installed in the study area in order to monitor changes in the tile drain water and groundwater quality, respectively.

Bacterial parameters tested for in the manure, tile drains, groundwater and soil included fecal coliform, fecal streptococcus, *Escherichia coli* and the biotracer, nalidixic acid resistant *Escherichia coli* (EC(NA)). The EC(NA) were introduced with the liquid manure to trace bacterial movement in the soil and water. The chemical parameters tested for in the tile drain water included; biochemical oxygen demand, suspended solids, free ammonia, total kjeldahl nitrogen, nitrate, nitrite, total phosphorus, dissolved reactive phosphorus, pH, chloride, conductivity, and potassium. The chemical parameters tested for in the groundwater included; dissolved organic carbon, ammonia, nitrate, dissolved reactive phosphorus, pH, chloride, conductivity and potassium.

Tilling of the land prior to manure application appeared to have decreased the amount of bacteria and nutrient loading to the tile drain water. In May 1991 the unfilled trial was one order of magnitude higher in the calculated bacterial and nutrient loading to the tile drains compared to the tilled trial. At the time of the November spreading event, tile drains were not flowing and no loading to the tile drains was observed. EC(NA) were found at depth in the soil profile for both the tilled and the untilled trials. However, at the 75 cm depth they were present in significantly higher concentrations on the untilled trial compared to the tilled trial. No EC(NA) contamination in the wells was observed in this event.

Injecting manure on cropland appeared to have increased the amount of bacterial and nutrient loading to the tile drain water compared to the irrigation method of application. In June 1991 the injection method of application resulted in the bacterial loading to the tile drains being two orders of magnitude higher and the nutrient loading being one order of magnitude higher compared to the irrigation method. Groundwater contamination was found to occur within 5 hours on both the injected (well depth 3.3 m) and the irrigated (well depth 4.1 m) trial. At the time of the October spreading event, tile drains were not flowing and no loading to the tile drains was observed. EC(NA) were found at depth in the soil profile for both the injected and the irrigated trials. However, at the 75 cm depth they were found in significantly higher concentrations on the injected trial compared to the irrigated trial. No EC(NA)

contamination was found in the wells. High fecal streptococcus counts were found in the well on the irrigated trial within two days of the manure application and remained high for 12 days. The wells on the irrigated trial were dry at this time.

No conclusions regarding the effect of blocking tile drain flow can be made from the May 1992 spreading event. Neither trial resulted in bacterial or nutrient contamination of the tile drain water even though tile drains were flowing. The sampling wells showed no signs of contamination. No soil data was available as no soil samples for bacterial analysis were taken. The 15 mm rain that fell the day prior to the spreading event may have reduced the preferential transport of the manure components.

In late November 1991 nitrate and chloride levels increased in all the samples taken from the tile drains and sampling wells compared to the samples taken earlier in the year. The increase can not be attributed solely to the manure applications as fertilizer application and crop residue breakdown may also be contributing factors.

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INTRODUCTION

Previous research conducted by the Ausable Bayfield Conservation Authority (ABCA) in 1989 and 1990 (Dean and Foran, April 1991) revealed that land application of liquid manure can rapidly degrade tile drain water quality under normal farming practices. Of the twelve manure spreading events that were monitored, eight resulted in water quality degradation within 20 minutes to 6 hours. It was concluded that the rate of manure application (L/ha) had little bearing on whether or not tile drain contamination occurred; that no or very low tile drain flow resulted in least contamination; and that macropores appeared to be the main pathway for manure components to travel through the soil column and enter receiving water. Studies by Patterson *et al.* (1974) and Evans and Owens (1972) found contamination in the field tiles after the application of swine slurry within 30 minutes and two hours, respectively. Soil macropores were thought to be the main pathway for manure components to reach tile drains. In agreement with this, Chandler *et al.* (1981) found that contamination of subsoils following an application of piggery effluent occurred at a rate far in excess of the infiltration capacity of the soil suggesting flow of effluent through soil cracks.

Macropores may develop due to physical (shrink/swell, freeze/thaw, tillage) or biological (earthworm, insects, roots) factors. Macropores may be continuous for distances of at least several meters in both vertical and lateral directions (Beven and Germann 1982). Quisenberry and Phillips (1978) concluded that in some soils with strong structure, rapid water addition results in almost all flow through the soil macropores and essentially no displacement of soil water occurs. Ahuja *et al.* (1991) affirm that the macropore size had very little effect on macropore flow and transport, but the smallest size retarded the downward chemical movement by wall adsorption a bit more than the largest size.

Van Es *et al.* (1991) state that the relative importance of matrix and preferential drainage is dependent on soil type, antecedent soil water conditions and rainfall intensity. In a laboratory test with soil that contained macropores, Shipitalo *et al.* (1970) showed that a light 5 nun simulated rainfall which preceded two 30 mm rain events reduced preferential transport of atrazine, bromide and strontium in comparison to losses occurring when the light rain was omitted. Similar to this, a study by Ahuja *et al.* (1991) found no or negligible macropore flow was generated by five weekly rainfalls of 25 mm each in a medium heavy soil which indicated that macropore flow and transport may not occur during many of the natural rains.

Steenhuis and Parlange (1991) cited that in clay and loam soils, most of the soil is of relatively low permeability with usually less than one percent of the area consisting of cracks and passages formed by roots and earthworms. They also stated that the concentration of the percolating water is dependent on the rate that the water is applied.

Germann *et al.* (1984) and Bicki and Guo (1991) studied the effect of water application rate on the movement of bromide tracer under different tillage regimes. Both studies indicated that solutes move deeper into undisturbed soils, especially when water application rates are high. A study by Quisenberry and Phillips (1978) concluded that macropore need not extend to the soil surface for flow down them to occur, however, the flow rates are reduced. The lower the infiltration rate the longer the retention time in the upper soil zone and therefore the more efficient the filtering of bacteria or nutrients.

Almost half of all waterborne diseases are caused by contaminated groundwater (Gerba and Bitton 1984). Although pathogenic bacteria and viruses present in liquid manure may not multiply underground they still may travel considerable distances and survive long enough to be of concern (Bouwen 1984). Bouwen (1984) also pointed out that the size of the water-filled pores including cracks will influence the mobility of bacteria and viruses in the soil column.

STUDY OBJECTIVES

The objectives of the study are as follows:

1. To compare the irrigation and injection methods of liquid manure application and determine their relative impact on tile drain water quality.

2. To determine manure application impact on tile drain water quality, when manure is applied to unfilled soil and recently tilled soil.

3. To monitor groundwater contamination, with observation wells, in conjunction with each of the above mentioned objectives.

METHODS

Description of Study Area

The five manure application trials were conducted on a four hectare field of imperfectly drained Perth clay loam approximately 20 kilometres southwest of Exeter, Ontario. The soil profile description is included in Appendix A. This systematically tiled field, with 15 metre tile spacings, has been in a corn/bean/wheat rotation under conventional tillage for the past ten years. Figure 1 is a detailed sketch of the study area. The lagoon containing the liquid swine manure is located approximately 350 metres north of the study area.

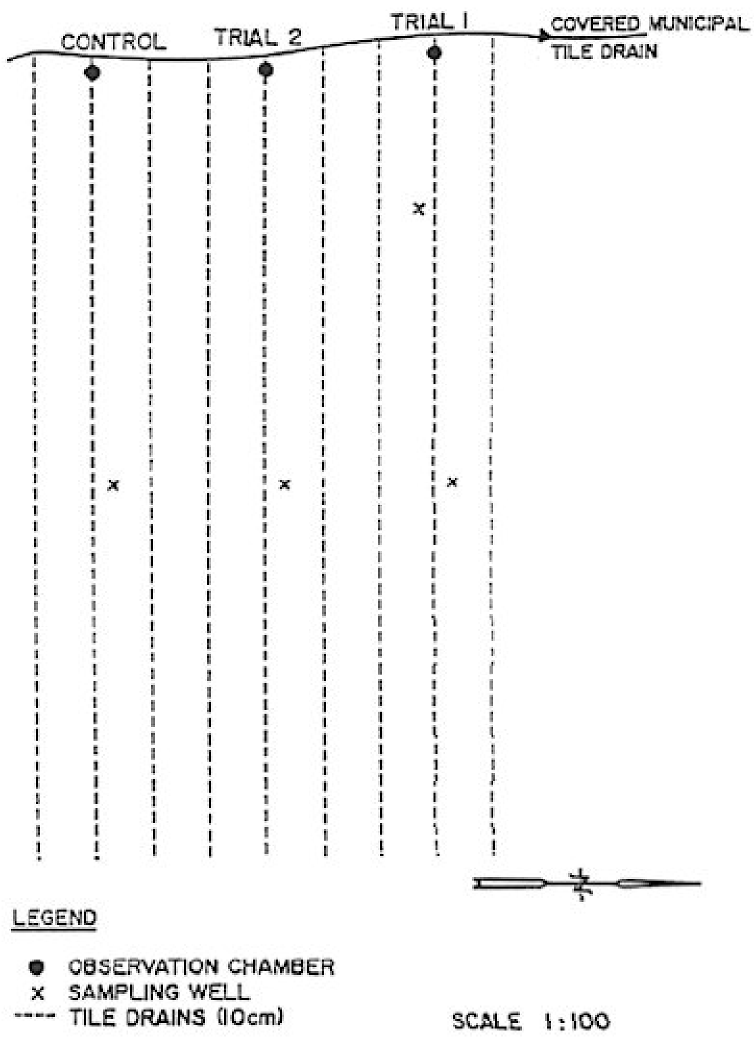

FIGURE 1: A Detailed Sketch Of The Study Area

Four sampling wells (Figure 2) which vary in depth from 2.2 to 4.1 metres were installed in late May 1991 to monitor groundwater quality in the study area. Also, three observation chambers (Figure 3) which facilitate taking water samples and discharge measurements from the tile drains were installed. One observation chamber was located at each trial site.

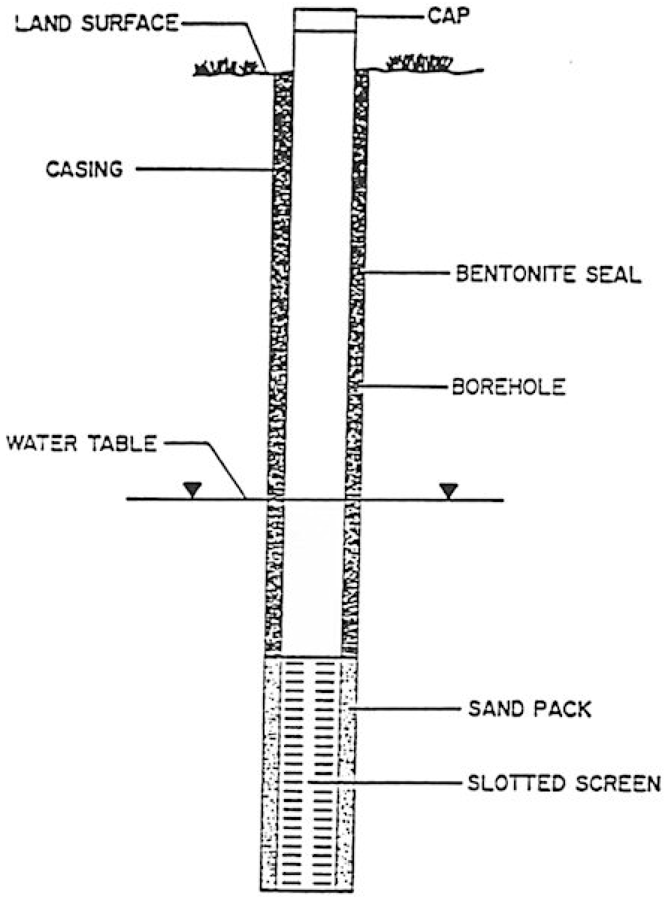

FIGURE 2: Cross Section Of A Sampling Well

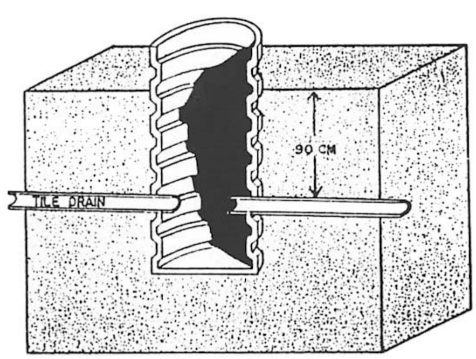

FIGURE 3: Cross Section Of An Observation Chamber

Water and Manure Sampling and Analysis

Samples of the liquid manure were taken from the manure storage prior to manure application. Samples were also taken from collection pans placed in the area of manure application. A minimum of three bacterial and two chemical samples were taken from the manure storages and collection pans so average concentrations could be calculated. Concentrations of bacteria and nutrients in the collection pans confirmed whether or not changes in concentrations occur as a result of pressurization during application or during transport to the field.

Weekly grab samples of water from the tile drains were taken for one month prior to the scheduled manure application. More intensive sampling was done on the day of manure application. Daily water samples were taken for approximately one week immediately following spreading. Tile drain discharge measurements were taken at time of sampling. This was accomplished by measuring the amount of time it took to fill a container of known volume.

Weekly grab samples of water from the wells were taken for one month prior to the scheduled manure application. The wells were bailed approximately three days prior to the manure applications. Daily samples were taken for approximately one week immediately following manure application. A sterilized copper tube was lowered down into the well in order to obtain the samples. The water depth in the wells at the time of sampling was measured using a water sensor. From May 23 to July 15, 1991 samples for bacterial analysis were taken. Upon review of the data, samples for chemical analysis began on July 18, 1991.

Bacterial parameters analyzed in the water and manure included; fecal coliform, fecal streptococcus, *Escherichia coli* and the biotracer, nalidixic acid resistant *Escherichia coil* ((EC(NA)). The biotracer was added to the irrigation pipe prior to pressurization and to the injector tanker in order that their movement could be traced through the soil column and into the receiving water. The tracer organism was originally isolated from the environment by G. Palmateer, Ontario Ministry of Environment Southwestern Region (OME-SWR). The EC(NA) is non-enteropathogenic, is easily recovered from water and soil and is not commonly present in the natural environment. The tracer bacteria was injected in concentrations that are approximately equal to the concentrations of the indigenous bacteria found in the liquid waste. Water and manure samples were stored on ice immediately and analysis was performed within 24 hours.

The chemical parameters analyzed in the tile drain water and manure for Events 1 to 4 included; biochemical oxygen demand, suspended solids, free ammonia, total kjeldahl nitrogen, nitrate, nitrite, total phosphorus, dissolved phosphorus, pH, chloride, conductivity and potassium. The chemical parameters analyzed in the tile drain water and manure for Event 5 included; total kjeldahal nitrogen, total phosphorus and potassium.

The microbiological and chemical analysis was preformed at the OME-SWR. Laboratory methods used by the microbiology and chemistry departments were those outlined by the Handbook of Analytical Methods of Environmental Samples (OME 1984b). In addition the microbiology department used the *Standard Methods for the Examination of Water and Wastewater* (APHA 1985). For the final spreading event the chemical analysis was preformed at the Enviroclean Laboratory in London. Laboratory methods used were those outlined by APHA (1985).

Soil Sampling and Analysis

Soil samples for bacterial analysis were taken a few days prior to and within three hours following manure application for Events 1, 3 and 4. Samples were taken using a sterilized coring device. Soil samples were taken at 5-10 cm, 30-35 cm, and 70-75 cm depths in the soil column. Soil samples were collected in sterile glass jars, stored on ice, and analyzed within 24 hours. The same bacterial parameters described for the manure and water were examined in the soil samples. Again, samples were analyzed at the OME-SWR. The multiple tube fermentation technique was used to determine the bacterial concentrations in the soil (APHA 1985). Results of the examination of replicate tubes and dilutions were reported in terms of the Most Probable Number (MPN).

RESULTS AND DISCUSSION

Climatic Conditions

Appendix A includes the mean hourly temperature, relative humidity, and wind velocity for each day of the manure spreading events as well as the daily rainfall data from May 1, 1991 to December 31, 1991 and April 1, 1992 to June 15, 1992. The climatic data was obtained from a weather station at Centralia College, Huron Park. No significant amount of rain fell immediately before the May 1991 or June 1991 events. The rainfall received in the study area during the months of June to September 1991 was less than half the average precipitation. This lead to very dry soil conditions for the months of July to November 1991. Field tile drains in the study area stopped flowing by mid July 1991 and did not resume flow until November 20, 1991. The shallower wells (depth 2.2 m and 3.3 m) were dry by mid August and September. The deeper wells (depth 4.1 m) were able to be sampled year round. The fifth spreading event was originally scheduled for late April 1992 but had to be delayed until May 19, 1992 because of rains and conflicts in laboratory schedules.

For the five spreading events, the mean daily temperature ranged from -3.2 C in Event 4 to 21.4 C in Event 1. The relative humidity on event days ranged from 52 % in Event 1 to 60.4% in Event 4.

Details of Spreading Events

A description of each of the manure spreading events including date, tile flow rate, application method, application rate, soil moisture percentage and soil surface conditions is given in Table 1. Two events involved the comparison of applying manure to cropland that had been recently tilled and to cropland that had not been recently tilled. The spreading events took place in May 1991 and November 1991. Many cracks were present at the soil surface in both events. Two events involved the comparison of the irrigation versus the injection methods of manure application. These spreading events took place in June 1991 and October 1991. Scuffling had destroyed any surface cracks or pores between corn rows in June. A few surface cracks and pores were present in the October event. The May 1992 spreading event involved the comparison of loading from a field tile drain with blocked flow for six days versus a field tile drain with unblocked flow at the time of manure application.

The field tile drains were not flowing at the time of Events 3 and 4 due to the low precipitation received in June through September. The manure application rate for all events in 1991 were to be approximately 80,000 L/ha but, the operator incurred problems with calibrating the irrigation gun. Corn was planted in the study area in late May 1991 and scuffled in mid June. On June 24, 1991 corn was at the 8 to 10 leaf stage. The corn was harvested for silage in late September. The whole study was chisel plowed in mid November 1991. The study area was cultivated and planted into spring barley on May 7, 1992.

Table 1. Description of Manure Application Events

Event	Date	Trial	Tile Flow Rate L/s	Application Method	Application Rate L/s	% Surface Residue	Surface	Pre Application Soil Moisture % Depth 5cm 30cm 70an
1	May'91	1	0.0032	irrigation	101,000	7	- cultivated, loose, friable surface - no cracks or pores	24 20 19
		2	0.0032	irrigation	101,000	10	- fall plowed, many cracks (0.5 - 3mm) - many pores <0.5 and few pores 1 mm dia.	
2	June'91	1	0.0026	injection	81,700	20	- scuffled, no cracks or pores between rows - interrow: few cracks 1-2 mm, numerous pores <0.5 mm	24 21 20
		2	0.0015	irrigation	121,000	24	- scuffled - similar to Trial 1	
3	Oct'91	1	----	injection	82,150	30	- corn stubble, no obvious pores - few cracks 0.5-1 mm and few <0.5	20 19 9
		2		irrigation	93,400	26	- corn stubble - similar to Trial 1	
4	Nov'91	1	-----	irrigation	67,700	10	- chisel plow, few cracks 0.2 mm - numerous pores 0.2 mm	19 17 15
		2		irrigation	67,700	25	- corn stubble, few pores 0.5-1 mm - many cracks 05-1 mm	
5	May'92	1	0.0045	irrigation	60,000	25	- barley, some cracks 1 mm, very few pores 1 mm	22 19 17
	May'92	2	0.0026	irrigation	60,000	27	- barley, some cracks 0.5-1 mm - no obvious pores	

Comparison of Untilled and Tilled Trials

<u>May 1991</u>

Figure 4 shows the EC(NA) loadings to the tile drains in the first 24 hours after manure application. On Trial 2, the untilled site, the tile water began being contaminated with EC(NA) within one hour of the biotracer being introduced into the line. It reached its peak loading of contamination in about 1.75 hours, then the contamination decreased considerably within 24 hours. The manure application resulted in the tile discharge rate increasing up to seven times its initial rate. On Trial 1, the cultivated site, EC(NA) contamination of the tile drain water began in about 2 hours time with the peak loading occurring in about 3.5 hours time. The peak loading was much less compared to the untilled site. The tile discharge rate increased to four times its initial rate. The Control site had no manure application and the water samples showed no sign of contamination. Appendix B gives the bacterial and chemical water quality data for each of the spreading events.

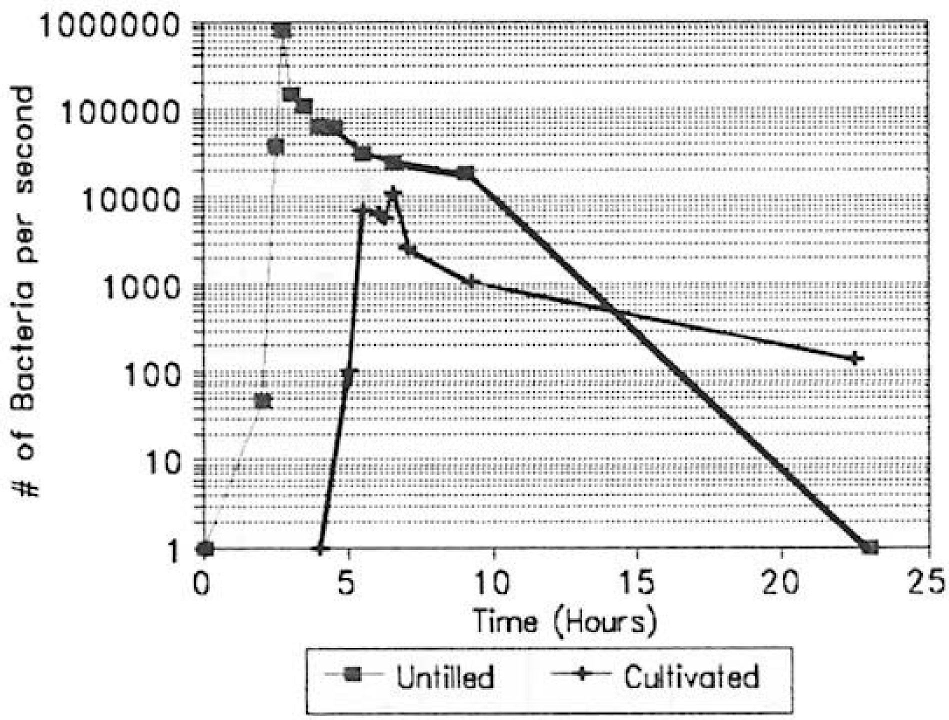

Figure 4: *E.coli* (NA) Loading - May 1991

Figure 5 shows the Total Kjeldahl Nitrogen (TKN) loadings to the tile drains in the first 24 hours after manure application. The untilled site had a much higher loading of TKN than the cultivated site. The peak loading was within 2 hours time for the untilled trial and 3.5 hours time for the cultivated trial. The TKN loadings decreased considerably within 24 hours for both trials. Loading graphs for Total Phosphorus(TP) and Potassium(K) for the first 24 hours after manure application had a similar pattern to the TKN loadings.

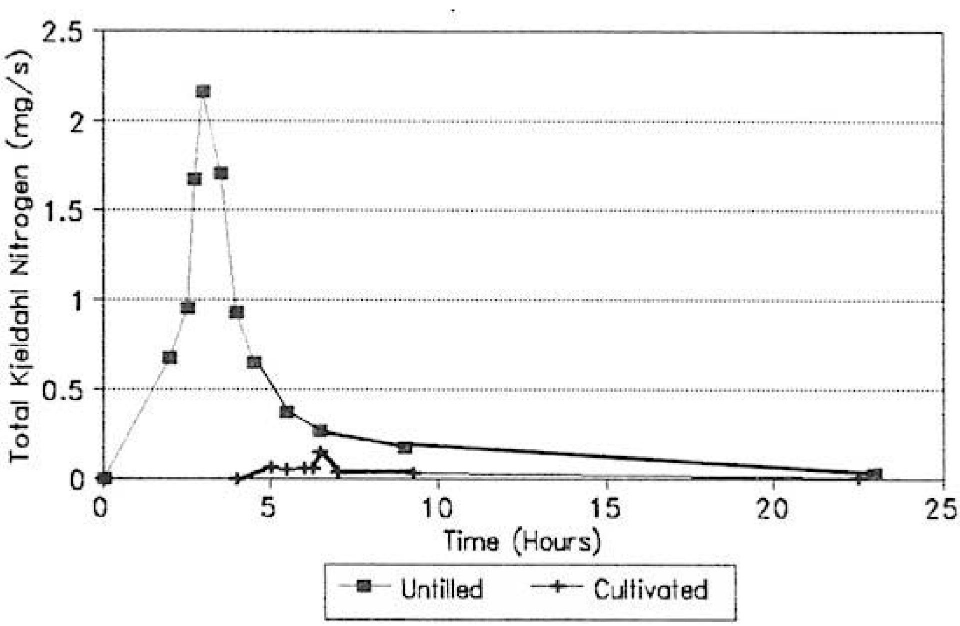

Figure 5: TKN Loading - May 1991

Table 2 shows the average loads of EC(NA), TKN, 'FP and K discharging from the tile drains in the first 24 hours after manure application as well as the percent of the load applied that reached the tile drains. Trial 2, the untilled site, was one order of magnitude higher in the number of bacteria/ha/day that discharged from the tile drain compared to Trial 1. Trial 2 also was one order of magnitude higher in the amount of TKN and K that discharged from the tile drain compared to Trial 1. The TP was two orders of magnitude higher. Trial 2 had a higher percentage of the load applied that reached the tile drain for all components compared to Trial 1. The bacterial component appears to be of more significance than the nutrient components.

Table 2. Loads of Bacteria and Nutrients to Tile Drains for 24 Hours After Manure Application For May 1991

SITE	Loads From Isolated Tiles				LOADS				Percent Of Load Applied That Reached Tile Drain			
	bacti /day	- - - g/day - -			bacti /ha/day	- g/ha/day -						
	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K
Trial 1 cultivated	8.6×10^7	1.8	0.17	0.7	2.4×10^8	4.9	0.5	1.9	0.043	0.007	0.0066	0.0026
Trial 2 unfilled	2.4×10^9	24	4.3	14.4	6.7×10^9	67	12	39.5	1.13	0.099	0.17	0.054

Soil samples taken prior to the manure application showed very low bacteria concentrations (<40 bacteria per 100 g of soil) at all depths sampled. Figure 6 shows the soil EC(NA) concentrations after manure application. On the cultivated site no tracer bacteria was found below the surface soil layer while on the untilled site the tracer bacteria can be found in significant concentrations to the lowest depth measured. Appendix B contains the soil bacteria data. The sampling wells were installed on May 21, 1991 and were not ready for sampling for the May spreading event.

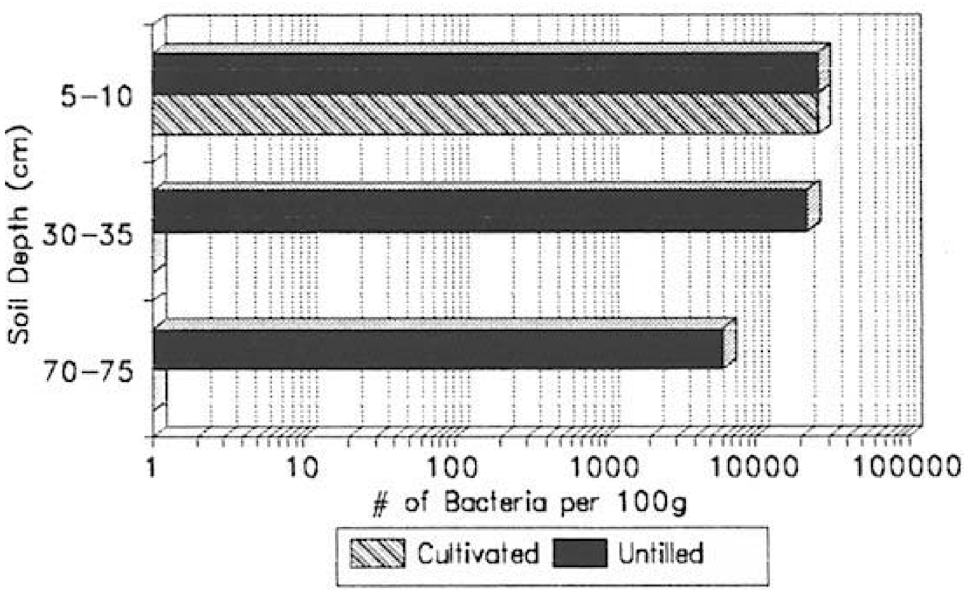

Figure 6: Soil EC(NA) Concentrations - May 1991

November 1991

There was no tile flow in the field drains at the time of this spreading event and there had not been any flow since mid July. No flow resulted from the spreading event. The pre manure application soil samples at the 5 - 10 cm depth showed about 25 percent of the EC(NA) had survived from the October spreading event. Very few were found at the lower depths. Figure 7 shows the soil EC(NA) concentrations after the manure application. The surface EC(NA) concentrations were similar for both trials. A much greater decrease was seen at the lower depths on the chisel plowed trial compared to the untilled trial. The post application bacterial soil data would suggest that had there been tile flow the untitled trial would have resulted in higher levels of contamination compared to the chisel plowed trial. It appears that tilling the soil surface prior to the manure application slows the infiltration rate and allows for more filtering of the manure components to take place.

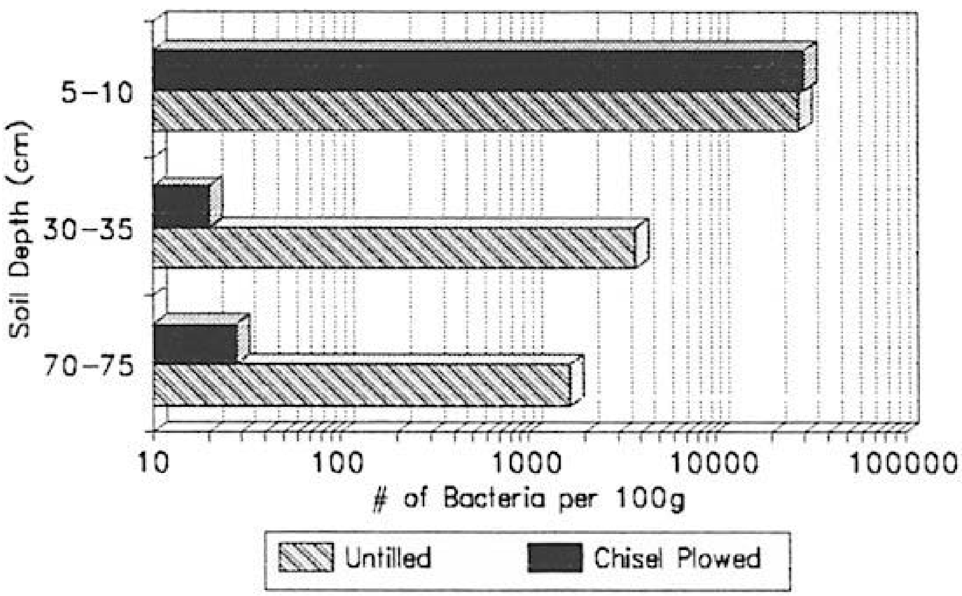

Figure 7: Soil EC(NA) Concentrations - November 1991

Tile drain flow resumed on November 20, 1991 for Trials 1 and 2. No EC(NA) was found in the tile waters. Fecal streptococcus were present at approximately 1000 per 100 mL for the first two days after flow began. Soil bacteria samples were taken again on November 26. EC(NA) was only found in the surface horizon for both Trial sites. The rapid decline at depth found in EC(NA) can not be explained (G. Palmateer, personal communication).

The sampling wells on the chisel plowed trial were dry at the time of the November manure spreading event. Bacterial water samples were able to be taken from one well on Nov. 21, 1992 and no EC(NA) was found. The well on the unfilled trial showed no signs of bacterial contamination on the event day or later that month. Also, the well on the Control trial showed no sign of bacterial contamination on the day of the event. The chemical parameters measured showed no significant changes in any of the wells.

The May and November spreading events agree with what was found by Germann *et al.* (1984) and Bicki and Guo (1991). Both studies indicated that solutes move deeper into undisturbed soils, especially when water application rates are high. A study by Quisenberry and Phillips (1978) concluded that macropores need not extend to the soil surface for flow down them to occur, however the flow rates are reduced.

Comparison of Injection and Irrigation Application Methods

June 1991

Figure 8 shows the EC(NA) loadings to the tile drains in the first 24 hours after manure application. On Trial 1, the injection site, the tracer bacteria was found in the tile drain water within 15 minutes of it being injected and reached its peak loading of contamination within 30 minutes. The contamination decreased considerably within 24 hours. On Trial 2 the tracer bacteria was detected in the tile drain water within 30 minutes of it being introduced into the line and the peak loading occurred in about 75 minutes time. The peak loading was much less than on the injected site. The tile discharge rates had increased up to 20 times the initial rates for both Trials 1 and 2. The Control site had no manure application and the water samples showed no sign of contamination.

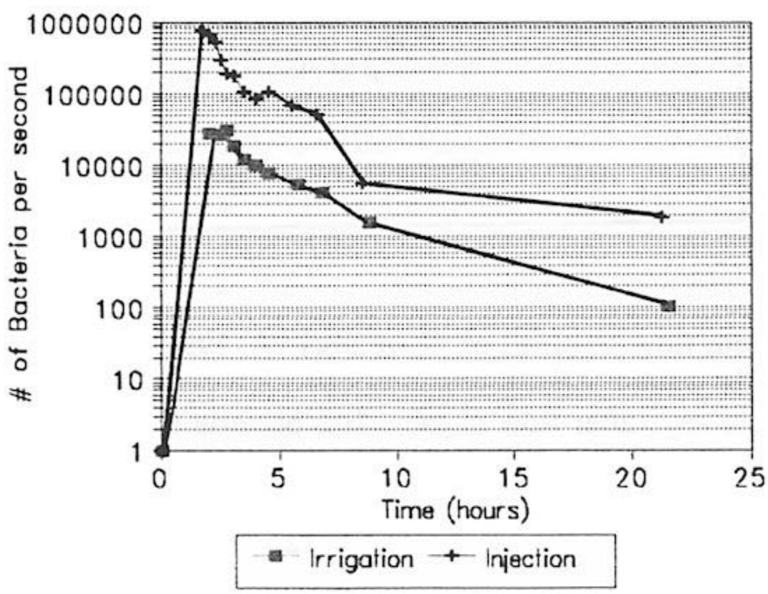

Figure 8: *E. coli* (NA) Loading - June 1991

Figure 9 shows the TP loadings to the tile drains in the first 24 hours after manure application. The injection site had a much higher loading of TP than the irrigation site. The peak loading for Trial 1 was within 2 hours and for Trial 2 within 3 hours after spreading began. For both trials the TP loadings have decreased considerably within 24 hours. Loading graphs for TKN and K for the fu-st 24 hours after manure application have a similar pattern to what can be seen on the TP graph.

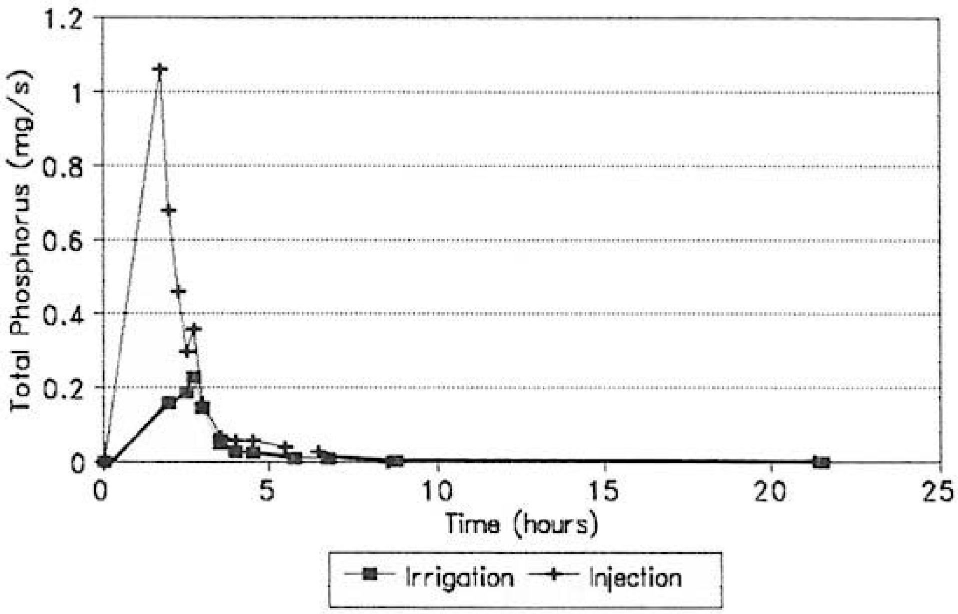

Figure 9: Total Phosphorus Loading - June 1991

Table 3 shows the average loads of EC(NA), TKN, TP and K discharging from the tile drains in the first 24 hours after manure application as well as the percent of the load applied that reached the tile drains. Trial 1, the injection site, was two orders of magnitude higher in the number of bacteria/ha/day that discharged from the tile drain compared to Trial 2. Trial 1 was one order of magnitude higher in the nutrient loading compared to Trial 2. Trial 1 also had a higher percentage of the load applied that reached the tile drain for all the components compared to Trial 2. The bacterial component appears to be of more significance than the nutrient components.

Table 3. Loads of Bacteria and Nutrients to Tile Drains for 24 Hours After Manure Application for June 1991

SITE	Loads From Isolated Tiles #/day	- - - g/day - - -			LOADS #/ha/day	- g/ha/day -			Percent Of Load Applied That Reached Tile Drain			
	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K
Trial 1 injection	3.4×10^9	53	6.0	47.5	9.1×10^9	119	12.0	130	5.78	0.241	0.284	0.21
Trial 2 irrigation	3.6×10^7	21	1.8	17.5	9.9×10^7	57	4.9	48	0.11	0.068	0.062	0.05

Appendix B contains the water quality data for the sampling wells. For Trial 1 one well (3.3 m depth) showed increased indigenous bacteria concentrations within 5 hours from the start of manure application. The fecal coliform (FC) counts increased from 4 to 346 FC per 100 ml. The biotracer bacteria showed up within 24 hours of being spread. For Trial 2 the well (4 m depth) showed signs of bacterial contamination within 5 hours of manure spreading initiating. The tracer bacteria was found in well samples within 3.5 hours of the tracer bacteria being introduced into the irrigation pipe. The Control Well (4.1 m depth) showed no sign of contamination from the spreading event.

Pre and post manure application soil samples were not taken due to laboratory time restrictions.

October 1991

There was no tile drain flow at the time of this manure application and there had been no flow since mid July. No contamination of the tile drain water resulted from the manure application. Pre-manure application soil bacteria analysis showed very low bacteria concentrations at all depths sampled. Figure 10 shows the soil EC(NA) concentrations after the manure application. The concentration decreased from the surface to the 70-75 cm depth for both methods of application. The irrigated trial has a lower number of EC(NA) in the surface layer compared to the injected trial even though the application rate was higher.

The EC(NA) on the irrigated trial upon contacting the soil surface may have died or became dormant. The irrigated trial also has a considerably lower concentration at the 70 to 75 cm depth compared to the injected trial. The bacterial soil data would suggest that had there been tile flow the injected trial would have resulted in higher levels of contamination compared to the chisel plowed trial.

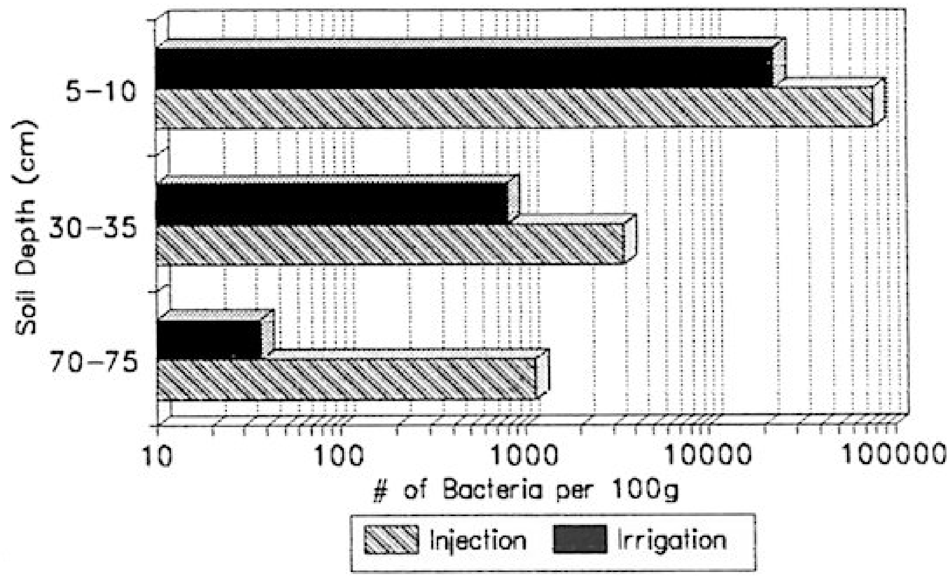

Figure 10: Soil EC(NA) Concentrations - October 1991

Water samples taken from the well on the irrigated trial showed fecal streptococcus concentrations going from <10 to 144 per 100 ml two days after the spreading event. A high concentration of 980 per 100 ml was recorded eight days after the event. No EC(NA) was found in the well. The chemical parameters measured showed no significant changes. The Control Well showed no change in bacterial or chemical concentrations. The wells on the injected trial remained dry and no water data is available. All well data is included in Appendix B.

From the June and October spreading events it appears that the injection method of application causes higher loading to the field tile drains compared to the irrigation method. Manure is injected below the soil layer with the higher organic matter content and is placed in an area of least disturbed macropores thus there is less opportunity for filtering to occur. As well, in this research, the time taken to apply the same amount of manure using the injection method (30 - 40 min) versus the irrigation method (90 min) may have an effect on the contamination results. Studies by van Es *et al.* (1991) and Bicki and Guo (1991) have found the higher rate of water addition the deeper the solutes move in the soil.

Comparison of Blocked vs Unblocked Flow

May 1992.

The study area had some surface cracks (1 mm width) present and barley growth was at 10 on the Zadok scale. Tile drains were flowing. Liquid swine manure was irrigated from the same lagoon as the other four spreading events at a rate of 60,000 L/ha. No water contamination resulted from this manure application. Five days after the manure application a 4 mm rain fell but no manure contaminates were transported into the field tiles. Due to laboratory time restrictions no soil bacterial samples were taken and therefore the depth of penetration of the manure in the soil profile was unknown.

A 15 mm rain fell the day prior to the spreading event and may have caused swelling in the clay loam soil resulting in smaller sized macropores. Ahuja *et al.* (1991) stated that the macropore size had very little effect on macropore flow and transport, but the smallest size retarded the downward chemical movement by wall adsorption a bit more than the largest size. Another reason perhaps affecting the transport of the manure through the soil was the solid content of the liquid manure in this event. The average suspended solids content of the liquid manure taken from the lagoon in 1991 was 1183 mg/L. The manure samples analyzed from this event showed an average suspended solid content of 77,000 mg/L, which is 65 times thicker than what was sampled in 1991. The range in percent dry matter for liquid swine manure analysed at the University of Guelph laboratory in the past four years was 0.07 to 3.0 % with an average of 0.9 %. The percent dry matter for the pan samples analysed for this spreading event was 7.7 %. The change in water content was partially due to repairs done to water leaks in pipes, nipples and troughs in the barn. Repair work was under taken on 140 drinking troughs that were leaking a total of 2800 litres per day. As well, the location of the intake hose in the lagoon may have influenced the solid content as the lagoon was not agitated prior to pumping beginning.

A preliminary observation from this spreading event may be that a thicker liquid manure would result in less preferential flow as it may cause physical blocking of the cracks and pores.

Table 4 shows the soil moisture content before the manure application and six days after the manure application for the two trials. The blocking of the field tile drain appeared to have affected the soil moisture content at the 30-35 and 70-75 cm depths by 5 and 10 %, respectively. If there had been tile drain contamination from this manure application, perhaps the blocking of the field tile drain would have allowed bacteria and nutrients to adsorb or bind with the soil at these depths.

Table 4. Soil Moisture Percentage

Soil Depth	Soil Moisture Percentage		
	Before	After (6 days after appl)	
		Blocked	Unblocked
5-10 cm	22.3	26.8	26.0
30-35 cm	19.3	27.7	21.5
70-75 cm	17.3	24.6	14.5

Nitrate Leaching

Table 5 shows the rate of application of nutrients for the 1991 and 1992 spreading events. The amounts of TKN, TP, and K applied in May 1992 is significantly higher than the amounts applied in the other four spreading events in 1991. The increase in the TP concentration would be directly related to the solid content. The bacteria concentration in the pan and lagoon samples are similar for 1991 and 1992.

Table 5. Rate of Application of Nutrients for 1991 and 1992 Spreading Events.

Trial		Rate L/ha	Concentration TKN mg/L	TP mg/L	K mg/L	Rate of Application TKN kg/ha	TP kg/ha	K kg/ha
May 1991	1&2	101,000	675	70	721	68	7	74
June	1	81,700	760	63	767	62	5	63
	2	121,000	760	63	767	71	6	72
Oct	1	82,150	1,192	93	1,090	98	8	90
	2	93,400	1,192	93	1,090	111	9	102
Nov	1 & 2	67,700	1,315	88	1,082	89	6	73
May 1992	1&2	60,000	4,350	54,900	12,600	261	3294	756

In late November 1991 all the field tile drains had higher nitrate levels compared to earlier levels recorded in the year. Nitrate levels were around 10 mg/L and increased about 40 mg/L for Trials 1 and 2. The Control tile increased to about 20 mg/L. The source of the increased levels of nitrates in the tile waters could be attributed to manure applications, breakdown of crop residue and fertilizer application. No increase in phosphorus and potassium were noted in the tile drain waters.

Both the nitrate and chloride concentrations increased in the well water in late November 1991. The greatest increase occurred in the one well (depth 3.3 m) on Trial 1. During the early part of 1991 nitrate concentrations were <1 mg/L and after November 21 the concentrations ranged between 50 and 63 mg/L. Chloride levels doubled at this time also. For the well on Trial 2 (well depth 4.1 m), nitrate levels increased from <1 to just over 1.0 mg/L. The difference between the two trials can not be explained as both received approximately the same amount of manure throughout the year. The only difference is in the depth of the wells. The Control well was at the same depth as Trial 2 but did not receive any manure yet, the nitrate levels in the Control well were higher than what was found in the Trial 2 well.

CONCLUSIONS

Cultivation of the land prior to manure application appeared to have decreased the amount of bacteria and nutrient loading to the tile drain water. In the May 1991 spreading event the untilled trial was one order of magnitude higher in the calculated bacterial and nutrient loads compared to the cultivated trial. A higher percentage of the applied bacteria was detected in the tile drain water compared to applied nutrients for both trials. Soil bacterial samples taken after the November spreading event showed significantly higher counts of EC(NA) were found at the 75 cm depth on the untilled trial compared to the chisel plowed trial. It is believed that had the field tile drains been flowing at he time of the manure application, greater contamination of the water would have resulted on the untilled trial.

The injection method of manure application results in higher bacterial and nutrient loading to the tile drain water compared to the irrigation method. In June 1991 spreading event, the injected trial was two orders of magnitude higher in the bacterial loading and one order of magnitude higher in nutrient loading compared to the irrigated trial. Either application method contaminated groundwater in equal time. Soil bacteria samples taken after the October 1991 spreading event indicated that significantly more EC(NA) were found at the 75 cm depth on the injected trial compared to the irrigated trial. It is believed that had the field tile drains been flowing at the time of the manure application, greater contamination of the water would have resulted on the injected trial. No EC(NA) was found in the wells, however higher count of fecal streptococcus were found in the sampling well on the irrigated trial for 12 days following the manure application. The sampling wells on the injected trial were dry at this time.

No conclusions regarding the effect of blocking tile drain flow on bacterial and nutrient loading to the tile drains can be made from the May 1992 spreading event as no water contamination resulted from the spreading event on either trials. A preliminary observation may be that a higher solid content in liquid manure results in decreased macropore flow.

RECOMMENDATIONS

From the previous year of research recommendations to avoid or lessen field tile drain contamination from liquid manure application are as follows:

1) Apply manure when tile drain flow is absent or very low

2) Till soil prior to manure application

3) Apply manure using irrigation method as opposed to injection method

4) If injecting manure avoid injecting directly over tile line

As well, over application of manure should be avoided as it may result in nitrate and chloride leaching to field tiles and groundwater in the Fall.

Other practical methods of reducing the impact of liquid manure on water quality worthy of future research would include increasing the solid content of liquid manure before spreading and blocking tile flow when manure is being spread.

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APPENDIX A

Soil Pit Description

Rainfall Data

Climatic Data

SOIL PROFILE DESCRIPTION

Soil Type: Perth Clay Loam

Horizon	Depth (cm)	Texture	Clay Content %	Stones Present	Mottles Present	Structure
Ap	0-27	cl	39	x		SAB*
Btgj	27-53	C	45	x	x	SAB
Btg	53-70	C		x	x	SAB
Ckg	70+	sicl	36	x	x	SAB

Drainage: imperfect

Slope: lower slope position, 1.5% complex

Comments: Vertically oriented structural cracks
Free water at 90 cm
Roots to 75 cm
Many stones in C horizon

* subangular blocky

Rainfall Data for 1991

Rainfall data was obtained from the Ontario Ministry of Agriculture and Food Weather Bulletin Board System for the station at Centralia College of Agricultural Technology, Stephen Township. The rainfall data is collected using a tipping bucket rain gauge.

DATE 1991	**RAIN** (mm)	**DATE** 1991	**RAIN** (mm)	**DATE** 1991	**RAIN** (mm)
02-May	6.8	02-Jun	0	01-Jul	0
03-May	0.2	03-Jun	0	02-Jul	0
04-May	0	04-Jun	0	03-Jul	0
05-May	0	05-Jun	0	04-Jul	
06-May	3.2	06-Jun	0	05-Jul	
07-May	1.2	07-Jun	0	06-Jul	
08-May	0.2	08-Jun	0	07-Jul	0
09-May	0	09-Jun	0	08-Jul	
10-May	3.8	10-Jun	0	09-Jul	0
11-May	0	11-Jun	0.2	10-Jul	0
12-May	0	12-Jun	12	11-Jul	0
13-May	0	13-Jun	0.8	12-Jul	0
14-May	0	14-Jun	0	13-Jul	5
15-May	0	15-Jun	0	14-Jul	10.4
16-May	0	16-Jun	19.4	15-Jul	0.2
17-May	0	17-Jun	0	16-Jul	0
18-May	7.6	18-Jun	0.2	17-Jul	0
19-May	0	19-Jun	0	18-Jul	0
20-May	0	20-Jun	0	19-Jul	0
21-May	0	21-Jun	0	20-Jul	0
22-May	0	22-Jun	0	21-Jul	0.4
23-May	0	23-Jun	2	22-Jul	0.4
24-May	0	24-Jun	0	23-Jul	0.4
25-May	8	25-Jun	0	24-Jul	0
26-May	23.2	26-Jun	0	25-Jul	0
27-May	26.2	27-Jun	0	26-Jul	0
28-May	0	28-Jun	0	27-Jul	0
29-May	14.6	29-Jun	0	28-Jul	0
30-May	0	30-Jun	0	29-Jul	0
31-May	0.2			30-Jul	8.8
01-Jun	0.2			31-Jul	0.4

DATE 1991	RAIN (mm)	DATE 1991	RAIN (mm)	DATE 1991	RAIN (mm)
01-Aug	0	01-Sept	0	01-Oct	1.2
02-Aug	7.4	02-Sept	0	02-Oct	23.8
03-Aug	4.8	03-Sept	6.8	03-Oct	9
04-Aug	6.6	04-Sept	0.8	04-Oct	10.6
05-Aug	0	05-Sept	0	05-Oct	0
06-Aug	0	06-Sept	0	06-Oct	3.4
07-Aug	0	07-Sept	0.8	07-Oct	0
08-Aug	1.8	08-Sept	0	08-Oct	0
09-Aug	0	09-Sept	0	09-Oct	0
10-Aug	0	10-Sept	0	10-Oct	2.6
11-Aug	0	11-Sept	0	11-Oct	0
12-Aug	1.2	12-Sept	0	12-Oct	1
13-Aug	0	13-Sept	0	13-Oct	0.2
14-Aug	0	14-Sept	0	14-Oct	5.8
15-Aug	20.8	15-Sept	0.2	15-Oct	2.4
16-Aug	0.4	16-Sept	3.8	16-Oct	1.2
17-Aug	14.2	17-Sept	0	17-Oct	0
18-Aug	0.2	18-Sept	0	18-Oct	0
19-Aug	0	19-Sept	2.2	19-Oct	3.6
20-Aug	0	20-Sept	4.4	20-Oct	0
21-Aug	0.6	21-Sept	0	21-Oct	0
22-Aug	0	22-Sept	1.2	22-Oct	0.2
23-Aug	0	23-Sept	10	23-Oct	0.2
24-Aug	0	24-Sept	0	24-Oct	3
25-Aug	0	25-Sept	2	25-Oct	21.4
26-Aug	0	26-Sept	3	26-Oct	3.4
27-Aug	0	27-Sept	0.2	27-Oct	8
28-Aug	0	28-Sept	0.8	28-Oct	0
29-Aug	0	29-Sept	0	29-Oct	0
30-Aug	0	30-Sept	0.8	30-Oct	0.2
31-Aug	0			31-Oct	0.2

DATE 1991	**RAIN** (mm)	**DATE** 1991	**RAIN** (mm)
01-Nov	0	01-Dec	0
02-Nov	0	02-Dec	0
03-Nov	0	03-Dec	0
04-Nov	0	04-Dec	0
05-Nov	0	05-Dec	0
06-Nov	0.2	06-Dec	8.2
07-Nov	0.2	07-Dec	0.2
08-Nov	0.2	08-Dec	0.6
09-Nov	0	09-Dec	0
10-Nov	0	10-Dec	0
11-Nov	0.8	11-Dec	2.6
12-Nov	0	12-Dec	2
13-Nov	0.2	13-Dec	1.8
14-Nov	22	14-Dec	0
15-Nov	0	15-Dec	0
16-Nov	0	16-Dec	0
17-Nov	5.6	17-Dec	0
18-Nov	3.4	18-Dec	0
19-Nov	20	19-Dec	1.4
20-Nov	0	20-Dec	6.6
21-Nov	0.2	21-Dec	0
22-Nov	2.6	22-Dec	0
23-Nov	0	23-Dec	0
24-Nov	0	24-Dec	0
25-Nov	0.6	25-Dec	0
26-Nov	1.2	26-Dec	0
27-Nov	0.4	27-Dec	0
28-Nov	27	28-Dec	10.8
29-Nov	2	29-Dec	0
30-Nov	0	30-Dec	0
		31-Dec	0

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Rainfall Data for 1992

DATE 1992	RAIN (mm)	DATE 1992	RAIN (mm)	DATE 1992	RAIN (mm)
01-Apr	3.4	01-May	0	01-Jun	0.2
02-Apr	0.6	02-May	19.6	02-Jun	0
03-Apr	0	03-May	0.4	03-Jun	0
04-Apr	0.2	04-May	0	04-Jun	0
05-Apr	0.2	05-May	0.2	05-Jun	3.2
06-Apr	0	06-May	0	06-Jun	0
07-Apr	5.4	07-May	0	07-Jun	5.6
08-Apr	0.2	08-May	0	08-Jun	0.2
09-Apr	0	09-May	2.2	09-Jun	0
10-Apr	0	10-May	0.4	10-Jun	0
11-Apr	39.2	11-May	0	11-Jun	0
12-Apr	5	12-May	0	12-Jun	0
13-Apr	0	13-May	2.2	13-Jun	0
14-Apr	0	14-May	0	14-Jun	0
15-Apr	0	15-May	0	15-Jun	0
16-Apr	31.6	16-May	0		
17-Apr	19.2	17-May	0		
18-Apr	1.2	18-May	15.2		
19-Apr	0.2	19-May	0		
20-Apr	0	20-May	0		
21-Apr	18.4	21-May	0		
22-Apr	2.2	22-May	0		
23-Apr	0	23-May	0.4		
24-Apr	9.6	24-May	4		
25-Apr	7.4	25-May	0		
26-Apr	1.8	26-May	0		
27-Apr	0	27-May	0		
28-Apr	0	28-May	0		
29-Apr	0	29-May	0		
30-Apr	5	30-May	8.6		
		31-May	6.8		

Climatic Data for Each Spreading Event

	Mean Temp C	Rel. Hum. %	Mean Wind Vel. m/s	Wind Dir.
Event #1 May 22, 1991	21.4	52	2.4	SSW
Event #2 June 24, 1991	19.3	54	2.5	ESE
Event #3 Oct. 7, 1991	7.0	59.1	5.2	NW
Event #4 Nov. 5, 1991	-3.2	60.4	5.0	SW
Event #5 May 19, 1992				

APPENDIX B

Soil Bacteria Data

Tile Water Quality Data

Well Water Quality Data

SOIL BACTERIAL ANALYSIS
L. RATZ FARM
MANURE APPLICATION ON MAY 22, 1991.

BEFORE APPLICATION: MAY 13, 1991.						AFTER APPLICATION: MAY 22. 1991			
CULTIVATED SITE						GEOMETRIC MEANS			
		FC	EC	FS	EC(NA)	FC	EC	FS	EC(NA)
TRIAL 1	SURFACE	<40	<40	796	<40	600000	600000	34000	26000
	30-35 cm	<40	<40	180	<40	320000	320000	4600	<400
	70-75 cm	<40	<40	<40	<40	10000	10000	<400	<400
UNTILLED SITE									
TRIAL 2	SURFACE	<40	<40	<40	<40	2600	26000	400	26000
	30-35 cm	<40	<40	<40	<40	34000	34000	<400	22000
	70-75 cm	<40	<40	<40	<40	6000	6000	<400	6000
CONTROL SITE									
CONTROL	SURFACE	<40	<40	<40	<40	220	220	<40	<40
	0 -35 cm	<40	<40	<40	<40	<40	<40	<40	<40
	70-75 cm	<40	<40	<40	<40	<40	<40	<40	<40

SOIL BACTERIAL ANALYSIS
L. RATZ FARM
MANURE APPLICATION ON OCT. 7/92

BEFORE APPLICATION: SEPT 23,1991.						AFTER APPLICATION: OCT 7, 1991				
INJECTION SITE							GEO. MEAN			
		FC	EC	FS	EC(NA)		FC	EC	FS	EC(NA)
TRIAL 1	SURFACE	<40	<40	340	<40	SURFACE	77460	77460	9295	77460
	30-35 cm	<40	<40	4800	<40	30-35 cm	3458	3458	28	3458
	10-75 cm	<40	<40	160	<40	70-75 cm	1131	1131	20	1131
IRRIGATION SITE										
TRIAL 2	SURFACE	<40	<40	440	<40	SURFACE	27113	27713	5292	27713
	30-35 cm	<40	<40	2600	<40	30-35 cm	800	800	800	800
	70-75 cm	<40	<40	6000	<40	70-75 cm	47	47	28	37
CONTROL	SURFACE	<40	<40	10000	<40	SURFACE	469	469	133	469
	30-35 cm	<40	<40	< 40	<40	30-35 cm	1	1	6	1
	70-75 cm	<40	<40	<40	<40	70-75 cm	9	9	15	9

SOIL BACTERIAL ANALYSIS
L. RATZ FARM
MANURE APPLICATION ON NOV. 5/92

BEFORE APPLICATION:OCT 28,1991.						AFTER APPLICATION: NOV 05,1991				
							GEO. MEAN			
CHISEL PLOW SITE		FC	EC	FS	EC(NA)		FC	EC	FS	EC(NA)
TRIAL 1	SURFACE	18000	18000	2600	18000	SURFACE	100000	100000	6000	30000
	30-35 cm	160	160	<40	80	30-35 cm	20	20	1	20
	70-75 cm	160	160	<40	40	70-75 cm	566	566	566	28
UNWORKED SITE										
TRIAL 2	SURFACE	2600	2600	4800	<40	SURFACE	27713	27713	7563	27713
	30-35 cm	440	410	<40	<40	30-35 cm	3742	3742	5292	3742
	70-75 cm	260	260	340	<40	70-75 cm	2040	2040	2163	1600
CONTROL	SURFACE	<40	<40	<40	<40	SURFACE	0	0	0	0
	30-35 cm	<40	<40	40	<40	30-35 cm	0	0	0	0
	70-75 cm	<40	<40	<10	<40	70-75 cm	0	0	0	0

NOTE: <40 WAS INTERPRETED AS 0 FOR GEO. MEAN CALCULATIONS

SOIL BACTERIAL ANALYSIS
L. RATZ FARM
DATE: NOV 20, 1991 - 3 WEEKS AFTER NOV 5 SPREADING EVENT

			GEO. MEAN		
CHISEL PLOW SITE		FC	EC	FS	EC(NA)
TRIAL 1	SURFACE	21	21	40	13
	30-35 cm	0	0	1	0
	70-75 cm	0	0	0	0
UNWORKED SITE					
TRIAL 2	SURFACE	1183	1183	456	248
	30-35cm	0		0	0
	70-75 cm	0	0	0	0
CONTROL	SURFACE	0	0	150	0
	30-35 cm	0	0	0	0
	70-75 cm	0	0	0	0

NOTE: <40 WAS INTERPRETED AS 0 IN GEO. MEAN CALCULATION

Field Tile Drain TRIAL 1

Bacterial and Chemical Concentrations

DATE	TIME	OBSERVATIONS	FLOW L/s	FC #/100ml	E. Coli #/100ml	FS #/100ml	EC(NA) #/100ml	BOD mg/L	SS mg/L	NH3 mg/L	T.Kjeld mg/L	NO2 mg/L	NO3 mg/L	TOT. P mg/L	Diss. P mg/L	pH	Cl- mg/L	Cond µmhos /cm	K mg/L
22-May-91	11:10 am	TEMP-13,CLEAR	0.0032				<4	1.48	3.9	<0.1	0.52	0.05	10.8	0.070	<0.01	7.68	30.0	813	2.2
22-May-91	3:20 pm		0.0058				<10	0.40	4.7	<0.1	0.58	0.05	10.5	0.090	<0.01	7.54	29.8	800	2.1
22-May-91	4:20 pm	TEMP-10,	0.0091				1200	21.2	49.4	0.7	7.75	0.13	10.9	1.050	0.30	7.51	52.5	870	4.4
22-May-91	4:50 pm	TEMP-10, V. CLOUDY	0.007				100000	20.6	62.5	0.4	7.55	0.13	11.8	1.050	0.28	7.51	41.9	910	4.1
22-May-91	5:05 pm	VERY CLOUDY	0.0087				75000	20.4	49.4	0.3	6.5	0.13	11.4	0.880	0.29	7.47	42.4	900	3.7
22-May-91	5:19 pm	VERY CLOUDY	0.0079				74000	25.3	55.1	0.2	7.98	0.14	11.4	1.000	0.27	7.48	43.9	920	3.8
22-May-91	5:34 pm	VERY CLOUDY	0.0132				87000	35.3	66.4	0.1	11.00	0.19	11.8	1.250	0.28	7.58	48.9	920	4.3
22-May-91	6:09 pm		0.0057				46000	21.6		0.2	7.10	0.25	11.6	0.860	0.19	7.45	51.7	899	4.0
22-May-91	8:25 pm		0.0057				G19000	17.1	30.8	0.1	5.94	0.11	11.4	0.600	0.15	7.19	41.6	850	3.0
23-May-91	9:40 am	TEMP-13,CLEAR	0.0046				3000	3.06	5.7	<0.1	1.52	0.04	10.9	0.190	0.10	7.11	33.1	790	2.2
24-May-91	10:09 am	TEMP-13,CLEAR	0.0066				420	<0.01	3.9	<0.1	0.75	0.01	10.5	0.110	0.02	6.95	30.8	800	2.3
27-May-91	10:55 am	TEMP 17,CLEAR	0.0657				400	2.36	14.2	0.4	2.18	0.24	18.4	0.140	0.09	7.26	52.8	834	3.0
05-Jun-91	11:34 am	TEMP-14, SL. CLOUDY	0.0057	A700	<100	A400	184	0.40	25.4	0.1	0.76	0.01	14.9	0.110	0.05	7.30	42.7	870	2.5
17-Jun-91	11:39 am	TEMP-15,CLEAR	0.0084	440	230	A60	20	1.49	9.6	0.1	0.86	<0.01	17.4	0.100	<0.01	7.00	42.2	810	2.7
24-Jun-91	11:45 am	TEMP-15,CLEAR	0.00265	100	68	A50	PRESENT	1.80	5.9	<0.1	0.68	0.01	15.8	0.100	<0.01	6.68	40.1	1020	3.8
24-Jun-91	2:45 pm	TEMP-16,BLACK	0.0543	1700000	1700000	100000	1400000	186.0	244.0	122.0	169.0	0.40	<0.1	19.50	11.60	7.20	212.0	2930	150.0
24-Jun-91	1:59 pm	TEMP-17,OPAQUE	0.044	2100000	2100000	130000	1500000	187.0	161.0	84.0	126.0	5.20	<1.0	15.50	8.940	7.21	195.0	2680	105.0
24-Jun-91	2:15 pm	TEMP-17, OPAQUE	0.0038	2100000	1400000	A80000	1400000	143.0	366.0	46.0	85.0	5.50	6.0	12.00	4.410	7.20	149.0	2130	67.0
24-Jun-91	2:30 pm	TEMP-17,OPAQUE	0.0302	2400000	1700000	A30000	960000	108.0	174.0	31.0	64.0	3.70	10.0	10.00	3.260	7.18	122.0	1810	44.0
24-Jun-91	2:45 pm	Temp-17, Opaque, Clearing	0.0235	1110000	810000	25000	810000	128.0	221.0	21.1	47.2	1.77	13.4	15.40	2.340	7.15	97.1	1580	31.0
24-Jun-91	3:00 pm	TEMP-17, CLEARING	0.0275	1190000	830000	25000	660000	113.0	206.0	18.3	42.0	1.40	14.5	5.800	2.100	7.10	96.0	1520	26.0
24-Jun-91	3:29 pm	TEMP-17, CLEARING	0.0175	1250000	70000	31000	600000	108.0	107.0	15.4	35.9	0.57	14.9	4.200	1.770	6.90	94.5	1450	22.0
24-Jun-91	4:00 pm	TEMP-17,	0.0172	750000	750000	71000	510000	86.0	132.0	13.0	30.6	0.41	15.1	3.600	1.440	7.19	65.7	1360	19.5
24-Jun-91	4:30 pm	TEMP-17,CLOUDY	0.0193	740000	740000	53000	540000	81.0	71.6	10.3	26.5	0.28	15.2	3.200	1.480	7.15	81.2	1310	17.3
24-Jun-91	5:30 pm	TEMP-17,CLOUDY	0.0146	620000	620000	25000	480000	73.5	49.8	7.20	19.6	0.27	15.0	2.500	1.070	7.13	67.0	1190	12.6
24-Jun-91	6:29 pm	TEMP-17,CLOUDY	0.0132	370000	30000	24000	390000	230.0	36.5	5.70	16.5	0.26	15.1	2.000	0.840	7.14	67.2	1160	11.5
24-Jun-91	8:30 pm	TEMP-17,CLOUDY	0.0127	420000	420000	23000	420000	35.4	37.6	3.90	11.5	0.22	15.0	1.280	0.510	6.66	60.0	1120	8.9
25-Jun-91	9:14 am	TEMP-16.5,CLEAR	0.0072	64000	61000	3300	26000	6.68	8.8	0.80	3.05	0.12	16.0	0.400	0.200	6.80	52.5	990	5.1
26-Jun-91	9:14 am	TEMP-16,CLEAR	0.0051	23000	15000	1800	11000	1.26	<5.0	0.132	1.03	0.09	16.1	0.235	0.128	6.80	48.4	994	4.1
27-Jun-91	10:39 am	TEMP-16,CLEAR	0.0034	2700	2500	370	1500	2.18	7.3	0.002	0.73	0.13	16.5	0.161	0.038	6.77	44.8	1000	3.3
28-Jun-91	9:29 am	TEMP-16,CLEAR	0.0031	1400	1400	140	630	0.15	<5.0	0.016	0.71	0.04	16.4	0.148	0.107	7.42	42.0	960	3.2
02-Jul-91	9:14 am	TEMP-15,SL.CLOUDY	0.00139	180	180	24	110	1.47	<5.0	0.002	0.64	0.03	14.4	0.159	0.125	7.18	43.0	1060	3.2
04-Jul-91	10:39 am	TEMP-18,CLEAR	0.0197	570	570	G600	170	0.74	<5.0	0.01	0.66	0.06	20.7	0.106	0.079	6.75	39.8	910	3.0
08-Jul-91	9:40 am	TEMP-17, CLEAR	0.0027	110	110	A60	<10	0.39	13.5	0.01	0.60	0.02	17.4	0.108	0.089	7.71	43.8	930	3.0
20-Nov-91	9:20 am	TEMP-8, SL. CLOUDY		32	24	G600	<4												
21-Nov-91	9:45 am	TEMP-8, CLEAR		240	190	1220	A10												
02-Dec-91	9:14 am	TEMP-8,CLEAR	0.0155	28	20		12	4.08	5.7	<0.1	0.76	<0.05	38.0	0.100	0.05	8.04	72.3	912	1.9
11-Dec-91	9:40 am	TEMP-6, Some Sediment	0.0524	16	16	68	<4	0.44	162	0.2	0.83	<0.05	24.0	0.120	0.07	6.88	61.9	910	2.3
16-Dec-91	9:40 am	TEMP-6,CLEAR	0.0277	4	<4	4	<4	1.80	4.7	0.1	0.62	<0.05	45.0	0.030	0.03		70.3	980	2.0

TRIAL 1

Bacterial and Chemical Concentrations

DATE	TIME	OBSERVATIONS	FLOW L/s	FC #/100mL	E. Coli #/100mL	FS #/100mL	EC(NA) #/100mL	T. KJELD mg/L	TOT. P mg/L	pH	K mg/L
24-Mar-92	10:05 am	TEMP 4 CLEAR	0.027	<4	<4	<4	<4	0.88	0.09	7.79	2.4
06-Apr-92	09:20 am	TEMP 4 CLOUDY	0.015	<100	<100	830	<100	0.40	0.06	7.61	1.8
13-Apr-92	09:45 am	TEMP 4 CLEAR	0.065	<10	<10	<10	<4				
21-Apr-92	09:10 am	TEMP 6 CLEAR	0.034	4	4	8	<4	0.89	0.08	7.78	2.1
28-Apr-92	09:25 am	TEMP 7,CLEAR	0.045	<4	<4	16	<4				
11-May-92	09:10 am	TEMP 9, CLEAR	0.008	<4	<4	4	<4				
19-May-92	09:15 am	TEMP 11, CLEAR	0.0045	<10	<10	A10	<10	0.49	0.13		2.20
25-May-92	09:25 am	TEMP11, CLEAR		<10	<10	A20	<10	0.58	0.07	7.60	2.33
25-May-92	09:30 am	TEMP 11, CLEAR	0.0051	<10	<10	<10	<10	0.44	0.06	7.60	2.31
25-May-92	09:40 am	TEMP 10, CLEAR		<10	<10	<10	<10	0.64	0.05	7.70	2.30
25-May-92	10:00 am	TEMP 10, CLEAR	0.005	<10	<10	<10	10	0.65	0.06	7.70	2.36
25-May-92	10:30 am	TEMP 10, CLEAR		<10	<10	<10	10				
25-May-92	11:00 am	TEMP 10.5, CLEAR	0.003	<10	<10	<10	<10	0.08	0.06	7.70	2.27
25-May-92	12:00 pm	TEMP 10, CLEAR	0.003	<10	<10	<10	<10				
25-May-92	01:30 pm	TEMP 11, CLEAR	0.0037	<10	<10	<10	<10	0.30	0.06	7.60	2.30
01-Jun-92	09:15 am	TEMP 12, CLEAR	0.0025	<4	c4	36	<4	0.30	0.10	8.00	2.69

Field Tile Drain
TRIAL 2
Bacterial and Chemical Concentrations

DATE	TIME	OBSERVATIONS	FLOW L/s	FC #/100ml	E. Coli #/100ml	FS #/100ml	EC(NA) #/100ml	BOD mg/L	SS mg/L	NH3 mg/L	T. Kjeld mg/L	NO2 mg/L	NO3 mg/L	TOT. P mg/L	Diss. P mg/L	pH	Cl- mg/L	Cond µmhos/cm	K mg/L
13-May-91	9:50 am	TEMP-12,CLEAR	0.0056	<4	<4	<4	<4	0.34	49.2	0.004	0.40	<0.01	5.1	0.044	0.009	7.78	26.8	768	1.3
22-May-91	11:20 am		0.0032				<4	0.38	14.4	<0.1	0.50	0.03	5.1	0.060	<0.01	7.59	28.3	778	4.6
22-May-91	1:10 pm		0.0108				440	51.5	623	37.3	62.8	0.60	3.6	7.00	3.00	7.79	99.3	1730	47.0
22-May-91	1:40 pm		0.018				210000	42.0	463	30.5	53.0	0.63	3.2	5.80	2.10	7.54	100.0	1530	38.0
22-May-91	1:50 pm		0.0223				4000000	95.5	714	42.0	75.0	0.72	<0.1	8.00	3.28	7.65	133.0	1850	54.0
22-May-91	2:10 pm		0.0247				600000	137.0	708	52.0	87.5	0.21	<0.1	10.5	4.36	7.70	164.0	2140	59.0
22-May-91	2:40 pm		0.0215				500000	148.0	1479	40.0	79.5	1.92	<0.1	7.50	3.40	7.68	144.0	2030	48.0
22-May-91	3:07 pm		0.0175				370000	99.0	358	26.0	53.0	0.98	3.3	5.10	2.18	7.60	120.0	1640	31.0
22-May-91	3:40 pm		0.0162				380000	93.0	266	18.2	40.1	0.54	5.0	4.00	1.51	7.58	99.4	1450	22.0
22-May-91	4:40 pm		0.0138				230000	65.0	154	10.5	27.4	0.38	5.4	2.80	1.09	7.54	76.9	1280	15.3
22-May-91	05:50 pm		0.0133				190000	47.0	107	7.20	20.2	0.32	5.4	2.30	0.36	7.52	63.8	1061	11.2
22-May-91	8:05 pm		0.0133				140000	12.5	67.5	4.40	13.4	0.24	5.5	1.35	0.59	7.42	47.2	950	7.3
23-May-91	10:05 am	Temp-13,clear	0.0072				<4	8.72	22.2	1.40	4.80	0.08	5.7	0.490	0.15	7.31	38.4	830	3.5
24-May-91	11:50 am	Temp-15,clear	0.0064				9900	3.09	9.2	0.50	2.36	0.04	5.8	0.250	0.05	7.26	35.0	810	2.5
05-Jun-91	11:45 am	Temp-15,very Cloudy	0.003	7000	6300	200	1600												
17-Jun-91	11:34 am	Temp-15,clear		3700	2900	600	740		NO CHEM										
24-Jun-91	12:00 pm	Temp-15, Cloudy	0.0015	310	310	A100	120	2.40		<0.1	0.84	<0.01	11.1	0.210	0.06	7.38	38.6	930	2.9
24-Jun-91	2:05 pm	Temp-17,blackish	0.025	330000	180000	A60000	110000	148.0	1081.0	37.8	72.0	8.80	29.1	6.20	2.00	7.39	185.0	2200	60.0
24-Jun-91	2:30 pm	Temp-17,blackish	0.0225	500000	360000	260000	120000	177.0	659.0	63.0	104.0	9.60	25.5	8.50	3.90	7.37	223.0	2520	85.0
24-Jun-91	02:45pm	Temp-17,blackish	0.289	380000	170000	110000	110000	177.0	700.0	54.0	93.5	9.30	35.0	8.00	3.26	7.40	222.0	2500	88.0
24-Jun-91	3:00 pm	Temp-17,blackish	0.0185	250000	250000	A60000	100000	177.0	828.0	55.0	93.5	7.90	30.0	8.00	3.44	7.43	210.0	2410	72.0
24-Jun-91	3:30 pm	Temp-16,blackish	0.0123	320000	320000	31000	100000	106.0	136.0	25.8	52.6	1.85	31.0	3.700	1.50	6.95	146.0	1880	36.0
24-Jun-91	4:00 pm	Temp-17,clearing	0.0098	190000	190000	55000	100000	128.0	90.5	17.9	39.2	0.51	29.3	2.900	1.06	7.11	124.0	1620	26.0
24-Jun-91	4:30 pm	Temp-17,clearing	0.0096	190000	A70000	39000	81000	<27	57.3	14.7	34.1	0.41	26.8	2.600	0.92	7.15	108.0	1530	20.0
24-Jun-91	5:45 pm	Temp-18,clearing	0.0073	G340000	G170000	10000	72000	49.0	30.4	8.50	20.3	0.33	20.3	1.500	0.57	7.20	87.7	1280	15.0
24-Jun-91	6:45 pm	Temp-18,clearing	0.0075	G250000	G150000	18000	56000	37.2	42.5	7.20	17.1	0.41	18.5	1.250	0.49	7.16	83.4	1220	12.9
24-Jun-91	6:40 pm	Temp-18,cloudy	0.0056	80000	42000	13900	28000	23.0	20.1	4.80	11.1	0.32	16.2	0.840	0.20	6.80	65.3	1120	9.3
25-Jun-91	9:30 am	Temp-17,cloudy	0.0024	12000	12000	2400	4400	3.36	26.3	1.50	3.46	0.29	13.9	0.360	0.11	7.03	49.4	1000	5.8
26-Jun-91	9:36 am	Temp-17,sl.cloudy	0.0018	2900	2900	1300	A400	0.44	13.5	0.237	1.12	0.21	12.7	0.185	0.12	6.94	42.6	950	3.7
27-Jun-91	10:15 am	Temp-17,clear	0.0013	1200	A400	1000	<100	0.06	<5.0	0.003	0.86	0.10	11.7	0.150	0.023	6.67	40.3	940	2.8
28-Jun-91	9:50 am	Temp-17,clear	0.0016	A800	A400	1100	80	0.25	<5.0	0.027	0.63	0.02	11.2	0.133	0.102	7.35	39.3	910	2.8
02-Jul-91	9:25 am	Temp-17,sl.cloudy	0.00085	650	380	580	96	0.79	18.4	0.007	0.59	0.02	8.9	0.155	0.119	7.80	40.7	890	2.6
04-Jul-91	10:30 am	Temp-19, V. Cloudy		1900	1100	2700	A400		NO CHEM										
08-Jul-91	10:00 am	Temp-17, Sediment In Water	0.0029	A400	A100	1000	<100												
15-Jul-91	9:20 am	Temp-17,sl.cloudy	dripping	230	170	G20000	<4		NO CHEM										
20-Nov-91	9:30 am	Temp-08,sl.cloudy	0.0256	88	88	G600	<4	6.00	253.0	0.20	2.42	0.15	62.4	0.88	0.61	6.34	91.7	1120	4.4
20-Nov-91	2:51 pm	Temp-08,sl.cloudy	0.0271	800	610	G1500	A10	5.24	499.0	0.10	4.00	0.50	53.0	2.30	0.28	6.52	86.5	1030	18.3
21-Nov-91	10:04 am	Temp-08,clear	0.0255	36	36	G600	6	4.80	82.5	<0.1	1.11	<0.10	52.0	0.25	0.11	6.88	84.5	1060	2.6
25-Nov-91	9:20 am	Temp-7,sl.cloudy	0.0034	250	250	560	<10	28.0	293.0	0.20	1.60	10.0		0.76	0.50	6.48	25.0	990	6.3
2-Dec-91	9:30 am	Temp-6,clear	0.0174	A10	L10		<4	2.00	65.1	<0.1	1.03	0.05	56.5	0.21	0.11	7.94	76.9	1039	3.0
11-Dec-91	9:30 am	Temp-6, Cloudy	0.0336	G1000	G1000	1200	<10	1.20	222.0	0.10	1.54	<0.05	27.5	0.47	0.09	6.90	62.7	950	4.8
16-Dec-91	9:45 am	Temp-6,clear	0.0169	G1000	1000		<10	1.60	56.7	<0.10	0.82	<0.05	47.5	0.26	0.14		69.0	980	2.3

TRIAL 2

Bacterial and Chemical Concentrations

DATE	TIME	OBSERVATIONS	FLOW L/s	FC #/100mL	E. Coli #/100mL	FS #/100mL	EC(NA) #/100mL	T. KJELD mg/L	TOT. P mg/L	pH	K mg/L
24-Mar-92	10:15 am	TEMP 4 CLOUDY	0.0011	<20	<20	1500	<20	7.95	3.350	7.74	1.50
06-Apr-92	09.35 AM	TEMP 4 CLOUDY	0.0075	<100	<100	A70	<100	0.67	0.160	7.83	2.40
13-April-92	10,00 AM	TEMP 4 CLOUDY	0.0380	A10	A20	A70	<10				
21-Apr-92	09.20 AM	TEMP 7 CLOUDY	0.0240	A40	A40	260	<10	1.03	0.270	7.79	4.10
28-Apr-92	09:35 AM	TEMP 7, CLOUDY	0.0230	230	150	1050	<10				
11-May-92	04:25 am	TEMP 10, SL. CLOUDY	0.0043	392	296	160	<4				
19-May-92	09:40 am	TEMP 11, SL. .CLOUDY	0.0026	A20	A20	80	<10	1.00	0.130		1.56
19-May-92	12:45 pm	TEMP 11, SL. CLOUDY		<1000	<1000	<1000	<10				
19-May-92	03:15 pm	TEMP 13,		A10	<10	310	<10				
19-May-92	04:15 pm			A10	<10	A80	<10				
19-May-92	03:15 pm	CLEAR		<10	<10	A30	<10				
19-May-92	04:15 pm	TEMP 13, CLEAR		<10	<10	<10	<10				
19-May-92	12:50 pm	CLEAR		<10	<10	A60	<10				
20-May-92	09:40 am	TEMP 13, CLEAR		<10	<10	<10	<10	0.78	0.090		1.60
21-May-92	09:29 am	TEMP 14, CLEAR	0.0022	120	110	A20	<10	1.53	0.070		1.60
22-May-92	10:04 am	TEMP 11, CLEAR	0.0026	<10	<10	A10	<10				
25-May-91	10:00 am	TEMP 10, CLOUDY	0.0020	A10	Al0	220	<10	0.56	0.080	7.70	1.51
01-Jun-92	09:30 am	TEMP 12, CLOUDY	0.0026	<10	A20	<4	<10	3.70	1.000	8.00	2.80

Field Tile Drain

C0NTROL
Bacterial and Chemical Concentrations

DATE	TIME	OBSERVATIONS	FLOW L/s	FC #/100ml	E. Coli #/100ml	FS #/100ml	EC(NA) #/100ml	BOD mg/L	SS mg/L	NH4 mg/L	T. Kjeld mg/L	NO2 mg/L	NO3 mg/L	TOT. P mg/L	Diss. P mg/L	pH	Cl- mg/L	Cond µmhos/cm	K mg/L
13-May-91	10:15 am		0.003	<4	<4	<4	<4	0.25	11.1	<0.001	0.39	0.01	7.80	0.033	0.001	8.01	24.6	766	0.90
22-May-91	11:30 am						208		NO CHEM										
22-May-91	2:05 pm						<4		NO CHEM										
22-May-91	5:30 pm		0.0023				<4	1.98	<5.0	0.007	0.42	0.01	7.2	0.06	0.025	7.89	25.5	780	1.20
23-May-91	10:20 am	Temp-13, sl. Cloudy	0.00273				52000	<0.02	7.8	<0.1	0.32	0.03	7.9	0.05	0.040	7.40	26.0	760	1.00
24-May-91	10:25 pm	Temp-14, clear					<2		NO CHEM										
27-May-91	11:15 am	Cloudy	0.0583				PRESENT	4.32	42.1	0.90	4.84	0.11	11.4	0.18	0.090	7.88	47.1	758	2.70
05-Jun-91	12:10 pm	Temp-15, cloudy	0.0023				24	0.80	87.3	<0.1	0.77	0.02	11.2	0.13	0.040	7.42	30.6	800	1.40
17-Jun-91	11:40 am	Temp-12.5, sl.cloudy	0.00647	<100	<100	140	12	1.58	21.5	<0.1	0.50	0.01	14.7	0.11	<0.01	6.88	40.5	920	1.50
24-Jun-91	12:45 pm	Temp-15, sl.cloudy	0.0015	A40	A40	<10	A10	2.76	8.7	<0.1	0.42	<0.01	12.6	0.07	0.02	7.85	29.2	810	1.40
24-Jun-91	2:10 pm	Temp-15, clear	0.0015	A20	A20	<10	<10	3.16	6.5	0.10	0.92	<0.01	12.6	0.15	0.01	7.77	30.5	770	2.10
24-Jun-91	1:40 pm	Temp-15, clear	0.0016	10	<10	A10	<10	3.16	6.9	<0.1	0.37	<0.01	12.4	0.07	<0.01	7.52	29.8	820	1.50
24-Jun-91	8:50 pm	Temp-15, cloudy	0.0016	32	12	<10	<10	0.60	103.0	<0.1	0.53	<0.01	14.2	0.13	<0.01	7.20	30.5	830	2.20
25-Jun-91	09-45 am	Temp-16.5,clear	0.0012	A10	A10	<10	<10	8.24	37.9	<0.1	0.76	<0.01	13.9	0.11	<0.01	7.43	30.1	820	1.90
26-Jun-91	3:40 pm	Temp-16.5,clear	0.0012	20	8	<10	8		NO CHEM										
26-Jun-91	9:40 am	Temp-17,clear	dripping	A40	A40	300	<10		NO CHEM										
04-Jul-91	10:15 am	Temp-16.5,clear	0.0054	52	48	204	32	0.39	45.1	0.005	0.77	0.05	27.1	0.07	0.042	7.30	29.1	910	1.80
02-Dec-91	9:35 am	Temp-8, clear	0.0079	36	20		<4		17.1	<0.1	0.73	0.05	22.9	0.04	0.040	8.05	37.7	622	0.70
11-Dec-91	9:24 am	Temp-6, clear	0.0418	192	192	G600	<4	1.80	37.0	0.1	0.92	<0.05	10.5	0.15	0.130	6.92	28.7	520	1.30
16-Dec-91	9:55 am	Temp-6, clear	0.0122	A20	10	140	<10	2.84	314.0	<0.1	1.01	0.05	22.4	0.42	0.040		37.1	630	4.70

Sampling Well
CONTROL PIEZOMETER WELL DEPTH 4.11 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth (m)	FC #/100mL	E.COLI #/100mL	FS #/100mL	EC(NA) #/100mL	NH4 mg/L	NO3 mg/L	Diss. P. mg/L	pH	Chlor mg/L	Cond. mg/L	K mg/L	Diss. Org. C
23-May-91	10:55 am	Temp-13,clear					<4								
05-Jun-91	10:35 am	Temp-15, Clear, some Debris		4	4	<4	<2								
17-Jun-91	11:00 am	Temp-17.5, clear		<10	<10	<10	<4								
24-Jun-91	12:00 pm	Temp-17.5, clear		<4	<4	<4	<4								
24-Jun-91	05:05 pm	Temp-17.5,clear	2.14	<4	<4	<4	<4								
25-Jun-91	10:24 am	Temp-16,clear	0.65	<4	<4	<4	<4								
26-Jun-91	10:09 am	Temp-17,clear		<4	<4	<4	<4								
27-Jun-91	09:29 am	Temp-16,clear		<4	<4	<4	<4								
28-Jun-91	10:24 am	Temp-17, clear		4	<4	<4	<4								
02-Jul-91	10:20 am	Temp-17,clear	1.34	<4	<4	<1	<4								
04-Jul-91	10:04 am	Temp-18,clear		<4	<4	92	<4								
08-Jul-91	10:44 am	Temp-17,clear		<10	<10	<10	<10								
15-Jul-91	10:44 am	Temp-17.clear	1.10	<4	<4	<4	<4								
18-Jul-91	10:15 am	Temp-15,clear,pre-bail	1.30	4	4	8	<4	<0.1	0.35	<0.01	7.14	34.7	920	2.0	
19-Jul-91	10:30 am	Temp-17,clear,post-bail	1.05	<4	<4	<4	<4	<0.1	<0.01	<0.01	7.13	39.6	870	1.0	
20-Jul-91	09:50 am	Temp-15,clear	1.15	<4	<4	<4	<4	<0.1	0.02	<0.01	7.34	39.0	850	0.9	
29-Jul-91	09:49 am	Temp-14,clear / Cloudy	1.37	<4	<4	<4	<4	<0.1	0.02	<0.01	7.22	35.9	860	1.4	
06-Aug-91	10:39am	Temp-15, sl.cloudy	1.72	<4	<4	<4	<4	<0.1	0.01	<0.01	7.26	37.9	880	1.8	
12-Aug-91	09:29 am	Temp-15, Clear /Cloudy	1.95	<4	<4	<4	<4	0.1	0.02	<0.01	7.23	19.9	860	3.0	
19-Aug-91	09:55 am	Temp-18,clear	2.04	4	<4	24	<4	0.1	0.01	0.22	7.02	14.9	845	3.3	
26-Aug-91	09:34 am	Temp-15,clear	2.08	<4	<4	28	<4	0.1	<0.01	<0.01	7.16	9.5	880	3.0	
03-Sep-91	09:45am	Temp-15,clear	2.35		<4	<4	<4	<0.1	0.03	0.64	6.95	8.6	875	4.8	
09-Sep-91	09:29 am	Temp-14, B-clear, opaque	2.55	4	<4	48	<4	<0.1	<0.1	<0.01	7.15	9.7	860	55.0	
16-Sep-91	09:29 am	Temp-16, Clear	2.60	<10	<10	660	<10	<0.1	0.1	<0.01	6.85	8.0	860	4.9	
23-Sep-91	09:34 am	Temp-13,clear	2.76	<4	<4	12	<4	<0.1	<0.1	<0.01	7.17	8.8	870	3.2	
30-Sep-91	09:49 am	Temp-12, B-clear, C-cloudy	2.75	<4	<4	12	<4	<0.1	<0.1	0.12	6.95	7.4	880	3.3	
07-Oct-91	09:35 am	Temp-12,clear	2.84	<4	<4	4	<4	<0.1	<0.1	<0.01	6.74	8.3	910	3.2	
08-Oct-91	09:30 am	Temp-11,clear	3.20	4	<4	16	<4	<0.1	0.1	0.38	6.69	8.8	960	4.2	
09-Oct-91	09:20 am	Temp-12,clear	3.30	<4	<4	4	<4								
10-Oct-91	09:20 am	Temp-12,clear	3.20	<4	<4	6	<4	<0.1	<0.1	0.03	6.74	10.7	890	11.0	
15-Oct-91	09:20 am	Temp-12,clear	3.00	<4	<4	8	<4	<0.1	<0.1	0.04	6.70	1.1	380	4.1	
21-Oct-91	09:20 am	Temp-12, clear	3.05	<4	<4		<4	<0.1	0.1	0.04	6.71	8.4	890	4.4	
28-Oct-91	09:29 am	Temp-11,b-clear,c-cloudy	3.18	A10	<10	A50	<10	<0.1	<0.1	0.05	6.63	8.3	890	15.9	
01-Nov-91	10:15 am	Temp-9,cloudy	3.20	16	8	340	4	0.1	0.1		7.10	11.5	960	36.0	
05-Nov-91	03:25 pm	Temp-10,cloudy	3.40	<4	<4	<4	<4								
06-Nov-91	09:25 am	Temp-09, Cloudy	3.52	<4	<4	36	<4								
07-Nov-91	09:30 am	Tem-11, cloudy	3.60	<10	<10	<10	<4								
12-Nov-91	10:00 am	Temp-9,B-clear,C-cloudy	3.26	<4	<4	4	<4	0.1	0.1	0.05	7.23	8.4	880	8.8	1.1
18-Nov-91	09:25 am	Temp-9,B-clear,C-cloudy	3.20	<4	4	4	<4	0.1	<0.1	0.21	6.35	7.5	850	4.7	
20-Nov-91	09:35 am	Temp-10,clear	2.25	<4	<1	<48	<2	0.1	2.5	0.13	6.54	15.0	940	3.6	1.6
21-Nov-91	10:35 am	Temp-10,B-clear,C-cloudy	1.90	<4	<4	600	<2	<0.1	8.1	0.11	6.55	29.6	950	3.3	1.6
25-Nov-91	10:04 am	Temp-5,clear	1.90	<4	<4	160	<4	<0.01	7.7	0.04	6.93	28.3	920	3.3	1.5
02-Dec-91	10:04 am	Temp-8,clear	0.30	<4	<4		<4	<0.1	6.5	0.05	7.67	27.7	943	3.2	0.05
09-Dec-91	10:00 am	Temp-6,clear	0.30	<4	<4	68	<4	<0.1	9.0	0.10	6.48	29.5	950	2.8	
11-Dec-91	10:04 am	Temp-8,clear	1.00	4	<4	20	<4	0.2	10.9	0.01	6.77	32.9	930	2.5	1.2
02-Dec-91	10:04 am	Temp-8,clear													

Sampling Well
TRIAL 1 PIEZOMETER
WELL DEPTH 2.2 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth (M)	FC #/100mL	E.COLI #/100mL	FS #/100mL	EC(NA) #/100mL	NH4 mg/L	NO3 mg/L	Diss. P. mg/L	pH	Chlor mg/L	Cond. mg/L	K mg/L
22-May-91							<4							
23-May-91	11:30 am	TEMP-13, SL. CLOUDY					12							
24-May-91	11:30 am	TEMP-15, SL. CLOUDY					<2							
27-May-91	10:40 am	TEMP-17, CLEAR					52							
05-Jun-91	11:00 am	TEMP-11, YELLOWISH		A60	A60	100	<4							
17-Jun-91	11:55 am	TEMP-17, CLEAR		12	12	192	<4							
24-Jun-91		CLEAR		244	244	<4	28							
24-Jun-91	05:15 pm	TEMP-17, SL. CLOUDY	0.92	A10	A10	<10	<10							
25-Jun-91	10:15 am	TEMP-15.5, CLEAR	0.70	<10	<10	A20	<10							
26-Jun-91	04:50 am	TEMP-17, CLEAR		1	4	8	4							
27-Jun-91	10:55 am	TEMP-17, CLEAR		8	<4	12	<4							
26-Jun-91	09:20 am	TEMP-18, CLEAR	12.0	12	48	<4								
02-Jul-91	10:00 am	TEMP-17.5, CLEAR	1.29	8	<4	G600	<4							
04-Jul-91	10:50 am	TEMP-18, CLEAR		128	128	G600	<4							
08-Jul-91	10:30 am	TEMP-17, CLEAR		A60	A60	9000	<10							
15-Jul-91	10:25 am	TEMP-17, SL. CLOUDY	1.00	4	4	600	<4							
18-Jul-91	10:35 am	TEMP-16, SL. CLOUDY	1.92	A20	A20	570	<4	<0.1	0.68	<0.01	7.10	92.7	1360	7.1
19-Jul-91	09:29 am	TEMP-17, B-CLEAR, C-CLOUDY	0.80			150	<4	<0.1	0.44	<0.01	6.80	90.9	1260	9.6
22-Jul-91	09:25 am	TEMP-16,CLOUDY	1.12	16	8	84	<4	<0.1	0.40	<0.01	7.12	90.8	1260	11.8
29-Jul-91	09:20 am	TEMP-16,CLOUDY	1.30	60	44	124	8	<0.1	0.34	0.01	7.11	101.0	1230	137.0
30-Jul-91	10:10 am	TEMP-16,OPAQUE,POST RAIN	1.45	12	12	A80	<4	<0.1	0.23	0.04	7.09	89.6	1290	20.0
06-Aug-91	10:00 am	TEMP-16,VERY CLOUDY	1.58	<100	<100	<100	<100							
12-Aug-91	09:15 am	TEMP-15,OPAQUE	1.83	<10	<10	A50	<10							
09-Dec-91	09:35 am	TEMP-6,CLEAR	0.30	52	52	244	<1							
11-Dec-91	09:50 am	TEMP-8LEAR	0.93	44	12	100	<4							
16-Dec-91	09:35 am	TEMP-6,CLEAR	0.10	A10	A10	A80	L10	0.2	13.1	0.39	6.4	120.0	1000	2.0

TRIAL 1 PIEZOMETER
WELL DEPTH 2.19 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth (M)	FC #/100mL	E.COLI #/100mL	FS #/100mL	EC(NA) #/100mL	pH	K mg/L	TKN	TP
06-Apr-91	10:55 am	TEMP 5 CLEAR	0.60	<10	<10	A10	<4	7.66	3.20		
13-Apr-92	10:55 am	TEMP 5 CLEAR	0.45	<10	<10	<10	<4				
21-Apr-92	09:55 am	TEMP 7 CLEAR	0.35	<4	4	40	<4	7.82	1.60		
26-Apr-91	09:50 am	TEMP 7,CLOUDY	1.25	A20	A20	250	<4				
01-May-92	09:45 am	TEMP 10,CLEAR	0.70	<4	<4	4	<4				
19-May-92	10:10 am	TEMP 10,CLEAR		<10	<10	<10	<10		1.78	0.84	0.20
20-May-92	05:55 pm	TEMP11, CLEAR		<10	<10	<10	<10		1.70	0.92	0.07
21-May-92	08:35 am	TEMP 13,CLEAR	0.72	A10	<10	A30	<10		1.73	0.83	0.07
23-May-92	09:20 am	TEMP 13, SL.CL0UDY	0.80	<10	<10	<l0	<10		1.73	3.43	0.34
25-May-92	09:00 am	TEMP 11, CLEAR	0.75	<10	<10	<10	<10				
25-May-92	10:25 am	TEMP 8, CLEAR	0.70	<10	<10	<10	<10	7.50	2.08	0.16	0.44
04-Jun-92	09:40 am	TEMP 12, CLEAR	0.85	<10	<10	<4	<10				

Sampling Well

TRIAL2 PIEZOMETER
WELL DEPTH 4.1 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth	FC	E. Coli	FS	EC(NA)	NH4	NO3	Diss P.	pH	Chlor	Cond.	K	DOC
			(m)	- - - - - - - - #/100ml - - - - - - - -				mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
23-May-91	11:15 am	Temp-13,clear					<4								
24-May-91	12:14 pm	Temp-14.clear					<2								
05-Jun-91	10:44 am	Temp-11,yellowish		<10	<10	<10	<2								
17-Jun-91	10:59 am	Temp-17, Clear		10	<10	<10	<4								
24-Jun-91	12:05 pm	Temp-17, Clear		<4	<4	<4	<4								
24-Jun-91	4:59 pm	Temp-17,clear	1.26	980	980	404	A80								
25-Jun-91	10:30 am	Temp-17,clear	0.78	G400	G400	136	44								
26-Jun-91	10:05 am	Temp-16,clear		230	120	152	12								
27-Jun-91	9:20 am	Temp-17, Clear		76	44	4	<4								
28-Jun-91	10:35 am	Temp-17, clear		80	60	28	<4								
02-Jul-91	10:15 am	Temp-17,clear	1.25	24	24	12	<4								
04-Jul-91	10:00 am	Temp-17.5, Clear		12	12	G600	<4								
07-Jul-91	10:39 am	Temp-17, clear		<10	<10	8600	<10								
16-Jul-91	10:39 am	Temp-17, clear	1.05	<4	<4	104	<4								
18-Jul-91	9:49 am	Temp-14, sl.cloudy	1.8	<4	<4	28	<4	0.20	0.11	<0.01	7.04	9.0	1240	7.5	
19-Jul-91	10:09 am	Temp-15.5,b-clear, c-cloudy	0.9	<4	<4	<4	<4	0.10	<0.1	<0.01	6.95	4.5	1100	3.8	
22-Jul-91	9:40 am	Temp-16, clear	1.15	<4	<4	96	<4	<0.1	0.03	<0.01	7.21	4.2	1120	3.4	
29-Jul-91	9:40 am	Temp-16, Clear / Cloudy	1.3	<4	<4	<4	<4	<0.1	0.01	<0.01	7.04	4.6	1120	4.8	
30-Jul-91	10:20 am	Temp-15, cloudy,post Rain	1.3	<4	<4	A30	<4	<0.1	0.01	0.04	7.29	4.8	1075	4.7	
06-Aug-91	10:24 am	Temp-15, sl.cloudy	1.53	8	4	20	<4	<0.1	0.01	0.03	7.16	4.6	1080	4.0	
12-Aug-91	9:25 am	Temp-14, clear	1.8	24	<4	290	<4	<0.1	0.01	<0.01	7.20	4.3	1080	3.5	
19-Aug-91	9:45 am	Temp-18, clear / Cloudy	1.95	A60	A40	G600	<10	<0.1	0.03	0.03	7.11	4.0	1080	4.2	
26-Aug-91	9:25 am	Temp-17, clear	2.1	<4	<4	4	<4	0.1	<0.01	<0.01	7.17	3.7	1110	3.4	
03-Sep-91	9:35 am	Temp-15, clear, sunny	2.35		<4	<4	<4	0.1	0.01	<0.01	7.67	4.0	1052	4.1	
09-Sep-91	9:25 am	Temp-14, clear	2.53	<4	<4	12	<4	<0.1	<0.1	<0.01	7.11	4.2	1030	3.1	
16-Sep-91	9:20 am	Temp-16, cloudy	2.55	<4	<4	16	<4	<0.1	0.1	<0.01	7.08	3.5	1020	3.4	
23-Sep-91	9:29 am	Temp-13, clear / Cloudy	2.65	<4	<4	12	<4	<0.1	<0.1	<0.01	7.23	19.0	1020	15.8	
30-Sep-91	9:40 am	Temp-12, b-clear,c-cloudy	2.9	<4	4	12	<4	0.1	<0.1	0.09	7.13	4.1	1270	4.2	
07-Oct-91	9:25 am	Temp-12, clear	2.9	4	<4	4	<4	<0.1	<0.1	<0.01	6.95	4.8	1050	3.4	
08-Oct-91	09:20 am	Temp-11, b-clear,c-cloudy	3.05	<10	<10	<10	<10	0.1	<0.1	<0.01	6.81	3.6	1040	3.2	
08-Oct-91	9:17 am	Temp-12, sl.cloudy	3.15	4	<4	144	<4								
12-Oct-91	9:20 am	Temp-12, 8-clear-c-cloudy	3.05	32	24	160	4	0.2	<0.1	0.15	6.56	4.9	1060	4.6	
15-Oct-91	9:09 am	Temp-12, b-clear,c-cloudy	2.95	48	48	940	<4	<0.1	0.1	0.18	6.57	4.3	1060	4.0	
21-Oct-91	9:09 am	Temp-11, B-clear,c-cloudy	3.05	<4	<4	84	<4	<0.1	0.3	0.11	6.61	1.2	1070	3.3	
28-Oct-91	9:20 am	Temp-11, Cloudy	3.15	<10	<10	A30	<10	<0.1	0.3	0.18	6.55	4.2	990	132.0	
04-Nov-91	10:15 am	Temp-10, Cloudy	3.15	<10	<10	<10	<10	0.1	0.2		7.03	8.2	1040	85.0	
05-Nov-91	3:20 pm	Temp-10, cloudy	3.25	4	<4	<4	<4								
06-Nov-91	9:20 am	Temp-9, Cloudy	3.25	36	<4	<4	<4	<0.1	0.1	0.1	7.06	5.8	1120	4.4	
07-Nov-91	9:20 am	Temp-9, cloudy	3.25	<4	<4	<4	<4								
12-Nov-91	9:49 am	Temp-9, B-clear,c-cloudy	3.00	<4	<4	<4	<4	0.1	0.2	0.03	7.08	3.8	1070	3.4	
18-Nov-91	9:14 am	Temp-9, b-clear,c-cloudy	2.95	<4	<4	<4	<4								
20-Nov-91	9:49 am	Temp-10, clear	2.45	<4	<4	<4	<2								
21-Nov-91	10:24 am	Temp-10, clear	1.25	20	12	132	<2	<0.1	<0.1	<0.01	6.71	5.8	1110	3.2	1.1
25-Nov-91	10:03 am	Temp-5, clear	0.65	4	<4	66	<4	<0.01	1.3	0.04	6.65	7.1	1110	3.3	1.2
02-Dec-91	10:00 am	Temp-8, clear	0.75	<4	<4		<4	<0.1	1.7	0.45	7.86	8.4	1152	4.1	1.2
09-Dec-91	9:49 am	Temp-6, clear	0.30	<4	<4	28	<4	<0.1	2.5	<0.01	6.73	8.8	1160	3.3	1.1
11-Dec-91	10:00 am	Temp-8, Clear	0.65	<4	<4	20	4	0.2	2.6	0.03	6.68	8.6	1160	3.2	2.7
16-Dec-91	9:25 am	Temp-6, clear	0.25	<10	<10	A10	<10								

TRIAL 2 PIEZOMETER

WELL DEPTH 4.1 m

Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth (m)	FC	E. Coli	FS	EC(NA)	pH	K	TKN	TP
				- - - - - - - #/100ml - - - - - - - -					mg/L		
06-Apr-92	10:10 am	TEMP 5 CLEAR	1.45	<10	<10	<10	<4	7.57	<0.1		
13-Apr-92	10:25 am	TEMP 5 CLEAR	0.55	<10	<10	<10	<4				
21-Apr-92	9:40 am	TEMP 7 CLEAR	0.25	<4	<4	<4	<4	7.65	2.7		
28-Apr-92	10:05 am	TEMP 7, CLEAR	0.8	<4	<4	<4	<4				
11-May-92	09:55 am	TEMP 10. CLEAR	0.3	<4	<4	<4	<4				
19-May-92	10:20 am	TEMP 10, CLEAR		<10	<10	<10	<10		2.31	0.65	0.06
19-May-92	6:05 pm	TEMP 11,CLEAR		<10	<10	<10	<10		2.39	0.50	0.07
20-May-92	9:49 am	TEMP 13, CLEAR	0.85	<10	<10	<10	<10		2.32	0.60	0.07
21-May-92	9:50 am	TEMP 12, CLEAR	0.9	<10	<10	<10	<10		2.32	0.39	0.05
22-May-92	9:15 am	TEMP 11, CLEAR	0.35	<10	<10	<10	<10				
25-May-91	10:35 am	TEMP 9, CLEAR	0.85	<10	<10	<10	<10	7.20	2.46	0.11	0.11
01-Jun-92	9:55 am	TEMP 12, CLEAR	0.9	<4	<4	<4	<4				

Sampling Well

TRIAL1 PIEZOMETER 2
WELL DEPTH 3.3 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth	FC	E. Coli	FS	EC(NA)	NH4	NO3	DissP.	pH	Chlor	Cond.	K	DOC
			(m)	- - - - - - -	#/100ml	- - - - - - - -		mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L
23-May-91	11:19 am	TEMP-13,SL.CLOUDY					8								
24-May-91	11:39 am	TEMP-15,CLEAR					256								
05-Jun-91	11:10 am	TEMP-18,CLEAR		1600	1600	A10	34								
17-Jun-91	10:50 am	TEMP-18, CLEAR		290	220	200	24								
24-Jun-91	11:50 am	TEMP-17,CLEAR		4	4	8	<4								
24-Jun-91	4:50 pm	TEMP-18,CLEAR	1.10	346	332	<4	<4								
25-Jun-91	10:35 am	TEMP-16.5,CLEAR	0.78	580	380	<4	160								
26-Jun-91	10:00 am	TEMP-17,CLEAR		204	204	12	112								
27-Jun-91	9:14 am	TEMP-17, CLEAR		420	350	<10	A80								
28-Jun-91	9:20 am	TEMP-17,CLEAR		356	356	32	112								
02-Jul-91	10:09 am	TEMP-17, CLEAR	1.29	352	320	8	36								
04-Jul-91	9:49 am	TEMP-17.5,CLEAR		324	324	28	92								
08-Jul-91	10:15 am	TEMP-17, CLEAR		190	180	A20	A50								
15-Jul-91	10:35 am	TEMP-17, CLEAR	1.25	272	220	4	132								
18-Jul-91	9:25 am	TEMP-16,CLEAR	1.17	324	320	36	112	<0.1	0.58	<0.01	6.87	81.1	1340	3.8	
19-Jul-91	9:45 am	TEMP-15.5,CLEAR	1.07	170	170	12	A90	<0.1	0.37	<0.01	6.83	88.4	1340	3.2	
25-Jul-91	9:14 am	TEMP-16,CLEAR	1.18	84	76	<4	56	<0.1	0.27	<0.01	7.10	85.2	1290	3.5	
29-Jul-91	9:29 am	Temp-15, Clear / Cloudy	1.35	20	20	<4	<4	<0.1	0.29	<0.01	7.03	85.8	1275	4.5	
30-Jul-91	9:55 am	Temp-15, Clear / Cloudy	1.40	72	72	20	52	<0.1	0.31	0.05	7.09	89.3	1275	7.3	
06-Aug-91	10:09 am	Temp-15,clear / Cloudy	1.55	36	28	<4	16	<0.1	0.31	0.06	7.03	277.0	1320	6.9	
12-Aug-91	9:05 am	Temp-14,clear / Cloudy	1.82	40	20	<4	16	<0.1	0.17	0.03	7.03	85.5	1300	11.0	
19-Aug-91	9:25 am	Temp-18,clear / Cloudy	1.90	8	8	236	8	0.1	0.30	0.04	7.03	91.8	1305	6.0	
26-Aug-91	9:20 am	Temp-16,opaque	2.30	28	12	4	<4	0.1	0.13	<0.01	6.94	66.1	1320	111.0	
09-Sep-91	9:25 am	Temp-15,opaque	2.60		4	4	<4	<0.1	0.11	<0.01	7.57	54.6	1285	44.0	
09-Sep-91	9:14 am	Temp-14,b-cloudy, c-opaque	2.60	<10	<10	<10	<10	<0.1	8.20	<0.01	7.03	50.4	1270	19.3	
09-Sep-91	9:14 am	TEMP-16, CLOUDY	2.98	<10	<10	<10	<10								
21-Nov-91	10:09 am	TEMP-10,CLEAR	2.40	164	136	480	2	<0.1	63.0	0.01	6.71	130.0	1590	3.4	5.2
25-Nov-91	9:49 am	TEMP-5,CLEAR	2.10	64	64	100	<4	<0.05	57.5	0.05	6.74	138.0	1450	3.7	4.1
02-Dec-91	9:55 am	TEMP-8,CLEAR	1.70	16	8		<4	<0.1	55.5	0.01	7.39	115.0	1450	2.5	3.3
09-Dec-91	9:45 am	TEMP-6,CLEAR	0.35	4	4	80	<4	<0.1	51.0	<0.01	6.56	116.0	1430	2.8	2.6
11-Dec-91	9:55 am	TEMP-8,CLEAR	1.00	<4	<4	12	<4	0.1	24.0	0.04	6.49	112.0	1460	2.6	4.8
18-Dec-91	09:30 An	TEMP-6,CLEAR	0.60	4	<4	<4	<4								

TRIAL1 PIEZOMETER 2
WELL DEPTH 3.3 m
Bacterial Concentrations

DATE	TIME	OBSERVATIONS	Depth	FC	E. Coli	FS	EC(NA)	pH	K	TKN	TP
			(m)	- - - - - - - - -	#/100ml	- - - - - - - - - - - -			mg/L		
06-Apr-92	10:45 am	TEMP 5 CLEAR	0.8	<10	<10	<10	<4	7.24	5.8		
13-Apr-92	10:45 am	TEMP 5 CLEAR	0.38	<10	<10	<10	<4				
21-Apr-92	9:45 am	TEMP 7 CLEAR	0.35	<4	<4	G600	<4	7.38	2.2		
28-Apr-92	10:00 am	TEMP 7 CLEAR	1.8	<4	<4	G600	<4				
11-May-92	9:50 am	TEMP 10 CLEAR	0.4	<4	<4	<4	<4				
18-May-92	10:15 am	TEMP 10 CLEAR		<10	<10	<10	<10		1.90	0.88	0.08
19-May-92	6:10 pm	TEMP 11 CLEAR		<10	<10	<10	<10		1.91	1.03	0.08
20-May-92	9:45 am	TEMP 13 CLEAR	0.85	<10	<10	<10	<10		2.11	0.81	0.08
21-May-92	8:45 am	TEMP 12 CLEAR	0.9	<10	<10	<10	<10		2.12	0.71	0.05
28-May-92	10:00 am	TEMP 10 CLEAR	0.6	<10	<10	<10	<10	7.10	2.03	0.18	0.05
31-May-92	9:30 am	TEMP 12 CLEAR	0.9	<4	<4	<4	<10				

APPENDIX C

List of Presentations Given

Papers Published

List of Presentations Given Pertaining to Present Research

1) Ontario Soil Fertility Workshop. November 19, 1991. Royal Canadian Legion, Guelph, Ontario. Sponsored by OMAF, U. of Guelph and TFIO.

2) Environmental Research: 1991 Technology Transfer Conference. November 25 & 26, 1991. Four Seasons, Inn on the Park, Toronto, Ontario. Sponsored by MOE.

3) Perth County Soil and Crop Improvement Association, Annual Meeting. December 3, 1991. Stratford, Ontario.

4) Agricultural Nitrate and Impacts on Water Quality in Ontario. March 24 & 25, 1992. Lamplighter Inn, London, Ontario. Sponsored by OWMRSC.

5) Manure Management Workshop. March 30, 1992. Centralia College, Huron Park, Ontario. Sponsored by ABCA.

6) Safeguarding our Water Supply Symposium. June 12, 1992. Homesville, Huron County, Ontario. Sponsored by Huron County Health Unit.

List of Papers

Dean, D.M. and M.E. Foran., 1992. The Effect of Farm Liquid Waste Application on Tile Drainage. *S.W.C.J.,* July - August issue.

APPENDIX D

Newspaper Articles

Study finds manure enters tiles faster than previously thought

Soil type has some impact, but it's soil moisture that has the largest influence

By Peter Reschke

(Exeter) - Liquid manure being applied to fields when the tiles are running may be reaching water-courses a lot quicker than anyone believed possible.

That is one of the preliminary conclusions coming out of a multi-year study by two Ausable Bayfield Conservation Authority researchers.

Donna Dean and Mary Ellen Foran began their work monitoring tiles and drainage ditches during liquid manure applications in 1989. Alter three full seasons of work they are able in conclude that, under the right conditions, manure can find its way into the tiles within 20 minutes.

At that point they have found fecal bacteria counts in tile water can jump from virtually nothing to hundreds of thousands.

Coliform bacteria from liquid manure applications have long been considered the prime culprit in beach closings along the Lake Huron shoreline each summer. Health authorities regard beaches as unsafe for swimming when the bacteria count gels up to 100 per 100 milliliters of water.

They do acknowledge that it's not the only source of pollution. Faulty septic tanks, runoff from urban areas and cattle with access to watercourses are also contributors to the same problem.

Dean and Foran have seen manure entering the tile system anywhere from less than a half hour to six hours after spreading, with two hours representing the average.

They expect that conclusion will raise a few eyebrows among farmers who think their manure stays put unless washed away by heavy rains or spring runoff. "I think our findings have already surprised a lot of people", Dean says.

She speculates that manure is able to find is way to the tile through macropores- things like worm tunnels and cracks - in the ground.

Since 1989 the two researchers have monitored 12 spreading events on fields ranging from clay loam to silt and sandy loam. They even used a backhoe to dig observation channels at tile level in order to note changes in water quality.

Application rates ranged from 3,200 to 14,000 gal/acre. But rate differences alone did not account for the runoff problems, Dean stresses. In fact, the land can absorb relatively high amounts if it's dry enough.

She recalls one spreading in August of 1989 where 12,000 gal/acre were applied but the land was sufficiently dry that "nothing came through the tile". Dean admits they don't have enough data to show the significance of different soil types.

The key seems to be soil moisture. If the soil is really dry,"chances are (the manure) will just stay", Dean says. And the longer it sits in the soil, the more bacteria will die off and the more nutrients will be tied up, she adds.

But if the tile are running, even a little bit, at application lime, bacteria and nutrients can be in the system within minutes.

Dean and Foran have also found bacteria in groundwater as far as four meters below the surface.

Their findings may create a few headaches on area livestock operations. Dean acknowledges that the optimum time to spread manure from an environmental standpoint may not be the one that fits into the farmer's schedule. "It's a difficult situation," she says.

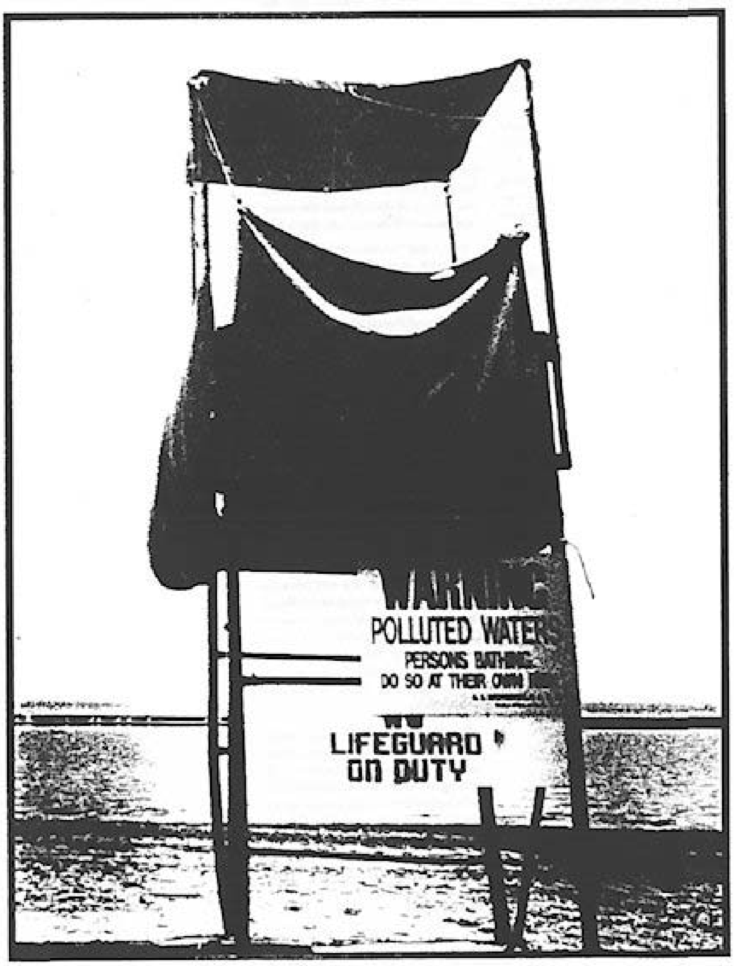
One management practice that could help slow down the flow is to lightly cultivate the soil prior to spreading; Dean suggests tillage may break up the macropores near the surface and impede manure seepage. But she also cautions that more study is needed before making such a recommendation.

She also plans to do more loading calculations, evaluating the amount of bacteria and nutrients that go on the field in comparisons to what ends up in the tile. At the moment it looks as though the loss of nutrients through the tile is not as significant as the loss of bacteria. That too will need more study to confirm, she says.

Dean and Foram plan to continue their work, which funded through the provincial Environment Ministry's Research and Technology Branch next season.

THE PROVEN PROVING GROUND
ENVIRONMENTAL RESEARCH & TECHNOLOGY DEVELOPMENT
June 1992

Reviving Rural Beaches



Here comes summer! Ontario residents will soon be flocking to beaches in the Great Lakes basin. Some will he disappointed when they arrive. This be greeted by warning signs alerting them to the danger of polluted waters.

Each year, over 100 Ontario beaches are declared dangerous for swimming, usually because of bacterial contamination from urban storm water, sewage and industrial sources. Yet isolation from metropolitan centres doesn't guarantee spotless shores. One quarter of these pollution alarms are posted at beaches in rural areas.

One source of bacteria at these rural sites is the runoff of liquid livestock manure into rivers and stream after being spread on the land. Such nutrients as phosphorous from this source may also impair water quality by stimulating the profuse growth of algae and other plants.

Researchers at the Ausable Bayfield Conservation Authority near Exeter, Ont., supported by the ministry's Environmental Research Program (ERP), have now confirmed another avenue for bacteria and nutrients to reach rural waters.

Starting in 1989, Ms. Donna Dean and Ms. Mary Ellen Foran monitored 12 separate applications of

See Beaches pg 2

From the Minister

Environment Ontario recognizes the important role that clean beaches play in ensuring healthy and thriving communities across the province. Beach closings not only disappoint swimmers, they threaten the livelihood of many. local people who depend on the annual summer influx of tourists and vacationers into their area.

The ministry has a number of programs in its Provincial Beaches Program which target the clean up and long-term protection of Ontario's recreational waterways. We're also supporting research to help identify and overcome the causes of beach pollution. Some examples are outlined in the front page story in this issue. The success of these initiatives will help guarantee. safe swimming for all Ontario residents.

This is the third issue of The Proving Ground. 1 hope you will find it as interesting and informative as previous editions. Good reading.

Ruth Grier

Beaches (continued)

manure, in order to investigate the movement of bacteria and nutrients through soil and into field tile drains. These drains are typically located approximately 90 cm below the soil surface.

They measured numbers of such natural bacteria as faecal coliform in soil and drain water, and also added special tracer bacteria to the manure which is not normally present in the natural environment.

In the majority of instances when monitoring was done, manure application resulted in rapid bacterial contamination of the tile drains. Bacterial concentrations of many thousand-fold increases over normal levels were recorded. Since these drains empty into ditches and rural waterways, bacterial levels at downstream beaches may be raised significantly.

Interestingly, drain water quality was not significantly affected by the amount of manure applied. Instead, soil conditions at the time of application appeared to be the critical factor. When conditions were so dry that tile drains were not naturally flowing, or the field was cultivated prior to manure application, contamination of drains was significantly retarded.

The researchers speculate that a critical factor leading to tile drain contamination may be the presence of soil macropores. Macropores are natural cracks in the soil or channels formed by plant roots or worm activity. Manure flowing through macropores bypasses the adsorptive and retentive capacities of the soil, thereby providing a direct route to tile drains.

Disturbing the soil surface by cultivation prior to manure application may avoid contamination by cutting off macropore openings to the surface. This would slow down the movement of manure and allow-for filtering of the bacteria and nutrients to occur.

Ms. Foran is currently extending this research to define more precisely the field conditions which reduce the risk of tile drain contamination. Preliminary results seem to confirm that cultivation of the land prior to manure application decreases bacterial and nutrient movement into these drains. Ms. Foran is also considering the effects of injecting the manure directly into the soil rather than applying it by conventional irrigation.

Such research activities as these complement the ministry's Clean Up Rural Beaches (CURB) program. Delivered by local conservation authorities, CURB supports farmers and other rural residents in carrying out pollution abatement activities. This may involve improving manure storage, or building fences and crossings to restrict livestock access to lakes, rivers and streams.

One region for which a CURB plan has already been prepared includes the Grand Bend and other Lake Huron beaches within the jurisdiction of the Ausable Bayfield Conservation Authority. In fact, Ms. Dean and Ms. Foran have been conducting the above research on farms whose drains lead to ditches that open into Parkhill Creek which flows into Lake Huron at Grand Bend . Their study therefore has immediate practical relevance.

A number of ministry programs including the Environmental Research, Clean Up Rural Beaches (CURB) and Great Lakes Remedial Action Plans (RAPs) programs support activities targeted at the abatement of rural waterway pollution. For example, projects under both CURB and RAPs involve restricting livestock access to rivers and lakes.

FARM UPDATE

ABCA study shedding light on pollution sources

By Adrian Harte

EXETER - After spreading manure on a field, a farmer imagines the nutrients and minerals will be absorbed into the soil over the next few weeks. providing an essential boost to the crops.

However, new research by the Ausable Bayfield Conservation Authority indicating that something very different may be happening under those fields.

Donna Dean and Mary Ellen Foran, water quality researchers at the ABCA, have monitored 14 manure spreadings in the watershed area, and have tested the bacteria count in water flowing through the drainage tile from those fields.

On some occasions, Dean and Foran have found bacteria-contaminated water making its way into the drains as quickly as 20 minutes after a spreading. or as long as seven hours. Either way, the manure was leaving the field quicker than previously thought possible.

"Conventional hydrology doesn't allow for that," said Dean. adding that the rapid flow of liquid manure through "macropores" such as worm holes, cracks and root cavities is the only plausible explanation.

A lot of people didn't believe what we were finding. I think they were a bit shocked, but it kept happening and we just reported what happened," said Dean.

"Even the researchers from Guelph didn't believe how fast it came through," added Foran.

Dean held up a slide taken at a test site. It shows water samples sitting under a blue sky with a dry field in the background. While previous samples had found clear water running through the field tile two hours earlier before manure was applied, the sample jars now contained a dark brown liquid.

The ABCA study is unique in that it is being conducted in actual field conditions, not a controlled laboratory.

"But that's more like the conditions the farmers are spreading under," said Foran.

The problem is that with bacteria counts ranging from the tens of thousands to the millions of fecal coliforms per 100 mililitres reaching drains, ditches and rivers, the chances for serious pollution are higher than previously thought. When bacteria counts reach 100 fecal coliforms per 100 miliiiters at the lake, the health units close the beaches - although faulty rural septic systems and cattle being given access to streams and rivers are also considered contributors to lakefront pollution.

If there is any good news to be found in the study, it is that Dean and Foran have discovered conditions under which this flow of bacteria can be slowed. When the tile drains are dry, or the field has been recently cultivated. then the manure products take longer to reach the watershed. When the manure remains in the soil longer, the nutrients are better absorbed and the fecal coliform bacteria eventually die off.

The discovery that cultivation slowed up the flow came as something of an accident. One of the farmers in the study was planting a late crop of beans and had just tilled his field before fertilizing. The assumption is that cultivation breaks up the macropores and allows retention of the manure spray.

Dean and Foran also added a harmless tracer bacteria to manure spread during the tests and even found it made its way to test wells in ground water 8-12 feet below the surface.

Local farmers who are participating in this study are watching the results closely because they may give an Indication of how future restrictions on manure application may be formed. Ontario has few, if any restrictions on the use of manure as a field fertilizer, whereas Quebec has already banned the winter spreading of manure to prevent contamination of spring run-off. The elimination of winter spreading would force many farmers into building storage tanks to keep manure until spring.

The fact that the ABCA study has uncovered better times for spreading, either dry periods or after cultivation, then that intent aid the creation of future regulations.

"There are conditions that are better than others," said Foran.

Other researchers across North America have been contacting Dean and Foran for the results of their tests, but as of yet the project is still ongoing with the pair spending long hours examining data for computer analysis.

Dean and Foran will also be presenting their findings at the Annual Meeting of the Soil and Water Conservation Society in Kentucky in August.

Conclusive evidence

Mary Ellen Foran (left) and Donna Dean have slides which show how manure fertilizer makes its way through to drainage tile faster than previously believed

ENVIRONMENT

Manure research findings shatter traditional beliefs

PROJECT PROFILE

- ☐ **Method:** The impact of liquid manure application was studied at 12 sites. The manure was sprayed onto fields through irrigation equipment at 11 sites, spread from a tanker at the 12th .
- ☐ **Major findings:** The manure and the bacteria it contains be can seeping into tile drains under fields in anywhere from 20 minutes to seven hours. much faster than previously believed possible.
- ☐ **Other findings:** Manure runoff is much slower in recently tilled fields. That may offer a solution on some farms. injecting manure into the soil with special equipment is tend studied as another possible solution.

The Southwestern Ontario study has found that manure runoff takes place more quickly than believed and could cause pollution at many beach areas.

By Peter Geigen-Miller
The *London* Free *Press*

A study by two Southwestern Ontario researchers is shattering the agriculture community's long-accepted ideas about what happens to manure when it is spread on farm fields and has identified what may be a prime cause of summer beach closings.

Donna Dean and Mary Ellen Foran, who work for the Ausable Bayfield Conservation Authority near Exeter are turning convention on its ear with their discovery that liquid manure — and the bacteria is contains — escapes into tiles running under fields more quickly than anyone thought possible.

Conventional wisdom has been that manure stays put on fields and is absorbed into the soil once applied, provided it is not spread before spring runoff or heavy rains.

SPEED SURPRISING:

A lot of people are surprised by how quickly it happens." Dean said Thursday. "It takes anywhere from 20 minutes to six hours but in most cases we see it coming through within two hours."

The researchers' observations are dramatic. The water in the tile will he running clear before manure is applied. Within two hours. it turns a dark brown.

The bacteria count in the tiles will go from zero to hundreds of thousands or even millions. said Dean.

The high bacteria counts are bad news for Lake Huron beach-goers because the tiles checked empty into streams which eventually empty into Lake Huron.

The research findings may explain why health officials occasionally are forced to close the Grand Bend beach when bacterial counts in the water inexplicably soar to the danger level.

Beaches are considered unsafe for swimming when the bacterial count hits 100 fecal conforms per 100 millilitres of water.

Manure is not the only source of lakefront pollution. Faulty septic tank systems and cattle defecating in streams also contribute to the problem. So does storm runoff from urban streets. parking lots and lawns.

Dean and Foran suspect the manure escapes into rile drains through pores in the ground — cracks, worm huffs and usher tiny openings.

UNABLE TO COMMENT:

Roger George, president of the Ontario Federation of Agriculture, said he had not heard of the study so he wouldn't comment on it.

But George, who is from Powassan, south of North Bay, said farmers are keenly aware of their obligations to protect the environment and are doing more to improve manure management.

"But we also have the right to go about our normal farming practices and spreading manure is a normal practice as far as I am concerned. You have to do something with it."

George said better methods for handling manure are emerging but they must be affordable for farmers. Manure management is costly — "a manure storage facility on a large livestock operation can cost $100,000." he said.

George said the provincial government should provide grants to help farmers solve their manure problems, just as it does for municipal sewage projects. But he doesn't want the government to impose manure regulations on farmers.

"That would put us in an impossible situation."